

RESEARCH AND  
INNOVATION NEWS  
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# Research

Volume 13: Number 3. Autumn 2018

THE FUTURE OF FOOD

SUCCESSFUL SUPPLEMENTATION

DEALING WITH DROUGHT

TAKING THE METH OUT OF BREATH

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## EDITOR

Catriona Boyle 076 111 1219  
catriona.boyle@teagasc.ie

## ADMINISTRATOR

Ann Kane  
ann.kane@teagasc.ie

## EDITORIAL STEERING GROUP

Catriona Boyle	Stephen Butler	Michael Diskin
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T: 01 856 1166 E: ann-marie@thinkmedia.ie [www.thinkmedia.ie](http://www.thinkmedia.ie)

Design: Tony Byrne, Tom Cullen and Niamh Short

Editorial: Ann-Marie Hardiman, Paul O'Grady and Colm Quinn



## 25 years of excellence

Since its inception a quarter of a century ago, the Walsh Fellowships Programme has produced some of Ireland's finest agricultural and food scientists.

This year marks the 25th anniversary of the establishment of the Teagasc Walsh Fellowships Programme (WFP), although postgraduate fellowships have been an important element of research delivery since the establishment of An Foras Talúntais in 1958. In the early years, the number of awards was small, and it was only with the formation of the WFP that the programme expanded to a position where more than 50 fellowships are now awarded each year.

Teagasc plans to mark this significant milestone by establishing a Teagasc Walsh Fellows Alumni Association, open to all Walsh Fellow graduates and to those who graduated from earlier Teagasc postgraduate programmes.

Walsh Fellow alumni have benefited from the unique postgraduate training model delivered by Teagasc and its university partners. Working in teams on targeted applied research questions of relevance to the agri-food sector, and with a focus on disseminating results to relevant stakeholders, our students develop specific analytical skills, as well as more generic teamwork and communication skills. These skills are highly transferable, making our alumni of value in many different roles.

Today, many of our alumni are employed in Teagasc, while many others are in key positions in universities, public services, agri-food companies and financial institutions at home and abroad. The vast majority work in Ireland or for Irish companies. Teagasc alumni have also been very successful in pursuing academic careers, many of them now acting as supervisors to new generations of Walsh Fellows and continuing the collaborations started when they themselves were students.

Through ongoing adaptation to the changing scientific and industrial environment, Teagasc has ensured that the Programme remained relevant and it has proven to be remarkably effective in meeting the training needs of young graduates and directing them into high-grade employment in industry, academia and the wider public sector.

I wish to formally acknowledge the vision and leadership of our former director, Liam Downey, in establishing the WFP, and the tremendous support and encouragement of Patrick Fottrell, who for many years chaired the Teagasc Authority Research Committee.



**Lance O'Brien**

Head of Strategy and the Walsh Fellowships Programme, Teagasc

## 25 bliain de bharr feabhais in oiliúint iarchéime

Tá comóradh 25ú bliain ó bunaíodh Clár Comhaltachtaí Uí Bhreathnaigh (CCB), Teagasc á cheiliúradh i mbliana, cé go raibh comhaltachtaí iarchéimí ina ngné thábhachtach maidir le taighde a sheachadadh ó bunaíodh an Foras Talúntais in 1958. Sna luathbhlianta, ba bheag líon na gcomhaltachtaí, agus ní go dtí gur cruthaíodh CCB gur leathnaíodh an clár go staid ina mbronntar níos mó ná 50 comhaltacht gach bliain.

Tá sé beartaithe ag Teagasc an gharscpríoc shuntasach sin a cheiliúradh trí Chumann Alumni Comhaltachtaí Uí Bhreathnaigh, Teagasc, a bhunú, a bheidh ar fáil do gach céimí de chuid Comhaltachtaí Uí Bhreathnaigh agus dóibh siúd a bhain céim amach ó chlár iarchéime níos luaithe de chuid Teagasc.

Bhain alumni Comhaltachtaí Uí Bhreathnaigh leas as an tsamhail uathúil oiliúna iarchéime seo arna sheachadadh ag Teagasc agus ag a chomhpháirtithe ollscoile. Agus iad ag obair i bhfoirne ar cheisteanna taighde feidhmithe spriocdhírthe a bhaineann leis an earnáil agraibhia, agus béim á cur ar na torthaí a scaipeadh ar na páirtithe leasmhara ábhartha, forbraíonn ár scoláirí scileanna sonracha anailíseacha, chomh maith le hobair foirne níos cineálaí agus scileanna cumarsáide. Is scileanna an-inaistrithe iad na scileanna sin, rud a thugann luach dá alumni i lear mór ról éagsúil.

Inniu, tá a lán dár alumni fostaithe ag Teagasc, agus tá a lán eile díobh i bpoist thábhachtacha in ollscoileanna, seirbhísí poiblí, cuideachtaí agraibhia agus institiúidí airgeadais sa bhaile agus thar lear. Oibríonn an formhór díobh in Éirinn nó do chuideachtaí Éireannacha. D'éirigh go han-mhaithe le alumni Teagasc chomh maith maidir le dul le gairmeacha acadúla, agus tá a lán díobh ag obair mar mhaoirseoirí anois ar ghlúnta úra Chomhaltachtaí Uí Bhreathnaigh agus ag leanúint leis an gcomhoibriú a thosaigh siad iad féin agus iad ina scoláirí.

Trí oiriúnú leanúnach don timpeallacht eolaíoch agus thionsclaíoch atá ag athrú, chinntigh Teagasc go raibh an clár fós ábhartha agus tá sé cruthaithe go bhfuil sé thar a bheith éifeachtach chun freastal ar riachtanais oiliúna céimithe óga agus iad a threorú chuig fostaíocht ardghráid sa tionsclaíocht, sa saol acadúil agus san earnáil phoiblí i gcoitinne.

Ba mhaith liom aitheantas a thabhairt go foirmiúil d'fhís agus do cheannaireacht ár n-iarstiúrthóra, Liam Downey, as an CCB a bhunú agus do thacaíocht agus spreagadh Patrick Fottrell, a bhí ina chathaoirleach le blianta fada ar Choiste Tacaíochta Údarás Teagasc.



**Lance O'Brien**

Ceann na Straitéise agus Chlár Comhaltachtaí Uí Bhreathnaigh, Teagasc

## DAFM research grant awards of over €14 million

The Minister for Agriculture, Food and the Marine (DAFM), Michael Creed TD, recently announced awards of almost €14.3 million in funding for collaborative research projects arising from last year's research call under his Department's three competitive research programmes.

The 23 projects funded cover topics across a wide range of areas, including: food safety and authenticity; functional foods for health and nutrition; novel food processing technologies; farm safety and animal well-being/biosecurity; forest inventory and remote sensing; tree breeding; and, biotic threats.

A number of the new projects focus on ensuring the environmental sustainability of our croplands, for example, examining the use of multi-species swards, the potential of carbon sequestration and sustainable pesticide use.

A total of 12 Irish research performing organisations will benefit from the awards, including Teagasc, the universities and the institutes of technology.

Full details of projects and the project co-ordinators can be found on the Department's website.

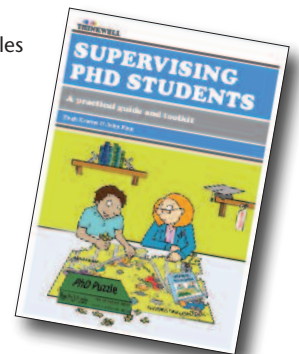


Pictured at the launch of the DAFM research grant awards are (from left): Breige McNulty, UCD; David Meredith, Teagasc; Minister for Agriculture, Food and the Marine, Michael Creed TD; Gary Lanigan, Teagasc; Alice Lucey, UCC; and, Charles Harper, UCD.

## Supervising PhD students

A new practical guide and toolkit for supervising PhD students has been published by renowned self-management expert Hugh Kearns and Teagasc's John Finn, Programme Director with the Agri-Food Graduate Development Programme and based at Johnstown Castle. This book is a guide to the practical activities, strategies and tools used by effective PhD supervisors. It looks at the main processes that relate to PhD supervision: the personal motivations of supervisors; recruitment; clarifying expectations; how to run productive meetings; providing effective feedback; academic writing; the interpersonal challenges that arise during the PhD; the PhD examination; and, professional development. John Finn explains: "We address these key supervisory practices by offering a range of practical advice and activities that can inform and guide supervisors.

Throughout the book, we highlight examples of good and bad practice that are inspired by real-life examples". The book provides a range of templates and supports that supervisors can provide to their PhD students. John says: "This is one of our strongest motivations for writing this text – to help supervisors to improve the experience of doctoral research not just for themselves, but also for their PhD students". The book can be purchased as hard copy or e-book at: [www.ithinkwell.com.au](http://www.ithinkwell.com.au).



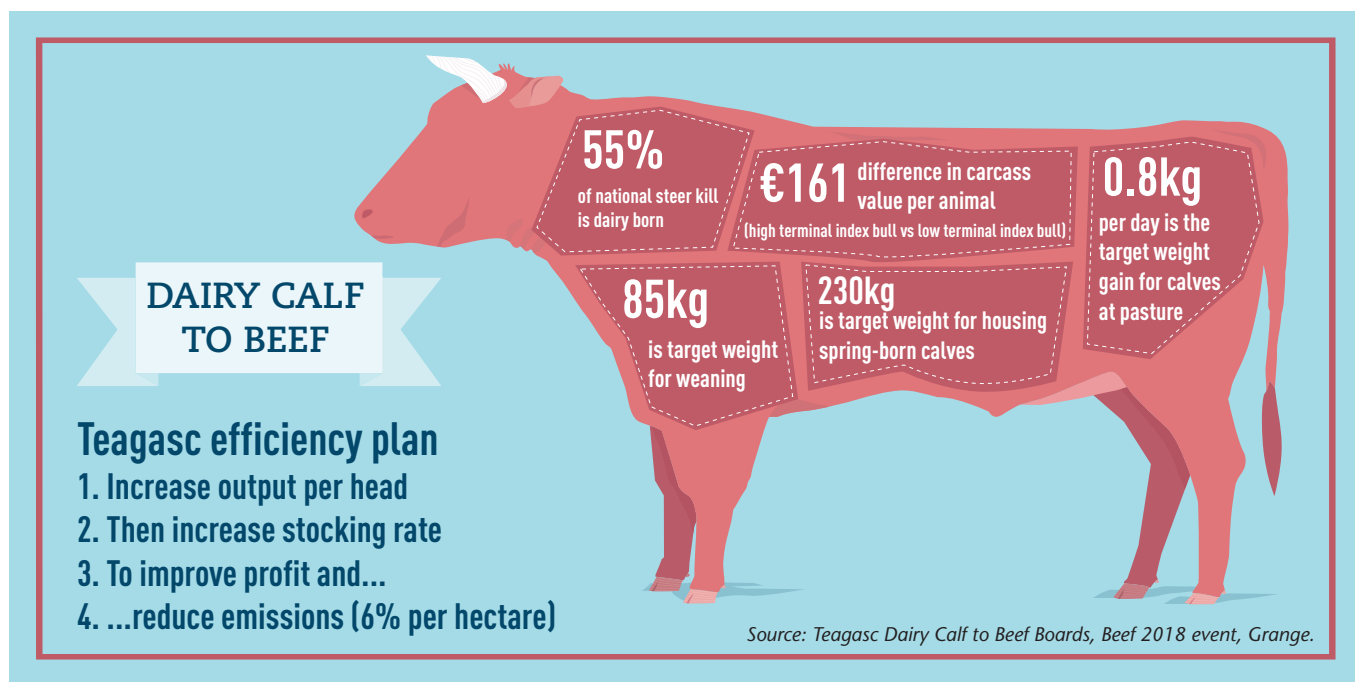
## Teagasc invests €5.2m in next generation of research leaders

A new programme to develop the next generation of research leaders to underpin the objectives of Ireland's Food Wise 2025 strategy was launched recently by the Minister for Agriculture, Food and the Marine, Michael Creed TD. This programme will fund 20 new experienced researchers for 36 months each, over the next five years. Operated by Teagasc, with co-funding from the European Commission, the programme opened in July. It offers applicants the opportunity to conduct their research in the best academic, or non-academic, organisation of their choice worldwide (outside of Ireland) for 18 months, followed by a return phase to Teagasc for a further 18 months. The programme will have a total value of €5.2 million and will have two funding calls, each funding 10 fellowships (total 20 fellowships). Each fellowship will last 36 months. There will be a strong focus on the career development of the researchers, with all fellows

undertaking an accredited management course, having a dedicated career mentor (separate to their scientific supervisors) and attending an annual retreat with presentations from established research leaders in industry, academia and civil society organisations.

This programme will also address the 'leaky pipeline', whereby many promising female researchers do not achieve senior positions. Remote review cohorts and the final review panel will be gender balanced.

A dedicated section of the website will highlight positive reasons for female researchers to apply for the fellowship. Successful female applicants will be facilitated in finding a senior female researcher to serve as a career mentor. This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant. Full details on the fellowships can be found on the Teagasc website at: [www.teagasc.ie/rl2025](http://www.teagasc.ie/rl2025).



## Beef 2018

A Teagasc study provides the first detailed information relating to on-farm usage of antimicrobials in suckler beef and artificially reared dairy calves from birth to six months of age. The results were presented at the recent Beef 2018 open day at Teagasc Grange Animal & Grassland Research and Innovation Centre. A total of 3,204 suckler beef calves and 5,358 dairy calves were included in the study. On beef farms overall, 12.7%, 5.7%, 2.9% and 20.4% of suckler beef calves were treated with antimicrobials for disease from birth to one month, one to three months, three to six months, and birth to six months of age, respectively. The corresponding values on dairy farms overall for calves treated with antimicrobials were 10.2%, 5.3%, 1.9% and 14.8%. The highest risk period for disease in the present study was between birth and one month of age, with approximately two-thirds of all disease events occurring during this time period.

The population correction unit (PCU) is a measurement developed by the European Medicines Agency (EMA) and takes into account the animal population, as well as the estimated weight of each particular animal at the time of treatment with antimicrobials.

A value of 45mg/PCU is indicated as a global estimation for cattle. In the present study the mg/PCU was 8.03, 2.70, 1.43 and 7.25 for suckler beef calves for the treatment periods from zero to one, one to three, three to six, and from birth to six months of age, respectively. The corresponding values for dairy calves were 9.74, 3.72, 0.95, and 7.11mg/PCU. The values of mg/PCU in the present study are low.

Researcher Bernadette Earley explains: "Disease prevention through proper nutrition, vaccination, adequate housing, and limiting stressors that compromise immunity are likely the most effective means of reducing antibiotic use".

## Student award at E3S symposium

Kim Millar, a Teagasc/Dublin Institute of Technology Walsh Fellow based at Teagasc Ashtown Food Research Centre, has won best student presenter award at the Annual E3S Symposium (European Sensory Science General Symposium) for her work on the use of yellow pea flour in bread. Kim explains: "As part of my PhD, I am looking at increasing protein in bread using pulse flours, with a focus on how these flours affect the sensory profile of the bread. This involves every aspect of bread making, from dough development and loaf volume, to the flavours produced. I was thrilled to be given the student award for best presenter, particularly given the high standard of all the presenters". The symposium took place at Teagasc Ashtown.



Kim's work focused on pea flour in bread.



## Sheep 2018



Well-known chef Catherine Fulvio demonstrating cooking with lamb at Sheep 2018.

Thousands of people attended the Sheep 2018 – Farm to Fork event in Teagasc Athenry recently. At the open day, there was a strong emphasis on technology transfer relating to all aspects of sheep production, in addition to factual and informative stands on farm partnerships, inheritance and farm management. The dedicated Food Village, which included food science, cooking demonstrations, artisan food, and food markets, was a hive of activity for all the families in attendance. Small food producers showcased the best of what is produced locally in the region, reinforcing the fact that Galway, justifiably, has been designated as

the European Region of Gastronomy. Sheep 2018 was one of the flagship events in the 2018 European Region of Gastronomy Programme in Galway. The Teagasc food research team highlighted the science behind food production.

Officially opening the event, Andrew Doyle TD, Minister of State at the Department of Agriculture, Food and the Marine, said: “This is the highlight of the year for sheep farmers and all other stakeholders in the sector, in terms of being able to interact and acquire knowledge in all areas of sheep production, which will help drive the future profitability of the sector”.

## Researcher profile

## Daire Ó hUallacháin



Daire Ó hUallacháin is a Senior Research Officer in the Environment, Soils and Land Use Department at Teagasc Johnstown Castle, Co. Wexford. He has over 15 years of research experience in the agri-environment sector, focusing in particular on farmland ecology and water quality.

Daire completed his PhD in the National University of Ireland, Galway (NUIG) in 2004, where his thesis focused on farmland ecology. He then worked for a period as a lecturer in NUIG and as a consultant ecologist. Daire joined Teagasc as a researcher in 2006, and since then his research has aimed to support sustainable production systems, which protect and enhance agri-ecology and associated natural resources.

Daire has established a broad research group, including PhD students, post-doctoral researchers and technicians, and collaborates with national and international universities and research institutes. He is currently

principal investigator on a number of studies focusing primarily on farmland ecology, water quality and mitigation methods, sediment dynamics, and ecosystem products and services. These projects are funded by a combination of national and international funding and cover a wide range of farming intensities, from very extensive farming systems such as those on the Aran Islands, to intensive dairy and tillage systems.

More recently, he has been involved with a number of successful European Innovation Partnership (EIP) projects. These EIPs afford groups of farmers, researchers, advisors and scientists an opportunity to

explore innovative approaches to addressing local environmental challenges, such as the preservation of agricultural landscapes, water quality or biodiversity.

Daire has published in a wide range of journals and is a reviewer for scientific journals, policy documents and third-level courses. He frequently partakes in more popular dissemination, contributing in Irish and English to television and radio on environmental and farming issues.

Daire is originally from north Louth and his interests include hiking, kayaking, fishing and following Louth GAA (dejectedly).

## Clare hurler scores Teagasc Fulbright Scholarship to Harvard

Shane O'Donnell, Clare senior hurler and a Teagasc Walsh Fellow based at Teagasc Moorepark Food Research Centre, is one of 37 recipients of a prestigious Fulbright Award.

An Tánaiste and Minister for Foreign Affairs and Trade, Simon Coveney TD, and Chargé d'affaires of the US Embassy in Ireland, Reece Smyth, announced 37 Fulbright Irish Awardees for 2018-2019 at an awards ceremony in the US Ambassador's Residence, Phoenix Park, recently.

Shane is pursuing his PhD in association with University College Cork (UCC). He has previously received a BSc in Genetics at UCC. His current research focuses on the effect the genus *Lactobacillus* has on human health through its impact on the gut microbiota. As a Fulbright student to Jing Kang's laboratory in Harvard University for a period of six months, he will conduct a trial analysing the impact *Lactobacillus casei* has on the gut microbiome. Specifically, he will look at the role of *L. casei* in ameliorating symptoms associated with irritable bowel syndrome, utilising a transgene mouse model capable of maintaining an ideal omega 3/omega 6 ratio.

Shane O'Donnell's PhD is co-supervised by Catherine Stanton, Teagasc, and Paul Ross, UCC, and is funded by the Department of Agriculture, Food and the Marine's Food Institutional Research Measure (FIRM). Shane said: "I am honoured to receive such a prestigious award and to be part of such a high-achieving cohort



Shane O'Donnell (left) with Lance O'Brien, Teagasc Walsh Fellowship Programme Manager.

of individuals. I am thoroughly looking forward to continuing my research in Harvard and embracing every experience that this opportunity will bring".

The next round of applications for Fulbright Irish Awards will open on August 31, 2018. Interested applicants should visit [www.fulbright.ie](http://www.fulbright.ie) for more information.

## SmartAgriHubs

EU Commissioner for Agriculture and Rural Development, Phil Hogan, recently launched (subject to grant agreement) the first of nine regional clusters, which will act as a one stop shop for two million farmers across the EU and the agri-food industry to access agri-tech research and supports.

The €20m SmartAgriHubs project aims to build a pan-European network of digital innovation hubs (DIHs) and centres of competence in all 28 European member states co-ordinated through nine regional clusters.

The SmartAgriHubs project is a new way for farmers, advisors and agtech SMEs to engage with research centres and research-active higher education institutions. As part of the project, 80 new solutions will be introduced into the market. A total of €6m has been set aside for open calls during the lifetime of the project.

As the co-ordinator for the UK and Ireland regional cluster, Waterford Institute of Technology, which has developed smart agri expertise through its Telecommunications Software & Systems Group (TSSG) research centre, will be the central point of contact for farmers, advisors, agtech and agri-food companies, who want to avail of

technology solutions from across Europe to farming and business problems. As the lead institute for research and innovation in agri-food in Ireland, Teagasc will play a central role in SmartAgriHubs. Teagasc, working with WIT, will lead two flagship innovation experiments in the project that demonstrate how technology can be used effectively in farming.

According to Frank O'Mara, Director of Research at Teagasc: "This is an exciting opportunity for Ireland, Teagasc and the other partners to step up our role in the application of digital technologies in Irish and European agriculture. The sector has great opportunity with the rising global demand for high-quality food and nutrition, but also faces many challenges such as profitability, climate change, water quality, and must also compete with other sectors for the people needed for the sector. Agri-tech has an important role to play in realising the opportunities while overcoming the challenges. We have put agri-tech at the heart of our strategy and are delighted to be leading two of the 28 flagship innovation experiments that will take place across Europe. We are looking forward to bringing our expertise and connections in this area to SmartAgriHub".





## Good IDEA – the algal value chain

The IDEA project is investigating the use of algae as a viable food, animal feed and care product ingredient.

You may unknowingly be familiar with *Spirulina* and *Chlorella*, two microalgal species that are often consumed today in smoothies and other health drinks. However, these microalgae are a rich protein source. Today, 70% of proteins in the European Union are imported. Clearly an alternative to this situation is needed. Due to their high growth rate and the small land area required, algae could become that alternative. However, we're not at that stage just yet. The challenge is to optimise the algae value chain, from local production to storage and handling, in such a way that it becomes a viable, economically relevant industry. That's the aim of the IDEA project, funded by the European Interreg North-West Europe programme, with partners in Belgium, the Netherlands, France, Germany and Ireland. In Ireland, Teagasc and Dr Maria Hayes and Caoimhe Gargan, both based at the research centre in Ashtown, Dublin, are leading the downstream processing and bio-refining work package.

### Algae value chain

When we think of algae production, southern countries with warm climates spring to mind. However, northwest Europe is also suitable for commercial algae cultivation using in-house closed algal cultivation systems. IDEA focuses on the complete value chain of algae production.

At the moment, the various steps all exist separately, as there is not yet a full chain that can continually guarantee the supply of high-quality algae on an industrial scale. In concrete terms, IDEA will work on the cultivation and harvesting of different types of algae, all year round (Figure 1).

The project will also investigate how water can be reused to make cultivation more viable, in both ecological and economical terms. In addition, IDEA will look into the various possibilities for storage and transportation of algae. Finally, the bio-refining of the algae will be studied, to ensure that it reaches the end user in optimal workable condition. In the IDEA algae value chain, this end user is not the consumer in the shop, but the producer of algae-based care products, food or high-quality animal feed, to name a few examples. IDEA's partners come from a range of different backgrounds: academics, SMEs and scientists.

They will all bring their specific expertise to the project, in order to develop the algae value chain and take it to a higher level, because there is demand for it, not least from the professional field.

Today, 70% of proteins in the European Union are imported. Clearly an alternative to this situation is needed.



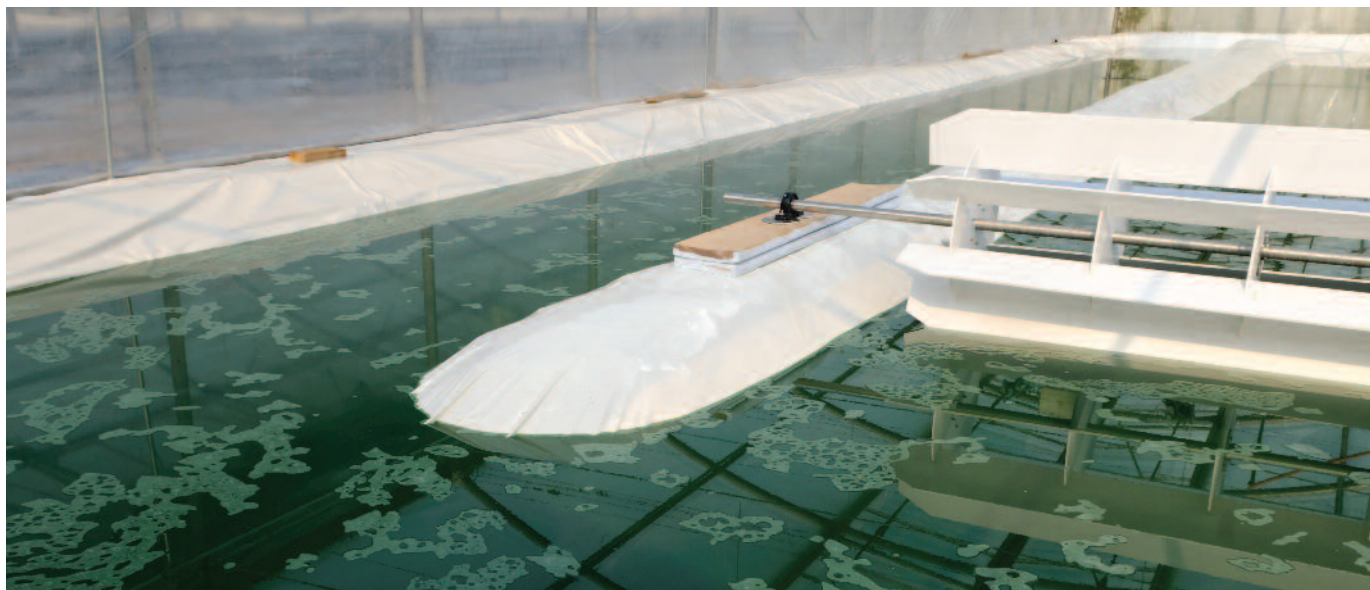


FIGURE 1: A Spirulina growth plant.

### Multiple opportunities

Microalgae are rich in proteins and vitamins, and can be used to produce high-quality fish food for aquaculture, for example. The entire sector is still being developed and the IDEA project is extremely important for the dissemination of knowledge. Financiers want to have guarantees. This international grouping helps by enabling us to expand and reinforce our skills by means of collaboration. Partners include industries that are looking for algae for use as raw materials for cosmetics, food protein blends and pharmaceuticals. The role of Teagasc in the IDEA project is the characterisation of different compounds in microalgae supplied by partners in Germany, and the isolation, characterisation and application of algae-derived ingredients, including proteins,

peptides, lipids and carbohydrates in different food products. To date, Teagasc has looked at four different microalgae and carried out initial proximate analysis of these algae to determine which ones are suited for further characterisation work. **Figure 2** details the protein, ash and lipid content of algae supplied by IDEA research partners in Germany. It is hoped that IDEA will lead to the development of new and nutritional protein blends: food ingredients with added health benefits and new sources of animal and aquaculture feed that could help to reduce production costs on farms on both land and sea, and improve the overall health of the Irish and European populace.

### Acknowledgments

IDEA is co-funded by Interreg North-West Europe and will be receiving €2.96m from the European Regional Development Fund (ERDF).

### Authors

#### Maria Hayes

Scientific Research Officer, Food BioSciences, Teagasc Food Research Centre, Ashtown, Dublin 15  
Correspondence: maria.hayes@teagasc.ie

#### Caoimhe Gargan

Technician, Teagasc Food Research Centre, Ashtown, Dublin 15

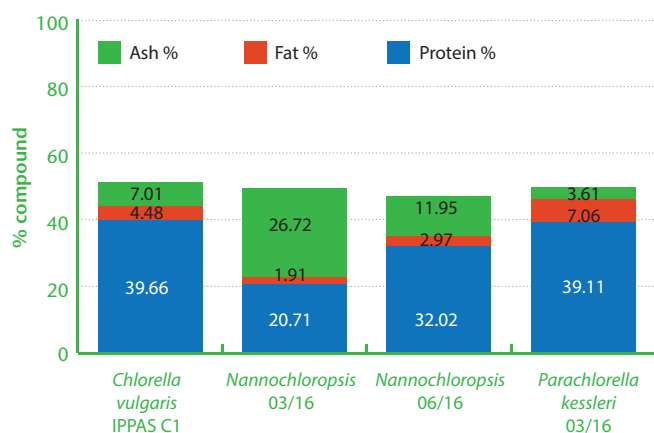


FIGURE 2: Proximate analysis including protein, ash and lipid content of microalgae analysed to date. Protein was measured using the AOAC method 968.06, 15th edition, Dumas method using LECO FP628; fats were measured using the total fats by acid hydrolysis filter bag technique, using Ankom hydrolysis and fat extraction; ash was measured using the furnace at 600°C.



# The future of food

Are research robots and virtual food a reality? Researchers in the Food Research Programme at **TEAGASC** are investigating the latest digital and robotic technology to discover its impact on food research and beyond.

A byte is a unit of digital information, and is extremely simple compared to the complex sensory information we experience when we bite into our food. The simplicity of digital information means it can be manipulated and used to visualise biological structures in food matrices and this has intrigued researchers at both the Moorepark and Ashtown Food Research Centres of Teagasc.

The use of robotics and digital technology has increased dramatically over recent years and this translates to an exciting time for the food industry, as we begin to adapt to this new interactive world. Teagasc researchers are realising this potential and starting to align digital with real world research applications in a targeted way. Exciting new developments in augmented and virtual reality (AR and VR) can potentially connect physical attributes, e.g., sensory and food preparation, with consumer attitudes and preferences. This is currently one of the most exciting developments in food science, and has potential at a number of points along the food chain.

## Food research robots

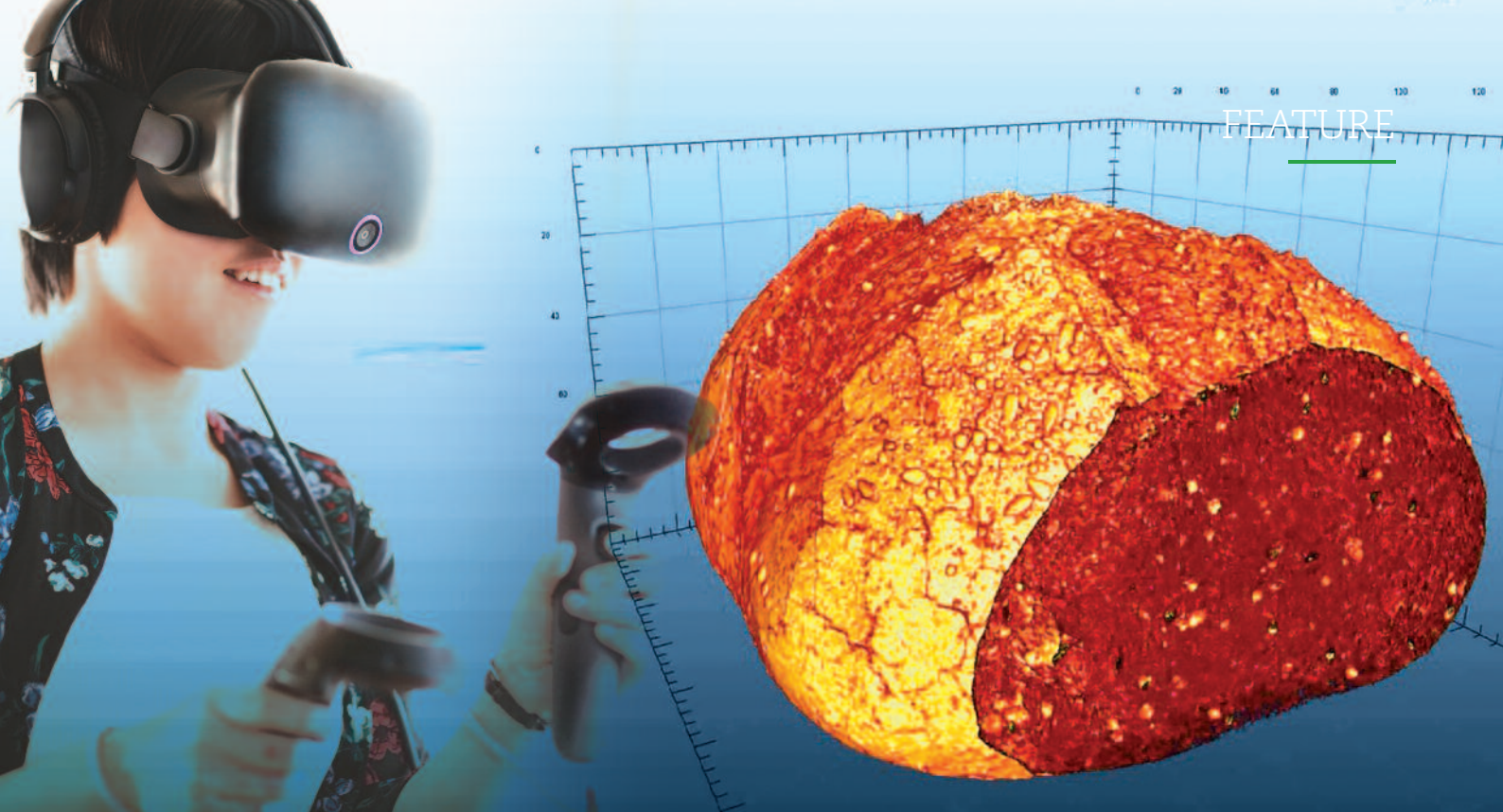
Teagasc Moorepark is pioneering the latest evolution in robotics, process analytical technology and image analysis tools to evaluate the rehydration performance of milk powders, for optimum reconstitution properties. Using the latest generation of collaborative robots, the research carried out by Norah O'Shea demonstrates that it is possible to consistently

measure the rehydration properties of powder across batches, while reducing variability compared to testing performed by a human operator. Built-in vision sensors in the arms of the robot capture digital images of unhydrated powder particles post rehydration and these images are then used in combination with vision system analysis, which can translate the output from the image into numbers for objective interpretation of powder quality by the operator. The major benefit of using robotics is that it has the potential to replace current subjective lab tests prior to product release, with an automated objective quantitative test to ensure optimal finished powder quality. Teagasc has developed collaboration with scientists from the Insight Centre for Data Analytics, Dublin City University, who are using biomechanical sensors to collect data that can accurately mimic the actions of people from different geographic locations around the world. This data will be used to programme arm movements of the robot to more accurately represent human movements involved in powder rehydration. This approach has potential for evaluating the functionality of many ingredients in real-world food applications.

## Immersing yourself in food

Combining AR and VR has the potential to revolutionise research methodologies for the visualisation of internal structures in food. Researchers within the Teagasc Food





Research Programme are using powerful new image analysis software, adapted from the medical sector, to enable interactive 3D visualisation of the inside of foods. When coupled with virtual reality hardware, the researchers can completely immerse themselves into the food and acquire measurement data of structures in real time. For example, using the new software and a VR headset, Eimear Gallagher, Head of Food Quality and Sensory Science at Teagasc, has been able to 'get inside her bread' to visualise internal structures in 4D. Eimear is currently working on ways of relating the structures that she sees inside the bread to sensory and texture attributes. In another application, Ciara McDonnell and Gonzalo Delgado-Pando have digitally recreated the carcass of a lamb from data generated using a CT scanner and examined it using VR. In both these applications, it is possible to take rapid measurements using hand controllers while immersed within the computer generated imagery-based VR food. Using 4D visualisation in this way is a world first and can enable researchers at Teagasc to continually re-analyse structures with unlimited observations and viewpoints within the same food. In fact, AR and VR can transform our understanding of the link between sensory parameters and the physics of food structure, potentially leading to new manufacturing practices, food products and customer experiences. The technology will enable food manufacturers to identify key structural components and benchmark them against existing high-quality foods. Deirdre Kennedy, Teagasc Moorepark, explains that the software works by interpreting a 3D image stack, for example, those obtained by a CT scanner or a suitable microscope. These layers of images are brought to life in 4D by a VR headset, such as the one used by Teagasc researchers. Measurements are then taken using hand controllers and powerful software tools. Emily Crofton (sensory scientist at Teagasc) is confident the AR and VR technology will grow beyond research to reach the consumer, and AR can

potentially be used to provide nutritional data about the food we eat. This is something that is currently under evaluation at the sensory facility at Teagasc, Ashtown.

### Acknowledgments

Insight Centre for Data Analytics, Dublin City University.

### Authors

#### Mark Fenelon

Head of Food Research, Teagasc Food Research Programme, Moorepark, Fermoy, Co. Cork  
Correspondence: mark.fenelon@teagasc.ie

#### Norah O'Shea

Research Officer, Food Chemistry and Technology Department, Teagasc Food Research Centre, Moorepark, Fermoy, Co. Cork

#### Deirdre Kennedy

Microstructure Technologist, Food Chemistry and Technology Department, Teagasc Food Research Centre, Moorepark, Fermoy, Co. Cork

#### Eimear Gallagher

Head, Food Quality and Sensory Science Department, Teagasc Food Research Centre, Ashtown, Dublin 15



# Scoping competitiveness



**TEAGASC** recently hosted two international conferences focusing on the competitiveness of dairy, beef and sheep production.

The International Farm Comparisons Network (IFCN) held its annual dairy conference in Teagasc, Moorepark from June 9-13. The conference brought over 80 participants from more than 40 countries to Ireland to see first-hand the sustainable low-cost grazing system operated by Irish dairy farms, review the profitability of dairy internationally, and discuss the latest international dairy developments. Conference participants included researchers and representatives from dairy and dairy-related companies. From June 14 into the following week, the agri benchmark beef and sheep series of events and Global Forum Conference were held in Galway. The conference brought participants from almost 30 countries to Ireland to see the grazing system operated on Irish beef and sheep farms, and to discuss the latest international beef and sheep developments, with a particular focus on profitability and environmental sustainability.

## Dairy developments

The IFCN dairy conference heard that about 876 million tonnes of milk are produced worldwide at the moment on an annual basis, with Oceania, the EU and India among the leading producers. Between now and 2030, the worldwide demand growth for milk and milk products will be three times the level of current US milk production, with more milk needed on the international market. The increase of demand is not only due to more people living in the world, but also because per capita consumption will increase, due to growing prosperity and worldwide investments in dairy product development. The dynamics of structural changes of dairy farms internationally will continue to be a feature of the sector and farms will intensify their farming systems. By 2030, the IFCN forecasts a global increase in milk production and demand of 35%. The short-term IFCN outlook points towards a continuing increase

in milk supply worldwide. In 2017 world milk production grew by nearly 2.7%, which is significantly higher than the growth level achieved in 2016. However, production growth has started to slow down significantly in 2018. Key factors in the slower production growth this year are climate anomalies in New Zealand, the EU and Argentina, and a challenging economic situation for dairy farmers in the United States.

For the second half of 2018, the IFCN expects supply and demand growth to be more aligned, with an expected world milk price level of 35-37USD/per 100kg energy corrected milk (ECM), or 30-32EUR per 100kg ECM, or 6.4-6.7NZD per kg solid, or 15-16USD/hundredweight (cwt) (see **Figure 1**).

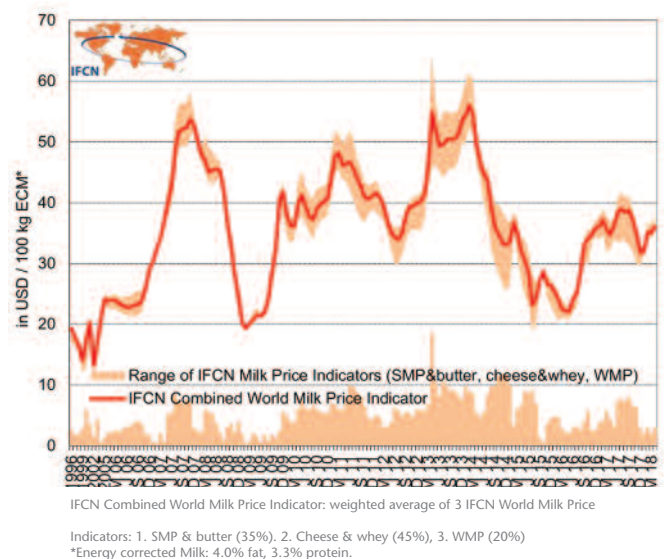


FIGURE 1: IFCN World Milk Price Indicator (Source: IFCN, 2018).





Participants at the IFCN Dairy Conference 2018.

### Beef and sheep developments

A key topic for discussion during the agri benchmark beef and sheep conferences were strategies to remain competitive and, at the same time, reflect society's concerns about the environment and animal welfare, all in the context of quickly developing technologies and alternative protein sources.

During the conference, the experience of the Australian beef and sheep sector was compared with the sector in Ireland. This comparison highlighted that Irish and Australian producers face many of the same challenges, especially in maintaining their status as successful global exporters in a market where existing consumers are becoming more discerning on food quality, provenance, sustainability and safety. In addition, both countries are working to understand the special needs of emerging consumers, particularly in Asia and the Middle East. Research presented at the agri benchmark conference from the University of Alberta in Canada focused on the need to set the right incentives at farm level in order to get livestock producers to commit to more sustainable production. The research from Canada shows that even those producers staunchly opposed to the acceptance of human-induced climate change, do adapt production practices that mitigate greenhouse gases. Another major topic of discussion at the Global Forum Conference in Galway was the Mercosur trade deal (with Argentina, Brazil, Paraguay, and Uruguay), which was stated as being "extremely likely" by Koen Dillen, a member of the global issues team at the European Commission's Directorate-General for Agriculture and Rural Development. Speaking at the Conference, Dillen said that the Commission has tried to minimise the potential adverse impact of a Mercosur deal. There was an acknowledgment that Mercosur won't bring a lot of benefit to the beef sector, with simple economics pointing towards a price drop for European beef.



Speakers at the Agri Benchmark Global Forum at the Galway Bay Hotel, Salthill are (from left): Joe Healy, President, IFA; Gerry Boyle, Director, Teagasc; Anne Kinsella, Trevor Donnellan, Kevin Hanrahan and Kevin Kilcline (all Teagasc); and, Michael Maloney, Director of Origin Green Programme, Bord Bia.

Despite the many challenges facing the European beef sector, the representative from the European Commission highlighted the need for a resilient beef sector, while noting public goods, the maintenance of permanent grasslands and territorial balance as the key benefits that the European Commission continues to associate with the beef sector.

### Acknowledgements

Sponsors of the IFCN Conference 2018: Teagasc, DSM, the Department of Agriculture, Food and the Marine, Alltech, Bank of Ireland, Dairygold, Keogh's Crisps, ICOS and Ornuia for their financial support.

Sponsors of the agri benchmark Beef and Sheep Conferences/Global Forum 2018: Teagasc, Bord Bia, Chanelle Group, Fáilte Ireland, Meet in Ireland.

### Authors

#### Fiona Thorne

Senior Research Officer, Rural Economy & Development Centre, Teagasc Ashtown, Dublin 15  
Correspondence: [fiona.thorne@teagasc.ie](mailto:fiona.thorne@teagasc.ie)

#### Anne Kinsella

Senior Research Officer, Rural Economy and Development Programme, Teagasc Athenry, Co. Galway





# Dealing with drought

This year's unprecedented drought has placed enormous pressure on farmers in Ireland. Whether the extended dry weather is an anomaly or a sign of things to come, **TEAGASC** researchers have been working to better understand and prepare for future drought events.

## Grassland mixture diversity for yield stability

John Finn is an environmental researcher in the Teagasc, Crops, Environment and Land Use Programme, Johnstown Castle. John explains: "As part of the EU AnimalChange experiment, we tested whether diversity in grassland mixtures could improve yield resilience when challenged with an experimental nine-week drought (see experimental rain shelters in the main article picture; Finn *et al.*, 2018). We sowed one-, two- and four-species combinations of perennial ryegrass, chicory, red clover and white clover". The four-species mixtures in this study were designed to contain a mix of functional traits related to nitrogen (N) acquisition and rooting depth, with the aim of improving access of the vegetation to utilisable N and soil water during drought events. Yield was harvested by cutting, and N was applied at 150kg/ha/year and 200kg/ha/year at two sites, respectively.

Overall, plant diversity was related to increased yield stability; as diversity increased from one to four species, there were higher yields, and lower variation in yields. Across all of the grassland plots, the experimental drought had a severe effect on yield (-87%) on the individual harvest at the end of the drought event. In contrast, drought effects on annual yields (the sum of yields before, during and after the drought period) of averaged monocultures and the four-species mixture were only -9% and -12%, respectively. This showed a remarkable ability of the total annual yield to be resilient to short-term weather events. These losses were much smaller than the yield advantage due to mixtures, which were 31% under drought and 34% under rainfed conditions (compared to the

average yields of the four monocultures); thus, the benefit of mixtures was maintained despite the drought. Importantly, once soil moisture levels were restored, we observed an immediate recovery in harvest yields, e.g., we observed few to no negative drought effects in the first harvest after the removal of the drought shelters. Within this two-year study, there was no indication of an increasing susceptibility to drought from one year to the next (Finn *et al.*, 2018). Further work on the potential role of multi-species grassland mixtures is currently underway at Johnstown Castle.

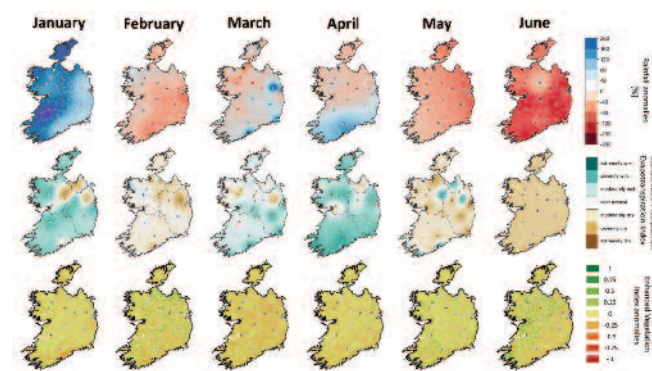


FIGURE 1: The Standard Precipitation Evapotranspiration Index.



### Space technology for monitoring drought

Stuart Green and Simone Falzoi in the Agrifood Business and Spatial Analysis Department, Teagasc Ashtown are using meteorological indicators and satellites to monitor the progress of the current drought. Stuart explains: "Monitoring conditions across the country shows us that, while the drought affects the whole country, its impact varies from place to place". The drought can first be seen in the rainfall record and when we compare rainfall totals in a month with average values, we see that while January was very wet, the following months had low rainfall. We can model the impact of reduced rainfall using one of many weather indices. The index shown in **Figure 1** is the Standardised Precipitation Evapotranspiration Index (SPEI). The SPEI looks at long-term rainfall at different timescales and compares it with expected demand as indicated by normal evapotranspiration – giving a single number indicating conditions. The images show that this year, up to June, every month was either drier or wetter than normal and that June was "severely dry". NASA's MODIS satellite can calculate the impact by measuring the greenness of the country, expressed as an "Enhanced Vegetation Index" - ranging from 1-0, 1 being very lush green pasture and 0 being completely barren. By comparing the index each month with the average, we can see how the landscape is coping. And now we can see some regional variability, with vegetation growth well below normal in the south and east (well-drained soils) in June but above normal in the north and west (poorly drained soils).

This is because the heavy soils in the north and west are at an advantage in that they hold moisture for much longer, allowing plants to take advantage of the higher temperatures. However, these soils can't hold out continually and, as the drought progresses, we shall see growth impacted in these regions too.

### Getting the MoSt from grass

Elodie Ruelle, a postdoctoral researcher at Teagasc Moorepark, is working on the Moorepark St Gilles (MoSt) grass growth model (Ruelle *et al.*, 2018), which was developed at Teagasc, Moorepark in conjunction with the INRA, France. Elodie explains: "The model takes into account historical weather, soil type and grass management (such as post-grazing height, stocking rate and N fertilisation) to predict grass growth, grass N content and grass N leaching. The model can accurately forecast grass growth and simulate grass growth when the model outputs are compared to outputs from PastureBaselreland (PBI), a grassland measurement database developed by Teagasc". Currently, the model is being live tested on the well-drained Curtins (Co. Cork) and poorly drained Ballyhaise (Co. Cavan) research farms. Every Monday, the model is used to predict the grass growth for each paddock for each farm for the next seven days using weather forecast data supplied by Met Éireann and farm management information available in PBI (e.g., N fertiliser application, rotation length, post-grazing sward height). The model can simulate soil moisture deficit due to its dynamic and mechanistic aspect and so it has been able to accurately predict the reduced grass growth as a result of the drought that the country is currently experiencing. It has also been able to predict the latency of the severity of the drought between Ballyhaise and Curtins due to the differences in weather and soil types between the two locations. The consequences of the drought have been more severe at Curtins, where a reduction in growth rate was

experienced two weeks earlier than at Ballyhaise. The model also predicted that growth would stabilise at around 15-20kg DM/ha/day at Curtins and at 40-50kg DM/ha/day at Ballyhaise farm. We are currently beginning the process of incorporating the MoSt grass growth model into PBI. When it is incorporated, the model will allow every farmer using PBI to better predict the impact of weather events on their farm based on their location, soil type and grassland management.

For more details on how to deal with the summer drought conditions, Teagasc has prepared advice for farmers: <https://www.teagasc.ie/rural-economy/farm-management/farming-in-difficult-weather-conditions/summer-drought-conditions/>.

### Funding

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### Authors

#### John Finn

Researcher, Soils and Land Use Department, Crops, Environment and Land Use Programme, Johnstown Castle, Co. Wexford

#### Simone Falzoi

Visiting Erasmus Scholar, Agrifood Business and Spatial Analysis Department, Rural Economy and Development Programme, Teagasc Ashtown, Dublin 15

#### Stuart Green

Senior Research Officer, Agrifood Business and Spatial Analysis Department, Rural Economy and Development Programme, Teagasc Ashtown, Dublin 15

#### Elodie Ruelle

Postdoctoral Researcher, Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork



# Unravelling the genetics of animal health

Ever wonder why all the cattle in a herd don't get infected during a contagious disease outbreak? Is genetics a major component of the animal health puzzle?

## Importance of animal health

Advancing the health and welfare of Irish dairy and beef cattle provides an opportunity to capitalise on increased productivity, while also taking cognisance of the responsibility of cattle production to be environmentally sustainable and socially acceptable. Strategies available for the control of cattle diseases in Ireland consist of herd management and biosecurity protocols, including vaccination and national eradication programmes. Antibiotic and anthelmintic treatments are used as mainstay treatments for bacterial and parasitic infections, respectively. Despite this, the persistently high prevalence of many diseases on farm reduces animal performance and farm viability. Furthermore, the incorrect usage of antibiotics and anthelmintic treatments is contributing to antimicrobial and anthelmintic resistance. Therefore, sustainable and cost-effective strategies to improve animal health status warrant investigation. Animal breeding is one such potential strategy.

## Breeding as a strategy to improve health

Breeding programmes have historically exploited the vast quantity of performance data available to achieve rapid on-farm improvements. Approximately half of the observed on-farm gains in reproductive and performance metrics in Irish cattle are attributable to genetic improvement. The same genetic advancements in animal health have not materialised. Lack of

genetic differences among cattle (i.e., genetic variability) is unlikely to be the underlying reason, but the lack of data to decipher genetically divergent animals for health has hampered progress. Nonetheless, international pressure to improve overall cattle health and well-being has led to the generation of many health datasets at research centre and national level. These datasets provide a rich opportunity to explore the extent of inter-animal genetic variability for health status. Analysis of these datasets can quantify the genetic variation for health traits and also the potential gains achievable from including health characteristics in national breeding goals.

## Obtaining health data

In 2015, the HealthyGenes project (funded by the Research Stimulus Fund) was launched to address the paucity of available health records in cattle. That project aspired to generate a large database of animal records for a range of diseases including hoof health, body condition score, locomotion, infectious bovine rhinotracheitis (IBR), Johnne's disease, liver fluke, *Neospora caninum* and stomach worms on over 10,000 dairy cows. Additionally, tuberculosis (TB) test results from the national TB eradication programme, liver fluke data from the Beef HealthCheck programme on slaughtered animals, and farmer-recorded details of incidences of mastitis and lameness, were available.



**Table 1: Prevalence of TB and liver fluke infection in cows identified as being high or low risk for infection based on estimated genetic merit for susceptibility to TB and liver fluke.**

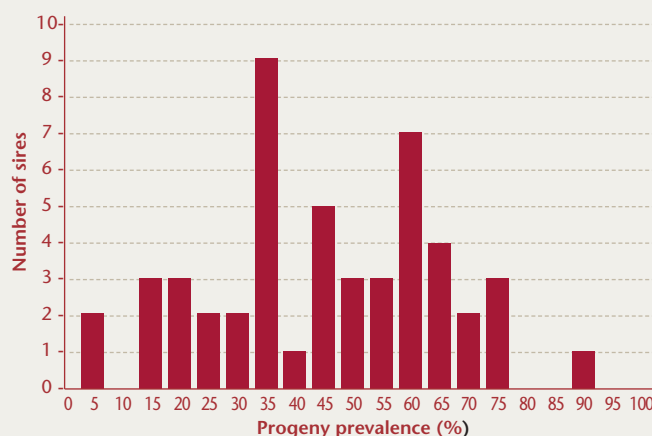
Genetic merit prediction	Cow prevalence	Herd prevalence
<b>TB</b>		
High risk	9%	10%
Low risk	7%	10%
<b>Liver fluke</b>		
High risk	47%	48%
Low risk	41%	45%

### Genetic variability exists for animal health

Recent research has revealed that 10% of the inter-animal variability in susceptibility to bovine TB is due to genetic differences among animals. A validation study was subsequently carried out to determine whether or not predicting animal genetic merit for TB susceptibility at birth, using only TB data from its relatives, could accurately predict the likelihood of an animal succumbing to TB. Considering only exposed herds, cattle in the worst 20% for predicted genetic merit for TB, deemed to be 'high risk', were compared to cattle in the best 20% for predicted genetic merit for TB, deemed to be 'low risk'. Following these animals throughout their life, 9% of the high-risk animals succumbed to TB versus 7% of the low-risk animals (**Table 1**). Therefore, predicting the genetic merit of cattle for susceptibility to TB infection would empower farmers to select cattle genetically more resistant to TB as candidate parents of the next generation. Such a strategy can complement the national TB eradication scheme. Similar conclusions are evident for Johne's disease, where up to 15% of the inter-animal variability in serological response is due to transmissible genetic effects.

Large variability in the prevalence of IBR existed among progeny of different sires. The progeny of some sires only had a 5% prevalence of IBR, while the progeny of other sires had a 90% prevalence, despite animals residing in common herds and being of similar age (**Figure 1**). Additionally, breeding for IBR resistance has been shown to have a favourable impact on genetic merit for both fertility and mortality in cattle. If more routine access to IBR (and other health data) becomes available through national programmes, the incidence of such diseases could be reduced through breeding, concurrent with traditional schemes.

Using data on livers examined by veterinarians at slaughter, significant genetic variation between cattle for liver fluke infection was detected. Although liver fluke infection was only 1% heritable, large exploitable genetic variation existed among the 95,522 animals analysed. Estimates of genetic merit for



**FIGURE 1:** Prevalence of positive blood tests for IBR in female progeny of sires with ≥25 daughters in ≥5 herds.

susceptibility to liver fluke infection were derived for animals at birth and were followed throughout their life. A six-percentage unit difference in the prevalence of liver fluke damage existed between cows predicted to be genetically high risk versus those predicted to be genetically low risk (**Table 1**). Therefore, genetic evaluations are a useful tool to breed cattle that are less susceptible to liver fluke, which will complement current control strategies.

### Acknowledgements

Funding for these initiatives originated from the Department of Agriculture, Food and the Marine (DAFM) Research Stimulus Fund projects HealthyGenes and FLUKELESS. The Irish Cattle Breeding Federation, Animal Health Ireland and DAFM also contributed to the data used in these studies.

### Authors

#### Siobhán Ring

PhD student, Teagasc Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

#### Alan Twomey

PhD student, Teagasc Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

#### Donagh Berry

Principal Research Officer, Teagasc Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork  
Correspondence: donagh.berry@teagasc.ie



# Successful supplementation

**TEAGASC** research examined the effects of dietary supplementation of gestating sows to improve offspring viability.

## The hyper-prolific sow

The number of pigs produced per sow per year is one of the most important key performance indicators in pig farming. Sow output in Ireland has increased by 4.7 pigs/sow/year in the last decade, from an average of 22.3 in 2007, to 27.0 in 2017 (PigSys 2017). This has been achieved primarily through genetic selection for larger litters. Large litters of piglets, however, are associated with a higher proportion of piglets with low birthweight and poor viability, leading to an increase in stillbirths and pre-weaning piglet mortality. Thus, to counter the negative effects of large litters, nutritional strategies to promote piglet growth and development in utero are increasingly important.

## Supplementation to improve sow output

L-arginine (ARG) is a progenitor for nitrous oxide, a vasodilator that promotes angiogenesis (formation of new blood vessels). Supplementing pregnant sows with ARG is hypothesised to increase the flow of oxygen, nutrients, ammonia and metabolic waste between the foetus and the placenta, and has previously been found to increase both the number of piglets born alive and birthweight. L-carnitine (CAR) is synthesised from lysine and methionine, and is involved in the transport of fatty acids across the mitochondrial membrane. Carnitine supplementation to pregnant sows has been shown to increase the number of muscle fibres that piglets are born with, piglet birthweight, piglet growth and overall litter size. There has been little work on ARG and CAR supplementation to highly prolific sows, and the effect of feeding both supplements in combination has not yet been investigated. We hypothesised that the supplementation of gestating sows with ARG and/or CAR would increase the number of piglets born, piglet weight and vitality at birth.

## Experimental set-up

The experiment was conducted on a 1,000-sow commercial unit. At 28 days of gestation, 429 sows were assigned to one of four dietary treatments in a 2x2 factorial arrangement until parturition. The two factors investigated were ARG supplementation (0 or 25g/day) and CAR supplementation (0 or 0.125g/day). Piglets from a subset of 218 litters, which were classified as prolific (>14 piglets) or not, were weighed at birth and at weaning (28 days). Piglets were categorised into one of five quintiles based on birthweight (very light, light, medium, heavy, and very heavy). Measures of vitality (bucket test, rectal temperature, body length and abdominal circumference) were recorded at birth for a further 10 litters per treatment. The bucket test is a rapid method of assessing the vitality of piglets within three hours of birth, and high scores are correlated with the likelihood of survival to weaning. The piglet is placed in a circular enclosure, and the number of circles completed, movement capacity, vocalisations, and udder stimulation movements are counted and added together.

## Sow performance

Neither ARG nor CAR had an effect on sow back fat depth at farrowing or weaning. Sows supplemented with ARG had fewer total piglets born ( $15.0 \pm 0.2$ ) and born alive ( $14.1 \pm 0.2$ ) than non-ARG sows ( $15.7 \pm 0.2$ ,  $14.7 \pm 0.2$ , respectively;  $P < 0.05$  for both), but CAR did not have an effect. When only considering the subset of sows that had birthweights of their piglets recorded, the results were similar.

## Piglet performance

ARG had no effect on piglet birthweight. Across all litters, CAR supplementation increased piglet birthweight, and also tended to increase piglet birthweight in prolific litters (**Figure 1**). There was no



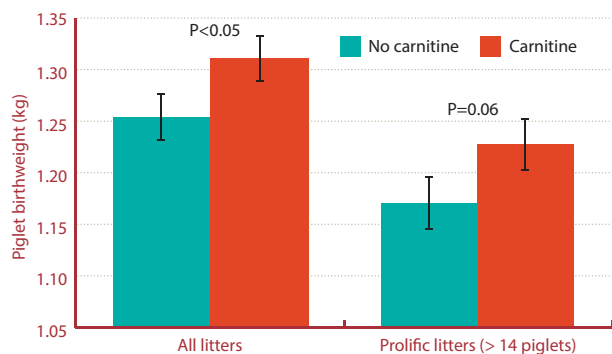


FIGURE 1: Mean birthweight of piglets from all litters and from litters of prolific sows (>14 piglets), when sows were or were not supplemented with 0.125g carnitine/day during gestation. Error bars represent the standard error of mean (SEM).

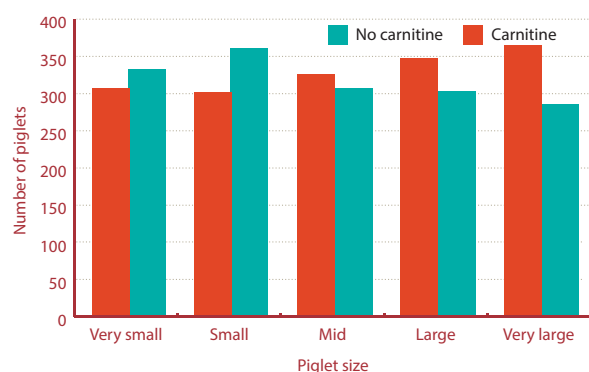


FIGURE 2: Numbers of piglets within each quintile at birth when sows were or were not supplemented with 0.125g carnitine/day during gestation.

effect of either supplement on average daily gain to weaning or on piglet weaning weight. A greater proportion of piglets from CAR-supplemented sows were in the top two heaviest quintiles at birth than in the bottom two ( $P < 0.001$ ; **Figure 2**). By weaning, this was no longer the case, as there were more carnitine piglets in all ranks other than the second lowest, and the overall percentage of carnitine piglets had increased from 50.9% to 53.2% ( $P = 0.12$ ). Thus more piglets from CAR-supplemented sows seemed to survive to weaning, particularly those from the lightest rank at birth.

### Piglet vitality at birth

Piglets from sows supplemented with CAR scored better in the bucket test than those from unsupplemented sows, but piglets from ARG-supplemented sows scored poorer than from unsupplemented sows (**Figure 3**). In the CAR treatment, piglets did numerically better in each of the four aspects of the bucket test, which led to an overall higher score. However, in the ARG treatment, piglets did numerically worse in all aspects, and significantly worse in both the number of circles completed, and the number of vocalisations ( $P < 0.05$  for both). There was no effect of any treatment on piglet rectal temperature, body length or abdominal circumference at birth.

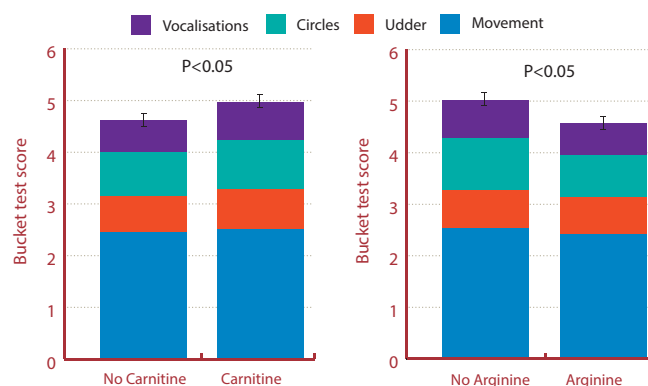


FIGURE 3: Piglet bucket test scores when sows were or were not supplemented with 0.125g carnitine/day, or 25g arginine/day during gestation.

### Conclusions

- ARG supplementation reduced litter size and piglet vitality. Thus, the benefits to sow performance previously reported in less prolific sows were not evident in this study.
- CAR supplementation resulted in a 56g increase in birthweight, and improved piglet vitality scores at birth.
- There were indications that more CAR piglets survived to weaning, and that CAR is especially beneficial in larger litters.
- Further work is ongoing to investigate the effect of CAR supplementation on muscle fibre development.

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### Authors

#### Keelin O'Driscoll

Research Officer, Teagasc, Pig Development Department, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork  
Correspondence: keelin.odriscoll@teagasc.ie

#### Peadar Lawlor

Principal Research Officer, Teagasc, Pig Development Department, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

#### Kathryn Reid

Walsh Fellow, Teagasc, Pig Development Department, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork



# Energising dairy decisions

A new tool developed by **TEAGASC** researchers easily and quickly allows dairy farmers to see their energy usage and evaluate how renewable sources could decrease energy costs.

## Background

The average cost of electricity on Irish dairy farms is €5 per 1,000 litres of milk produced. The main drivers of electricity consumption on dairy farms are milk cooling (31%), the milking machine (20%) and water heating (23%). There is a large variation in that figure – from €2.60 to €8.70 per 1,000 litres produced, or from €15–€45 per cow per year. These figures suggest that there is potential for many farmers to reduce their electricity usage by making changes to how they produce milk. Teagasc estimates that the average farm could save €1,800 (and approximately 5.8 tonnes of CO<sub>2</sub>) per year through altered management strategies and the use of energy-efficient technologies. A difficulty arises in delivering a set of generalised recommendations to farmers around energy efficiency because every farm is different in some key areas. These include herd size, infrastructure specification, farmer age and eligibility for grant aid, and availability of grant aid for specific technologies.

## Dairy energy decision support

Teagasc has partnered with Cork Institute of Technology (CIT) and the Sustainable Energy Authority of Ireland (SEAI) under the Research, Development and Demonstration funding programme to deliver an online decision support tool to aid farmers in making decisions regarding energy efficiency and technology investments. The tool, known as the Dairy Energy Decision Support Tool (DEDST) is available to use for free at: <http://meso.cit.ie/dairy>. The DEDST can be used to obtain farm-specific recommendations relating to energy use, technology investments, CO<sub>2</sub> mitigation and renewable energy consumption. It is an interactive and easy-to-use tool aimed at farmers, farm managers and farm advisors. It provides information to the user regarding key decisions that determine the energy efficiency and cost effectiveness of the milk production process, such as investment in certain technologies and changes in farm management practices. It can also be used to support government bodies in forming new policy relating to provision of grant aid for energy-efficient and renewable energy technologies.

## Description of the tool

The DEDST operates as a web-based platform, and encompasses a user interface that supplies information to a mechanistic model for dairy farm energy consumption. The user enters details of a specific farm, including farm size, milking times, number of milking units, cooling system type, water heating type and electricity tariff (**Figure 1a**). Details of an alternative technology to be evaluated on that

FIGURE 1: (a) input screen for DEDST; (b) alternative technology screen for DEDST.



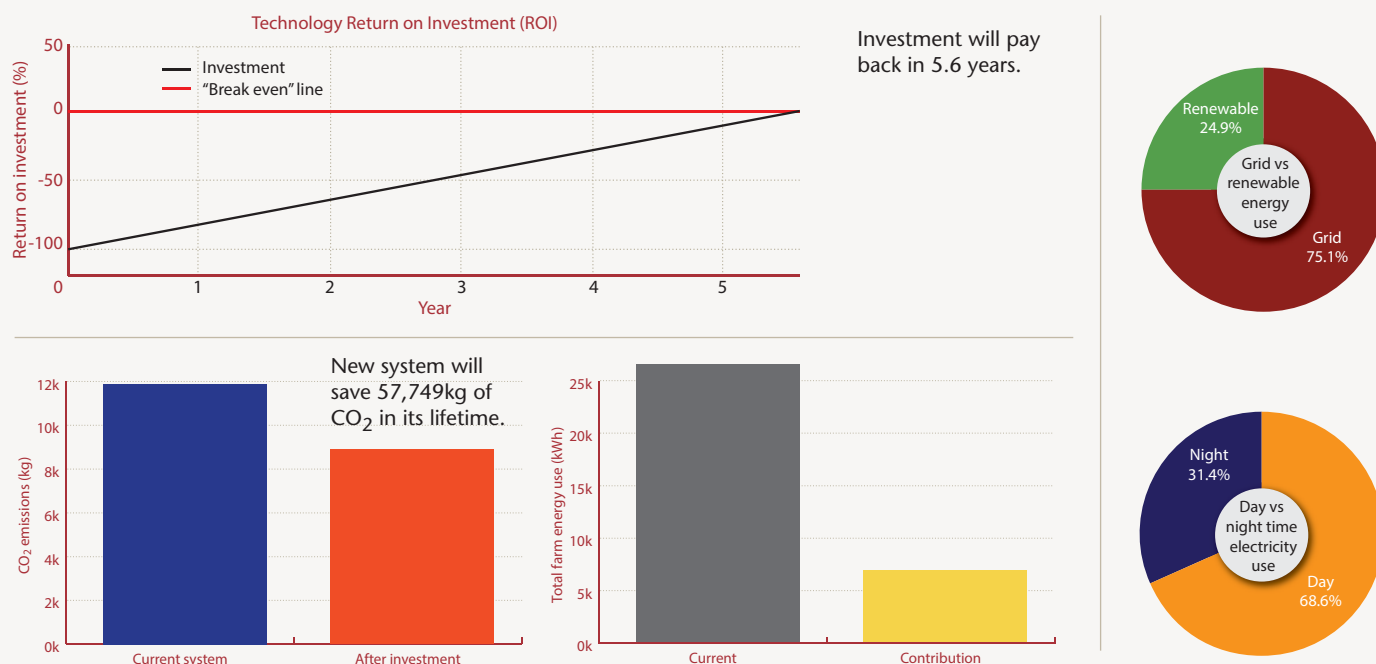


FIGURE 2: Output screen for the DEDST.

farm can then be entered (Figure 1b). Possible alternative technologies include plate coolers, variable speed drives, heat recovery systems, solar photovoltaics, wind turbines and solar thermal systems. The user may also enter economic details regarding potential future grant aid for the alternative technology, as well as renewable energy feed-in tariffs, and inflation. All energy and economic calculations are then computed by the model with the outputs being displayed on an easy to interpret output screen (Figure 2). The user can then easily change details relating to the farm or the alternative technology, with the displayed outputs updating accordingly.

### Example – investment in a solar photovoltaic system

Solar photovoltaic (PV) cells generate electricity using energy from the sun, which in turn can be used by the farm. These systems can be standalone (i.e., the generated electricity is only used by the farm) or grid connected (where surplus electricity is fed into the national electricity grid).

Unfortunately, in Ireland, micro-generators who export power to the grid from small-scale PV systems do not receive payment for exported electricity. Furthermore, there are no capital investment grants to subsidise the purchase cost of PV systems. Hence, the most logical solution for Irish farmers would be a stand-alone system sized so that all electricity generated is consumed by the farm.

For a 100-cow spring-calving herd, the ideal PV system size falls at around 6kW of installed capacity, which would cost in the region of €6,000. In the absence of a capital investment grant, this system would pay back after nine years. If a 40% technology investment grant were made available, the payback period would fall to 5.6 years. This change would result in 25% of a farm's electricity coming from a renewable source and would offset more than 57 tonnes of CO<sub>2</sub> over a 10-year period. The output screen of the DEDST for this example is shown in Figure 2.

### Benefits to industry

The methods deployed in the development of this tool utilised resources from multiple sources to package a suite of scientific outputs into a user-friendly decision support tool. The DEDST can now be used by farmers and advisors to make informed decisions around energy use and technology investments on a case-by-case basis. It will also allow policy makers to conduct macro-level analyses to inform decisions regarding provision of grant aid for specific equipment.

### Authors

#### John Upton

Research Officer, Livestock Systems Research Department, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork  
Correspondence: john.upton@teagasc.ie

#### Philip Shine

PhD student, Department of Process, Energy and Transport Engineering, Cork Institute of Technology, Bishopstown, Cork

#### Michael Breen

Teagasc Walsh Fellow, Department of Process, Energy and Transport Engineering, Cork Institute of Technology, Bishopstown, Cork

#### Michael D. Murphy

Lecturer, Department of Process, Energy and Transport Engineering, Cork Institute of Technology, Bishopstown, Cork



# AMR – three deadly letters

Drug resistance is a global problem in human and animal health. A **TEAGASC** team has studied antimicrobial drug usage in calves on commercial beef and dairy farms in Ireland.

While antimicrobial usually has a broader definition, in this article it means antibiotics (and their chemical derivatives) with an antibacterial range of action. Antimicrobial resistance (AMR) is the ability of bacteria (or microbes) to resist the effects of an antibiotic and is one of the leading health concerns in human and veterinary medicine worldwide. AMR occurs when bacteria change in a way that reduces the effectiveness of drugs, chemicals, or other agents designed to cure or prevent infections. Antimicrobial resistance (AMR) may cause treatment failure, both in humans and animals. This treatment failure results in a higher morbidity and mortality.

## Monitoring antimicrobial usage

In Europe, various monitoring programmes have summarised antimicrobial consumption for animals through annual antimicrobial sales data. These programmes are structured to observe trends at the national level and for comparison of data between years and countries. However, a limiting factor is that they are unable to provide more precise information, such as usage at farm level, variability between farms, etc.

## Teagasc study on antimicrobial drug usage in calves

The main objective of the study was to quantify antimicrobial drug usage in calves using health treatment records from Irish suckler beef and dairy farms. In this study, antimicrobial usage refers to the exposure of a given animal or group of animals over a period of time to the active substance in each antimicrobial that was administered.

## Data source

Data were obtained from a large-scale study on herd-level factors associated with the health and survival of calves on Irish farms. Farmers enrolled in this herd-level study recorded birth, disease and health treatment, and death information on their calves using standardised recording sheets. Case definitions were provided to the farmers to assist with the classification of disease. Farmers completed and submitted the project recording sheets on a monthly basis. All health treatment data were reviewed. Long-acting antimicrobials administered more than seven days apart, or other medications administered more than three days apart, were classified as separate disease events. Crude morbidity was

defined as calves being treated for at least one disease event, attributed to any cause, excluding injury. Calves treated for illnesses other than diarrhoea, pneumonia, navel infection, or joint infection/lameness were categorised as receiving treatment for 'other' disease events. The data collected were the antimicrobial trade name, the pharmaceutical form (oral solution, oral powder, parenteral solutions, tablets, bolus, etc.), the pack size (in L or mL for liquids, in g or kg for solids, in unit number for bolus or tablets, etc.), the total number of packages prescribed and dispensed to the farm, and the prescribed therapy (dose, administration frequency, duration).

## Antimicrobial usage

Defined daily dose for animals (DDDvet) (mg/kg animal/day) and used daily dose (UDDvet) (mg/kg animal) were the technical units used to measure antimicrobial consumption. The DDDvet is defined as the average maintenance dose for the main indication in a specified species and it is provided by the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) project for veterinary antimicrobial usage (European Medicines Agency), whereas the UDDvet is calculated

## Actions farmers can take to keep antimicrobials working

- Only give antimicrobials to animals under veterinary supervision.
- Always give the right dose, and the number of treatments, as prescribed by the vet.
- Do not use antimicrobials for growth promotion or disease prevention in healthy animals.
- Do not use antimicrobials to treat viral disease.
- Do not use a stronger antimicrobial as first-line treatment.
- Vaccinate animals to reduce the need for antimicrobials and use alternatives when available.
- Improve biosecurity on farms and prevent infections through improved hygiene and animal welfare.
- In the case of medicines used in food-producing animals, ensure that the Animal Remedies Record is updated on each occasion that a veterinary medicine is administered.



**Table 1. Antimicrobial drug classes administered to suckler beef (n=654) and artificially reared dairy calves (n=795) from birth to six months of age.**

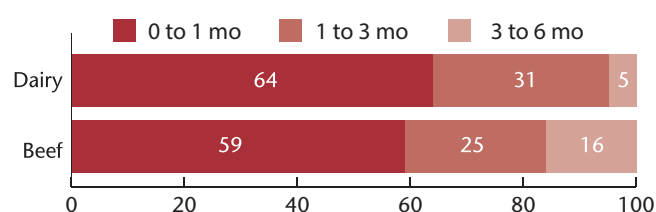
Antimicrobial class	Number of antimicrobial treatments		Tludd mean		Tludd mean	
	Beef	Dairy	Beef	Dairy	Beef	Dairy
Tetracyclines	97	160	0.70	0.60	4.46	28.9
Amphenicols	128	159	0.48	0.45	3.81	19.1
Penicillins	210	164	1.12	0.65	10.2	9.4
1st and 2nd GC <sup>1</sup>	0	1	0	0.02	0	15.3
3rd and 4th GC <sup>2</sup>	4	3	0.02	0.07	0.023	0.21
Sulfonamides	94	161	0.31	0.78	1.78	23.4
Macrolides	38	20	0.525	0.59	0.49	0.89
Lincosamines	2	0	0.002	0	0.014	0
Fluoroquinolones	202	181	0.93	1.29	13.13	26.5
Aminoglycosides	63	79	0.15	0.37	1.42	17.8
Spectinomycin	3	1	0.002	0	0.012	0.011

<sup>1</sup>First and second generation cephalosporins; <sup>2</sup>third and fourth generation cephalosporins.

as the amount of an antimicrobial drug administered during a given period (days) divided by the number of calves at risk and their average liveweight at the beginning of a treatment. In this way the UDDvet reflects the dose truly administered by the producer. Treatment incidence (TI) was the indicator used to quantify antimicrobial usage. The TI provides a standardised technical unit of measurement that quantifies how many animals out of a theoretical group of 1,000 animals receive a daily antimicrobial treatment. The population correction unit (PCU) is a measurement developed by the European Medicines Agency (EMA) and takes into account the animal population as well as the estimated weight of each particular animal at the time of treatment with antimicrobials. The milligrams (mg) of antimicrobial used per PCU was calculated.

## Results

This study provides the first detailed information pertaining to on-farm usage of antimicrobials in suckler beef and artificially reared dairy calves from birth to six months of age, in Ireland. A total of 123 farms (79 beef and 44 dairy), comprising 3,204 suckler beef calves and 5,358 dairy calves, representing 540,953 and 579,997 calf-days at risk, respectively, were included in the study. All calves were raised on farm of origin and most of the studied herds were closed herds. In this study, only animals showing signs of disease were treated with antimicrobials and no mass administration of antibiotics was practised. The highest risk period for disease in the present study was between birth and one month of age, with approximately two-thirds of all disease events occurring during this time period. This is reflected in the proportion of antimicrobials administered to calves at this time (**Figure 1**). The classes of antimicrobials most frequently prescribed for beef and dairy calves were: tetracyclines; amphenicols; penicillins; first and second generation cephalosporins (GC); third and fourth GCs; sulfonamides; macrolides; lincosamines; fluoroquinolone; aminoglycosides; and, spectinomycin (**Table 1**). A total of 1,770 antimicrobial treatments were prescribed and



**Figure 1. Proportion of antimicrobial treatments (%) for suckler beef and artificially reared dairy calves from birth to six months of age.**

administered to suckler beef (n=841) and dairy calves (n=929) between birth and six months of age.

Fluoroquinolones were the most prescribed antimicrobials with 383 treatments, followed by penicillins (n=374), amphenicols (n=287) and tetracyclines (n=257). The third and fourth GC accounted for a total of seven treatments (**Table 1**). The average cost of veterinary services was €41.25 and €43.37 per calf for beef and dairy calves, respectively; corresponding antimicrobial costs were €11.58 and €11.51 per calf.

## Acknowledgements

Funding from the Department of Agriculture, Food and the Marine (DAFM) (Dr B. Earley project leader) under the Stimulus Fund (11/S/131) is gratefully acknowledged. The authors also wish to acknowledge the participating farmers, their Teagasc advisors, Cynthia Todd and Olivia Butler with data collection, and the administrative staff at Teagasc Grange for their support of this research.

## Authors

### Bernadette Earley

Teagasc Grange Animal & Grassland Research and Innovation Centre, Dunsany, Co. Meath  
Correspondence: bernadette.earley@teagasc.ie

### Anastasio Arguello

Visiting Scientist, Teagasc Grange Animal & Grassland Research and Innovation Centre, Dunsany, Co. Meath

### Aidan Murray

Beef Specialist, Teagasc, Letterkenny, Co. Donegal

### Mark McGee

Research Officer, Teagasc Grange Animal & Grassland Research and Innovation Centre, Dunsany, Co. Meath



# Meat quality attributes of Irish male lambs

Researchers at **TEAGASC** and UCD are looking at whether castration affects the sensory and eating quality attributes of lamb meat.

In Ireland, the practice of castrating lambs has declined over the past decade. The use of entire ram lambs in production systems is favoured, at least in part, because of their increased growth rates and ability to utilise feed more efficiently, while producing a leaner carcass. The supply of a consistent product, which consumers will repeatedly purchase, is critically important to the sheep industry. Critical characteristics include the physical appearance and tenderness of the meat, as well as taste and the absence of off-flavours. Some processors and producer groups have expressed concern that leaving male lambs entire undermines the market for lamb because consumers find the eating experience of meat from entire male lambs unsatisfactory. This paper summarises the results of a series of recently completed Teagasc–University College Dublin (UCD) studies, which compared ram and wether (castrated) lambs fed on an all-concentrate diet prior to slaughter.

## Tenderness and sensory analysis

A total of 200 Scottish Blackface and Texel × Scottish Blackface lambs were identified, tagged and had their date of birth recorded on six commercial farms. Each alternate male lamb born alive was castrated using a scrotal rubber ring within 48 hours of birth. At five months of age, lambs were weighed and inspected visually on all six source farms to confirm sex and disease-free status, before being transported to the Teagasc Research Centre at Athenry.

Lambs were individually housed on expanded metal feeding pens for the indoor finishing period. Lambs were slaughtered at five points between October and April. Carcasses were graded for conformation using the EUROP scale and subcutaneous fat cover using a one to five scale (1 = low fat cover, 5 = excess fat tissue cover). The right side of each carcass was deboned at 24 hours post mortem. Steaks were cut from the loin and used for muscle colour assessment, Warner-Bratzler shear force (WBSF) tenderness measurements, total collagen content and proximate composition measurements, carcass pH and temperature measurements and sensory analysis.

## Consumer acceptability

The instrumental meat quality and proximate composition results were consistent across both breed types, age at slaughter and lamb gender. Results in **Table 1** show that although subtle differences were seen in traits between genders, meat produced from both genders would be deemed acceptable. Tenderness values, which were measured by the WBSF method, indicate the force required to cut through a piece of meat and are reported in Newtons (N). This test suggests that meat from wether lambs had, on average, higher tenderness values (lower WBSF values) than meat from ram lambs; however, meat from both genders was acceptably tender. Intramuscular fat was greater in wether lambs, which may explain the increased tenderness values seen for wether lambs. Ultimate pH of the carcass was greater in ram lambs than wether lambs, but both genders produced carcasses with pH values within the acceptable range. Sensory analysis by 100 consumers (**Table 2**) also recorded minimal differences between genders and few advantages of castration from a meat quality point of view (Gkarane *et al.*, 2017). Sensory analysis showed that although meat from wether lambs scored higher for traits such as overall liking and tenderness liking, meat from ram lambs also scored as acceptable (values greater than five) and the differences recorded between both genders were minimal.

**Table 1: Instrumental meat quality assessment of ram and wether lambs.**

	Gender		Statistical significance
	Ram	Wether	
Proximate composition			
Intramuscular fat (%)	2.61	3.19	Higher in wethers
25-hour pH	5.65	5.52	Higher in rams
Tenderness (WBSF, N)	37.1	34.2	Higher in wethers
Cook loss (%)	29.2	28.7	Similar
Total collagen (g/kg)	2.94	2.96	Similar





## Conclusion

It can be concluded that castration of lambs offers minor additional benefits in meat quality and the benefits are insufficient to compensate for the lower growth rates and lower feed conversion efficiencies of wether lambs compared to ram lambs (Claffey *et al.*, 2018). For this study consumers did not dislike meat from either castrate or ram lambs, deeming the meat from both genders to be acceptable. Therefore, the message to industry is that castration has a small effect on sensory attributes of lamb meat, though castration may still be required in some systems as a management tool.

## Acknowledgements

Funding from the Irish Department of Agriculture, Food and the Marine

**Table 2: Effect of gender on sensory attributes of meat from ram and wether lambs.**

	Gender		Statistical significance
	Ram	Wether	
Overall liking <sup>1</sup>	5.8	6.3	Higher in wethers
Aroma liking <sup>1</sup>	5.6	5.9	
Aroma intensity <sup>2</sup>	5.2	5.0	
Flavour liking <sup>1</sup>	5.8	6.2	Higher in wethers
Flavour intensity <sup>2</sup>	5.6	5.6	
Tenderness liking <sup>1</sup>	6.3	6.7	
Level of tenderness <sup>3</sup>	5.9	6.2	Higher in wethers
Juiciness liking <sup>1</sup>	5.9	5.9	
Level of juiciness <sup>4</sup>	5.4	5.3	
Off-odour <sup>5</sup>	1.4	1.2	Higher in rams
Off-flavour <sup>5</sup>	1.7	1.1	

Category/intensity scales:<sup>1</sup> 1 = dislike extremely, 9 = like extremely

<sup>2</sup> 1 = extremely weak, 9 = extremely strong

<sup>3</sup> 1 = extremely tough, 9 = extremely tender

<sup>4</sup> 1 = extremely dry, 9 = extremely juicy

<sup>5</sup> 0 = not detected, 1 = extremely weak, 9 = extremely strong

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## Authors

### Noel Claffey

Postdoctoral Researcher, Teagasc Mellows Campus, Athenry, Co. Galway. Correspondence: noel.claffey@teagasc.ie

### Rufielyn Gravador

Postdoctoral Research Fellow, University College Dublin

### Michael Diskin

Sheep Enterprise Leader, Teagasc Mellows Campus, Athenry, Co. Galway

### Frank Monahan

Head of Food Science and Nutrition, University College Dublin



# Practice change and water quality response

TEAGASC took part in an international research review which examined how long it takes for water quality to improve after changing a potentially polluting agricultural practice or introducing a set of mitigation measures.

## A global question

The time between the introduction of mitigation measures and a water quality response occurring is called time lag. How long it takes is a big question and an important one for farmers, as well as policy makers. Two components of time lag are, firstly, the physical movement of water and pollutants (hydrological time lag) and, secondly, the transformation of these pollutants before they affect water quality (biogeochemical time lags). Within agricultural catchments these time lag components interact and are influenced by the soil, the subsoil and the geology. To guide our expectations for water quality improvement in Irish river catchments, we looked at experiences from around the world for issues around phosphorus (P), nitrogen (N), suspended sediment (SS) and river biology.

## International catchment studies

A literature review was undertaken on 25 previous studies from across Europe, USA, New Zealand and Brazil, which were conducted in medium-sized river catchments (1-100km<sup>2</sup>) where mitigation measures had been implemented to improve water quality. For the review, we also defined the aspects of time lag:

- response time – how long does it take for the practice or measure to have been implemented before a change in water quality starts to emerge?
- measurement time – how much monitoring is required, including beyond the emergence of the change in water quality,

to say for certain that change has definitely happened? This is in order to statistically separate signals or responses from environmental noise.

- implementation lag – the time it takes for practice change to reach a maximum or threshold rate of implementation.

## Positive effects and catchment scale

Positive effects on one or more water quality indicators were measured in 17 of the 25 studies reviewed. These positive effects occurred one to ten years after practices were implemented (Figure 1). In contrast, four to 20 years were needed to statistically detect the positive effects on water quality (Figure 1). The longer times appeared to have a relationship with scale. The larger the catchment scale, the longer it took to respond to practice change and subsequently measure a water quality change. The review indicated that there was also a tendency for the response time to increase as the travel time of the pollutant flow pathway increased. For example, SS and P transport, which occurs predominantly via the overland flow pathway, had opportunities to be remediated quickly, whereas N leached via subsurface flow pathways took longer to remediate (Figure 2).

Implementation lag times ranged from 0.5-14 years, tended to increase with catchment size up to about 20km<sup>2</sup>, and were not always shorter when practice change was mandatory. A caveat in most of the studies was that nutrient management practice data,



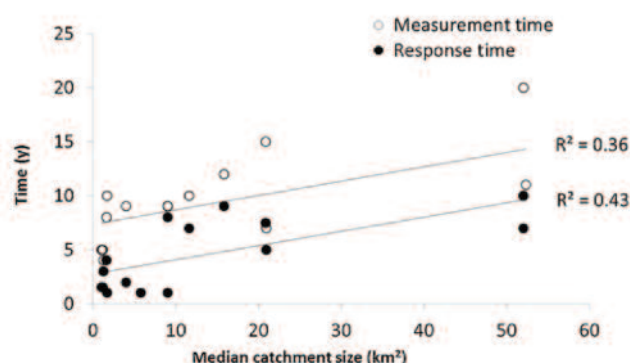


FIGURE 1: Response times and measurement times for positive effects on water quality following practice change – indicating a relationship with catchment scale and showing the extra time needed to detect a statistically significant change through monitoring.

such as the timing of fertiliser application, were often not as complete as water quality data, despite their importance in identifying cause–effect relationships.

There were also examples of simultaneous negative or immeasurable effects. For example, a study in New Zealand found positive effects for P and SS (and also faecal indicators), but no measured change was found in stream macroinvertebrate indicators, and river N loads increased. Important lessons can be learned here as both surface and subsurface flows transported farm pollutants in the catchment. The increased river N load was explained by higher N leaching losses owing to higher N fertiliser and supplementary feed inputs to the catchment over the period of measurement, whereas the positive effects were realised via mitigation of surface flow pathways. The neutral effect on stream macroinvertebrates was attributed to the short timeframe of the study (five years), poor recolonisation potential and non-limiting water temperatures prior to stream habitat restoration.

### The long-term view

The review highlighted that to measure water quality change in medium-sized catchments, scientists should account for long time lags, from four to 20 years, when designing measurement programmes. Scientists should also:

- highlight any ineffective practices (including pollution swapping);
- identify the degree to which water quality targets are likely to be achieved;
- estimate the temporal and spatial scale of effectiveness of practice change, because the appropriate monitoring period and location varies for different indicators of improved water quality; and,
- calculate the ratio of costs to benefits due to practice change.

The review indicates the need to consider the limitations of combining response data from multiple catchment scales and over multiple soil, subsurface and geological conditions, when gauging the effectiveness of practice change policies on water quality.

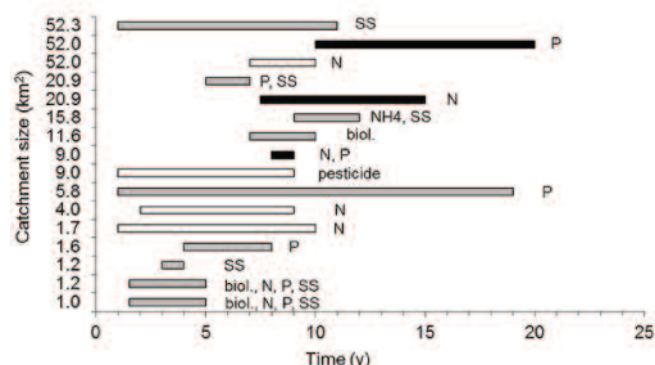


FIGURE 2: A comparison of catchment size and main water flow pathway against positive water quality response and measurement times. Left extent of bar = response time, right extent of bar = measurement time. Water quality indicators are also annotated as biol. (biological indicator), N (nitrogen species), NH<sub>4</sub> (ammonium only), P (phosphorus species) and SS (suspended sediment). The transport pathway contributing most to the state of the water quality indicator is represented as surface (grey bars), subsurface tile drains (un-shaded bars) or subsurface/groundwater (black bars).

### Acknowledgments

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### Authors

#### Owen Fenton

Principal Research Officer, Water Quality, Teagasc Environment Research Centre, Johnstown Castle, Co. Wexford  
Correspondence: owen.fenton@teagasc.ie

#### Phil Jordan

Professor of Catchment Science, School of Geography and Environmental Sciences, Ulster University, Co. Derry

#### Alice Melland

Research Fellow (Soils and Environmental Chemistry) National Centre for Engineering in Agriculture, University of Southern Queensland, Toowoomba, Queensland, Australia





# Return of the MACC

TEAGASC researchers have performed an analysis of abatement potential for greenhouse gas emissions in Irish agriculture for the commitment period 2021-2030.

## Climate change and agriculture

In order to address climate change, 197 countries signed up to the Paris Agreement, which seeks to keep global temperature rise this century below 2°C above pre-industrial levels. The EU has also set emissions reduction targets, with Ireland allocated a 20% reduction in emissions to 2020 and 30% to 2030, compared to 2005. Recently, the Department of Communications, Climate Action and Environment (DCCAE) published Ireland's roadmap for reducing emissions in the form of the National Mitigation Plan Consultation. Teagasc has submitted a response to this consultation outlining both the challenges and options available for emissions reduction.

Why are these climate targets a challenge to Irish agriculture? Well, firstly, agriculture accounts for one-third of national greenhouse gas (GHG) emissions.

Secondly, agricultural production, particularly dairy, is growing post quota removal, and Foodwise 2025 has set ambitious targets for further growth in primary production and exports. In order to meet these twin goals, there is the need for a roadmap that examines the potential of cost-effective GHG mitigation. Hence the need for a Marginal Abatement Cost Curve (MACC) that identifies the most cost-effective pathway to reduce sectoral emissions.

## Projecting emissions to 2030

Agricultural emissions in 2005 were 18.7Mt CO<sub>2</sub>e. In the absence of any mitigation, agricultural GHG emissions are projected to increase by on average 9% by 2030 relative to the 2005 baseline. This projected increase is mainly driven by increased dairy cow numbers and fertiliser use. However, the extent of any increase by 2030 is highly uncertain, and is dependent on future changes in total animal numbers and fertiliser inputs. The range in 2030 emissions projections in our analyses could be between 19.45 and 21.75Mt CO<sub>2</sub>e by 2030 (Figure 1). The projected baseline level of emissions, which is roughly at the midpoint of this range, would be 20.45Mt CO<sub>2</sub>e in 2030.

In this current GHG MACC, Teagasc has quantified the abatement potential of a range of mitigation measures, as well as their associated costs/benefits. The objective of this analysis is to provide clarity on the extent of GHG abatement that can realistically be delivered through cost-effective agricultural mitigation measures, as well as clarity on which mitigation measures are likely to be cost prohibitive and which should be prioritised.

## The solutions

Over the last number of years, Teagasc has been working to develop solutions. Much of the answer lies in farm efficiency: if we can produce food with fewer inputs, then this reduces emissions to the atmosphere and costs to the farmer. This will be achieved through adoption of measures such as dairy EBI, beef genomics, improved animal health, extending the grazing season, and use of sexed semen. These efficiencies will reduce the carbon footprint of dairy and beef, and stabilise methane emissions via increased product per head, improved fertility and/or reduced need for replacements. Improved nutrient management planning, particularly optimising soil pH, in combination



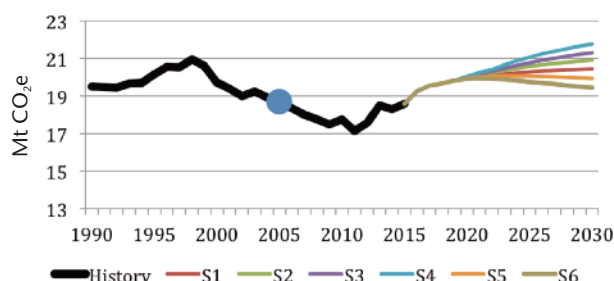


FIGURE 1: GHG emission projections under the six scenarios – this analysis excludes mitigation actions. The blue dot indicates the emissions level in 2005 against which future emissions reduction will be measured.

with optimal use of slurry and legumes, will help increase nitrogen efficiency and reduce nitrous oxide emissions. Other strategies can reduce GHG emissions even further. Examples include the development of novel, low-emission fertilisers, reducing crude protein in bovine and pig diets, fatty acids supplementation to reduce methane, drainage of poorly drained mineral soils, and adding amendments to manures during storage. The total mean abatement potential arising from cost-beneficial, cost-neutral and cost-positive mitigation measures for agricultural emissions (methane and nitrous oxide), and assuming linear rates of uptake, was 1.85Mt CO<sub>2</sub>e per annum between 2021 and 2030, compared to the baseline scenario. The maximum annual abatement in the year 2030 was 3.07Mt CO<sub>2</sub>e (Figure 2).

In addition, enhancing carbon sequestration and reducing soil carbon losses are key strategies to reduce sectoral emissions. This will principally be achieved through increased afforestation, reducing carbon losses on organic soils and enhancing pasture sequestration. Bio-energy and energy saving can also play a substantial role in reducing Ireland's dependence on fossil fuels. The main strategies include energy saving via the use of plate coolers in milking parlours and bioenergy via wood and wood residues for heat generation, short rotation coppice for bioenergy and biogas/bio-methane (generated primarily from grass production). However, realisation of the bio-energy potential of agriculture will depend on policy.

### Knowledge implementation

As the 2030 GHG reduction target is a multi-annual target (effectively targets for cumulative emissions reduction over time), the total amount of abatement achieved will be highly dependent on rates of uptake at farm level. Ultimately, the quicker adoption of measures should lead to a larger cumulative emission reduction. This means that understanding barriers to uptake and understanding the role of knowledge transfer (KT) in overcoming obstacles to adoption will both be more important than ever. Emissions reductions can only be realised if the desired mitigation actions are supported by a comprehensive KT programme.

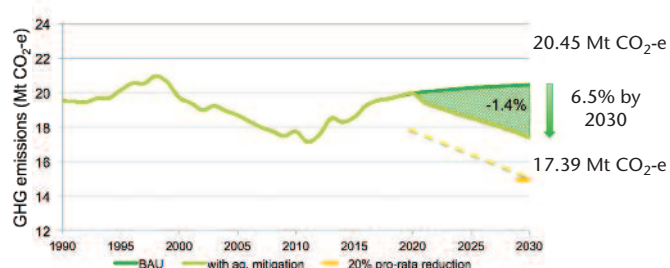


FIGURE 2: Agricultural GHG emissions from 1990 and projected to 2030, without and with mitigation. The orange line represents a pro-rata 20% reduction in sectoral emissions.

### Acknowledgments

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### Authors

#### Gary Lanigan

Principal Research Officer – Greenhouse Gas Emissions, Teagasc Crops, Environment and Land Use Programme, Johnstown Castle, Co. Wexford  
Correspondence: [gary.lanigan@teagasc.ie](mailto:gary.lanigan@teagasc.ie)

#### Trevor Donnellan

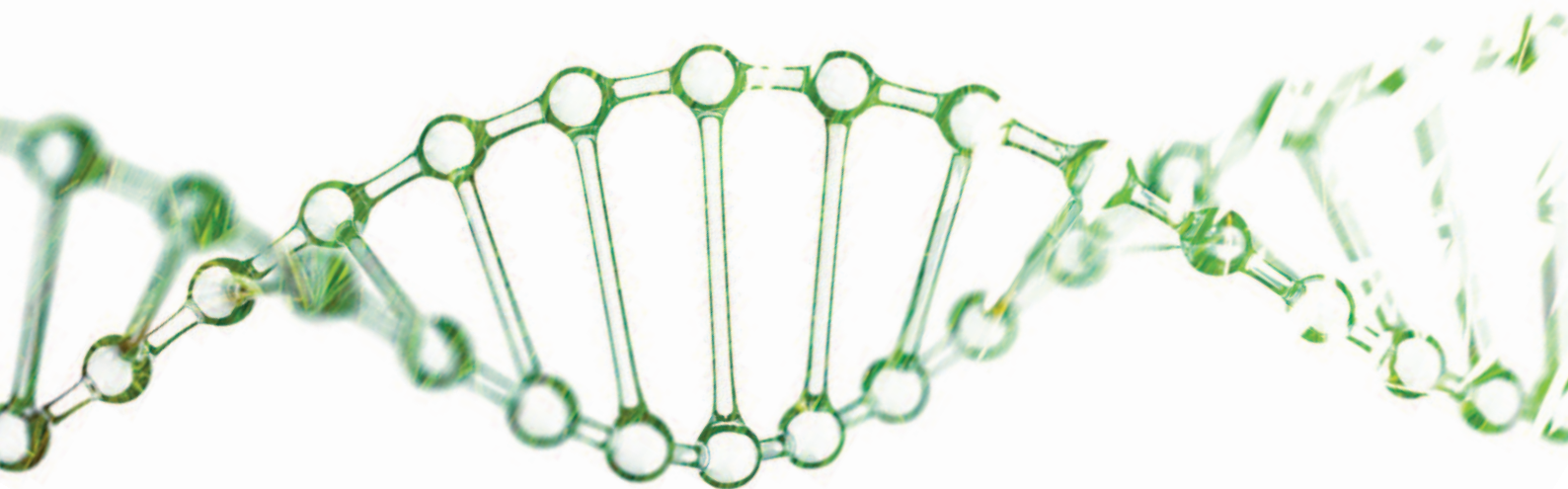
Head of Agricultural Economics and Farm Surveys Department, Teagasc Rural Economy and Development Programme, Athenry, Co. Galway

#### Kevin Hanrahan

Head of Programme, Teagasc Rural Economy and Development Programme, Athenry, Co. Galway



# Turbocharging perennial ryegrass breeding



A **TEAGASC** project is addressing how we can make faster selection decisions and develop improved grass varieties that will meet the needs of the agri-food sector.

## Breeding new varieties of perennial ryegrass

Teagasc has been breeding perennial ryegrass at Oak Park since the early 1960s and to date has successfully bred 27 varieties that have been commercialised by our partners. The release of a new variety is the culmination of 15 to 20 years of investment that consists of:

- plant breeding to construct an improved variety;
- independent variety testing to ensure value for cultivation and use, and distinctness, uniformity and stability; and,
- commercial seed production and release for use by farmers, typically in the form of varietal mixtures.

Teagasc is responsible for the plant breeding component, which consists of a multistep and cyclic process, known as recurrent selection, where the best plants (genotypes) are evaluated, selected and intercrossed to produce a new variety. The goal is to increase the frequency of favourable alleles and superior genotypes in the population over time.

A typical cycle of recurrent selection takes around five years and includes seed multiplication for establishing sward plots, multi-year field evaluation, and data analysis and selection. There is scope to increase the rate of genetic gain by reducing the length of time it takes to complete a single cycle of recurrent selection. This is a major goal of forage breeders worldwide and has led to the adoption of new and faster selection tools.

## Using DNA-based selection tools

Genomic selection is a new breeding tool that uses information from a plant's DNA to predict its breeding value. In recent years there has been increased interest in its application to forage grass breeding, mainly driven by a reduction in the cost of DNA sequencing, but also from the demonstrable success of genomic selection in animal breeding. In genomics-assisted breeding, DNA evaluations are related to field measurements in a reference population and used to develop statistical models for genomic selection.

Using these statistical models we can generate breeding values for progeny of the reference population based solely on its DNA. The huge advantage genomic selection offers grass breeding is that it allows the breeding values of plants to be computed in one year using information from the DNA alone. This compares very favourably to traditional field-based genotypic selection, which takes around five years per selection cycle. This means we can complete five cycles of genomic selection in the same time it takes to complete a single cycle of field-based selection. It also enables us to increase selection intensity, as there are fewer constraints on the number of genotypes that can be evaluated in the glasshouse using DNA techniques as opposed to multi-year field evaluations. The result of reducing the length of the breeding cycle and increasing selection intensity is greater genetic gain.



## Implementing genomic selection

Teagasc, Oak Park has initiated a project to evaluate the potential of implementing genomic selection in a tetraploid perennial ryegrass breeding population. A reference population of half-sib families (each family consists of plants with a common maternal parent) with features favourable for genomic selection was established. Families were evaluated in a replicated field trial over multiple years for forage yield under both simulated-grazing and conservation management. At the same time, we performed DNA evaluations on the parental plants by partially re-sequencing the genomes of each maternal plant. The data sets were combined, and we built statistical models and tested how well we could predict forage yield with genomic data. In particular, we were interested in predicting annual and seasonal forage yield weighted according to values from the Teagasc Pasture Profit Index (PPI). Our ability to predict breeding values for forage yield using genomics was encouraging, and assuming no degradation in predictive ability over generations indicated that we could more than double the rate of genetic gain by incorporating genomic selection into the Teagasc breeding programme. Our ability to complete a cycle of DNA-based selection in a fifth of the time it takes to complete a cycle of field-based selection ensures that we can overcome any loss in predictive accuracy when selecting using genomics. Based on these findings, we are now selecting tetraploid perennial ryegrass varieties using genomic selection in the commercial breeding programme. We will continue this over a number of years (**Figure 1**), and at each stage evaluate the new populations for improvement, and any promising populations will be

submitted for independent variety testing with a view to commercialisation.

In genomics-assisted breeding, DNA evaluations are related to field measurements in a reference population and used to develop statistical models for genomic selection.

## Future of grass breeding

Forage grass breeders will take advantage of all available tools and technologies at their disposal to increase genetic gain and produce varieties to meet the demands of industry. Genomic selection is just one such tool that we see being fully integrated into routine breeding activities. In such a scenario, field evaluations will be used to continually update and improve statistical models, and to add new traits as breeding goals evolve.

In future we also see forage breeders exploiting advances in high-throughput and speciality phenotyping, together with strategies to exploit hybrid-based breeding. Investment in plant breeding results in social, economic, and environmental benefits, and continued investment in forage grass breeding in Ireland will ensure the best genetics are available to meet the specific needs of Irish grassland farmers.

## Acknowledgments

Teagasc grant-in-aid, and the financial and commercial support to the breeding programme from Goldcrop Ltd is gratefully acknowledged.

## Authors

### Stephen Byrne

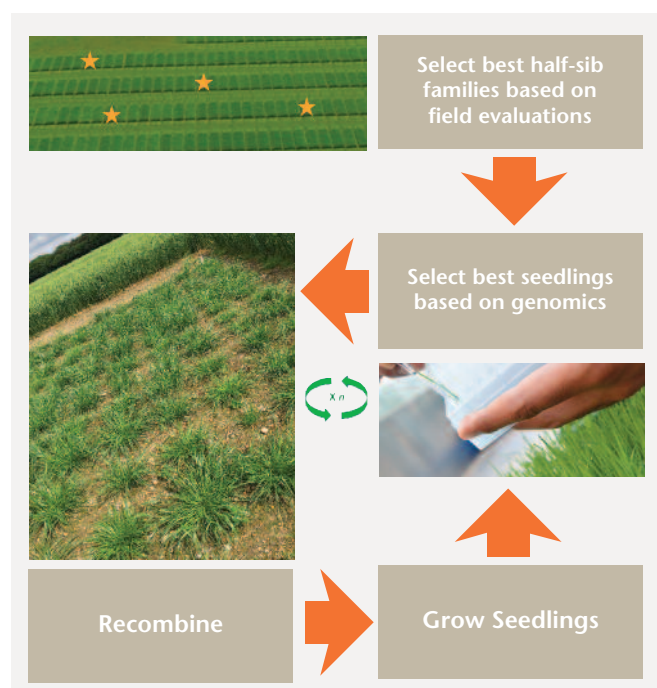
Crop Science Department, Teagasc Crops, Environment and Land Use Research Programme, Oak Park, Carlow  
Correspondence: [stephen.byrne@teagasc.ie](mailto:stephen.byrne@teagasc.ie)

### Dan Milbourne

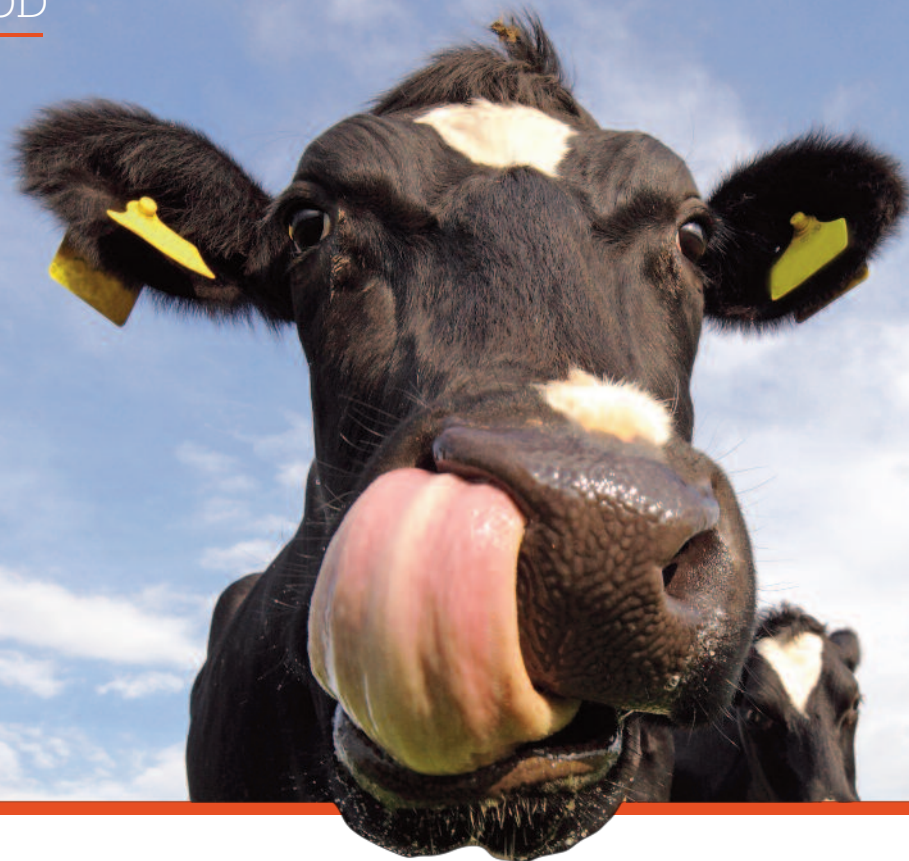
Crop Science Department, Teagasc Crops, Environment and Land Use Research Programme, Oak Park, Carlow

### Patrick Conaghan

Grassland Science Research Department, Teagasc Animal & Grassland Research and Innovation Centre, Oak Park, Carlow



**FIGURE 1:** Implementing genomic selection at Teagasc in a tetraploid breeding population. Using rapid cycles of selection with genomics, it is anticipated that we can more than double the rate of genetic gain for complex traits like forage yield.



# Taking the meth out of breath

New research from **TEAGASC** is exploring ways to reduce methane emissions from ruminants.

Methane (CH<sub>4</sub>) production as a result of fermentation of feeds by ruminant organisms represents a significant contributor to greenhouse gas (GHG) emissions (**Figure 1**). Agriculture contributes approximately 6-7% of total GHG emissions and reducing these is a challenge, particularly as agricultural intensity is increasing globally. The European Council has recently agreed on a set of climate and energy targets for 2030 (40/27/27 package), with important implications for the EU agricultural sector. Agriculture must contribute to mitigation efforts, if the EU is to meet its long-term target of reducing GHG emissions in 2050 by 80-95% compared to 1990 levels.

## The METHLAB project

Some animal dietary practices have shown promise to reduce methane emissions, including use of high-quality forages and dietary fat. On farm, lactic acid bacteria (LAB) are commonly used as direct feed microbials (DFMs)/probiotics and as silage inoculants. DFMs are products that contain live (viable) microorganisms and are used to modulate rumen function and induce beneficial health and productivity effects in ruminants. A limited number of LAB strains have been shown to affect ruminal fermentation, leading to downstream effects such as reduced methane production. However, the choice of strain(s) is key to the effectiveness and desired outcome of LAB application *in vivo*. In the METHLAB project, LAB will be targeted that directly inhibit

methanogens, which are the methane-producing organisms in the rumen. LAB strains will be screened for the ability to reduce methane production *in vitro*, and selected strains will be tested in ruminants (cows and sheep) to confirm efficacy of methane reduction *in vivo*. Additionally, inhibitory compounds from LAB-termed bacteriocins may be a potential strategy to target the methanogens in the rumen when fed to ruminants. The process of methanogenesis consumes from 8-12% of the energy used in the rumen. Inhibition of this pathway could in fact lead to a surplus of energy available for the ruminant itself, leading to better quality meat and milk production. Furthermore, the wide use of LAB as probiotics in humans and as preservatives in the food industry means their application to ruminant production systems will face fewer regulatory hurdles. Outputs from this work will advance the knowledge transfer of LAB on-farm technologies to address the reduction of enteric methane emissions in ruminant production systems. A better understanding of LAB's use for reduction of methane in on-farm technologies will be achieved and this would accelerate the objective of reducing anthropogenic contributions towards climate change. A route to market is considered relatively straightforward as DFMs and silage inoculants have LAB as a main microbial ingredient and are already commercially available, accepted, and used on farms worldwide. This proposal thus supports the development of a competitive, sustainable and profitable global agri-food sector.



## Global methane emissions per sector (%)

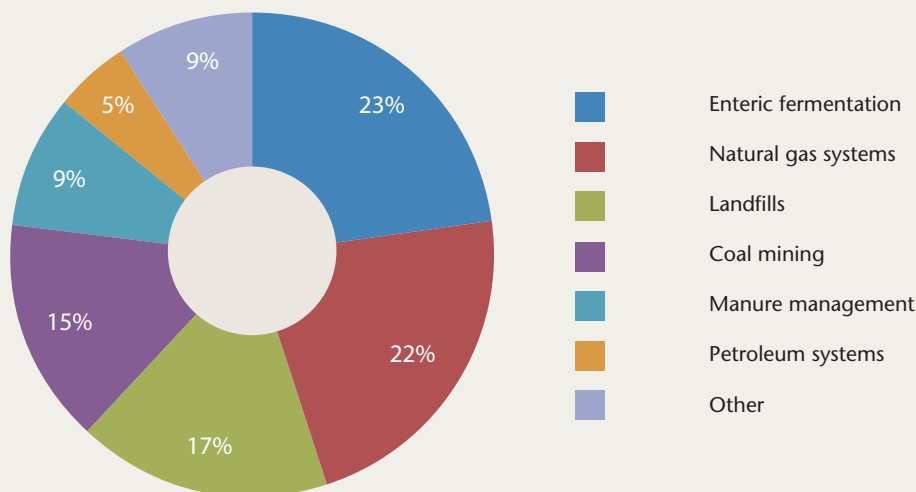


FIGURE 1: Global methane emissions per sector (%). Adapted from: <http://www.energytomorrow.org/blog/2015/01/14/the-new-move-to-regulate-methane>.

### Multidisciplinary initiative

From both scientific and technological aspects, the integration and ambitious objectives of the project demand a truly multidisciplinary approach that involves life sciences, food technology/food bioengineering, culture production and nutrition. This consortium is co-ordinated by Teagasc. The partners in this proposal are all from the Global Research Alliance (GRA) member countries that share the goal of reducing methane emission intensity across ruminant classes in a manner that maintains agricultural production and sustains environmental integrity. METHLAB brings together five partners from across the EU and one New Zealand partner, forming a unique set of inter-sectoral expertise, knowledge, technologies and personnel in a new collaboration, meeting market needs for new innovative solutions to be incorporated into ruminant feedstuffs to create more sustainable, emission-efficient food production systems. The multidisciplinary consortium has been strategically designed to facilitate discovery and innovation but also rapid bench-to-market commercialisation outputs, e.g., new innovative microbial technologies, and animal nutrition products with new functionality.

The project represents a long-term, high-value application of microbiology, animal nutrition, and formulation/excipient research to meet a defined market need for generation of added value, high-quality animal nutrition products and the technology to deliver them.

The innovative technology platform that the project will deliver will provide long-term impact and benefits to the EU (and the world) through increased knowledge and research expertise in animal nutrition, microbiology and fermentation to stimulate a more sustainable, efficient and productive agri-food sector. Another benefit from reduced methane emissions in any country, particularly where ruminants contribute a large portion of GHG (such as Ireland and New Zealand) is that their governments are seen to be addressing methane emissions and as such, are demonstrating a

commitment to maintain their international reputation by meeting climate change responsibilities. This action may influence future trade negotiations and alleviate barriers put in place that restrict the trading of products associated with high GHG emissions. It may also allow a premium to be placed on products originating from a low methane emission animal production system. If a methane mitigation strategy is able to improve digestive efficiency in the animal and capture some of the approximately 6-8% of the gross energy in the diet lost as methane and redirect into productivity gains, the economic benefits to the farmer could be large.

### Funding

The METHLAB project is funded by FACCE ERA-GAS, an EU ERA-NET Cofund programme, whereby national money is pooled to fund transnational projects, and the European Commission also provides co-funding for the action. FACCE ERA-GAS is the ERA-NET Cofund for Monitoring and Mitigation of Greenhouse Gases from Agri- and Silvi-culture, and comprises funding agencies and project partners from 19 organisations across 13 European countries. Teagasc is the overall co-ordinator of the ERA-NET. METHLAB was one of 10 successful projects to be funded from 79 proposals from across Europe, the USA and New Zealand.

### Author

#### Catherine Stanton

Project Co-ordinator, Teagasc Moorepark Food Research Centre, Fermoy, Co. Cork

Correspondence: [catherine.stanton@teagasc.ie](mailto:catherine.stanton@teagasc.ie)



# Ultrasonic extraction

Found in seaweed, fucoidans have many beneficial properties, but extracting them from the plant has proven difficult. UCD and TEAGASC researchers looked at one promising technology.

Fucoidans are sulfated water-soluble heteropolysaccharides found in brown seaweed and demonstrate a variety of biological activities including antioxidant, antimicrobial, antiviral, antitumour, anti-proliferative and immunostimulatory activities (Garcia-Vaquero *et al.*, 2017). Fucoidans are composed of fucose, glucose, xylose, galactose, mannose, glucuronic acid and sulfate substituents (Figure 1). They have been investigated in recent years for their potential applications in pharmaceuticals, food and animal feeds. Fucoidans are present in the cell wall of brown seaweed associated with proteins, alginates and other molecules (Figure 2), and play a crucial role in the protection of the seaweed against environmental challenges. However, the composition, activity and structure of fucoidans depends on the seaweed species, harvesting season, geographic location, tissues, growth stage, environmental conditions, molecular weight, monosaccharide composition, sulfate content, position of the sulfated ester group, as well as the extraction process. Fucoidan is a high molecular weight compound, hence its application in drug delivery is limited. Therefore, more research is focused on highly active low molecular weight fucoidans (LMWF) and the substructures of these large macromolecules. These LMWFs can be obtained by partial acid hydrolysis or by degradation of large fucoidan molecules using innovative techniques such as microwave or ultrasound during the extraction process. These processes may cause structural modifications, such as desulfation, debranching or degradation, which can result in distinct biological properties compared with the intact fucoidans.

## Extraction of fucoidan

The extraction of fucoidan in industry is mainly performed using conventional approaches, including the use of multiple and large volume of solvents (water, dilute acid or dilute alkali, etc.) and a wide range of extraction conditions including high temperatures (40-100°C) and long times of extraction (three to 24 hours). The fucoidan extracts are normally generated by applying these extraction conditions, one or multiple times over the same seaweed residue to achieve the desired high yield. Scientists are now exploring the use of innovative technologies to increase the efficiency of the extraction of fucoidan in terms of yield, time and cost of extraction, while lowering the consumption of energy and using more environmentally friendly

solvents. In the last decade, microwave-assisted extraction (MAE), enzyme-assisted extraction (EAE) and ultrasound-assisted extraction (UAE) have been successfully used for extraction of numerous biologically active compounds from a wide variety of natural resources. However, these novel extraction protocols developed using innovative technologies should be optimised not only to achieve high yields, but also to maintain the biological activities of biomolecules (Garcia-Vaquero *et al.*, 2017). In seaweed, multiple extraction technologies have been used to extract fucoidan, but ultrasound could provide an economically feasible technique with potential for scale-up.

## Ultrasound-assisted extraction

UAE is based on the application of sound waves that migrate via a series of compression and rarefaction cycles induced on the molecules of the solvent medium they travel through. During these cycles, small bubbles filled with vapours are produced, which grow to a certain size and collapse periodically, transforming the sound waves into mechanical energy, which disrupts the algal cell wall and facilitates the extraction of bioactive compounds. The formation of small bubbles in a liquid is defined as cavitation. Cavitation generates high-velocity inter-particle collisions and turbulence, which initiate the solid-liquid phenomenon including surface peeling, erosion, and particle breakdown. These effects increase the mass transfer by eddy and internal diffusion mechanisms, and improve the efficiency of extraction, expediting the release of fucoidans from the seaweed matrix (Kadam *et al.* 2015).

Low-frequency ultrasound (<200kHz) produces large but unstable bubbles which collapse during the compression cycle, releasing large amounts of heat and shockwaves. This creates high localised temperatures (around 5,000K) and pressure jets, while high-frequency ultrasound (>1MHz) generates tiny but more stable bubbles, which open and close, creating localised microstreaming effects. However, the high temperature and pressure jets generated from low-frequency unstable bubbles is helpful to burst the cell structures releasing intracellular components into the medium. Therefore, low-frequency ultrasound, also known as UAE, has been largely explored for the extraction of fucoidans from seaweed. During



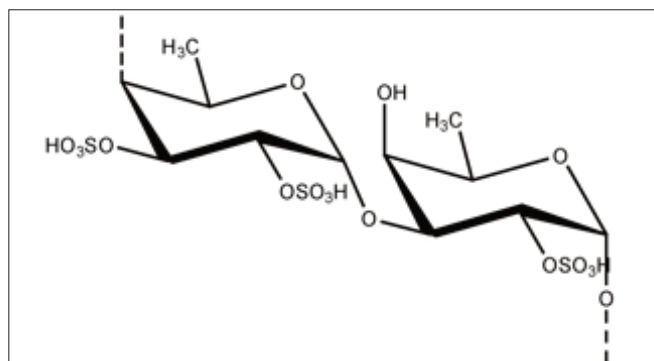


FIGURE 1: Chemical structure of fucoidan.

UAE, most of the polysaccharides (including fucoidans) are released from the degraded cell wall at the early stage of ultrasonic processing with suitable ultrasonic power. The acidic or alkaline medium makes the algal cell wall porous and wrinkled, leading to increased yields at low temperature (<60°C) over a short time (<3 hours), while a high temperature (around 90°C) and a longer time (around five hours) cause fucoidan degradation and lower sulfate contents, leading to structural alterations and reduced biological activity.

The application of ultrasound is simple, cost-effective and more efficient than other traditional extraction techniques due to its high extraction yields and short application times. UAE can be performed by using ultrasonic bath, probe, plates or tubular devices populated with small transducer ceramics. However, a number of parameters such as ultrasonic frequency, power, intensity, shape and size of the ultrasonic device/probe, solvents, time and temperature, greatly influence the extraction efficiency. Moreover, UAE can be combined with other technologies, e.g., UAE with microwave, to achieve higher yields of compounds if the molecules are resistant to heat.

### Future prospects

The production of food and pharmaceutical products must comply with good manufacturing practices (GMP). Therefore, reproducible cultivation and harvesting of seaweed must be established. Many traditional methods, as well as innovative technology-based protocols, are proposed for the extraction of fucoidans from seaweeds. Most of the studies are focused on obtaining high yields of fucoidan or polysaccharides in general, without optimising the technologies or extraction parameters. A promising approach using UAE to generate lower molecular weight fucoidan fractions that conserve the sulfate content and sugar backbone is required. Thus, successful optimisation of UAE parameters to control the degradation process, as well as beneficial biological activities, is important for the production of the appropriate active fucoidan at the required scale.

### Acknowledgements

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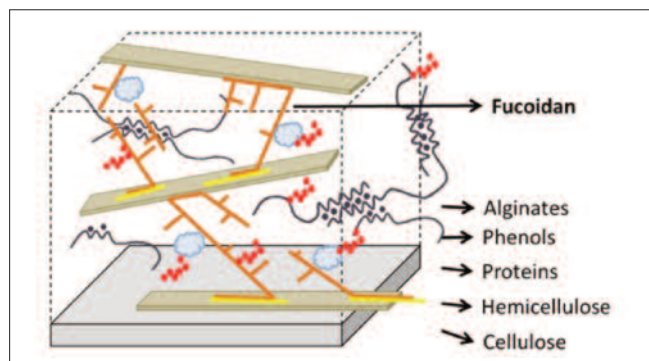


FIGURE 2: Fucoidan and other molecules integrating the cell wall structure of brown seaweeds.

John O'Doherty, Professor at the School of Agriculture and Food Science, UCD, also contributed to this article.

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### Authors

#### Marco Garcia-Vaquero

Postdoctoral researcher, School of Veterinary Medicine, Veterinary Sciences Centre, University College Dublin, Belfield, Dublin 4

#### Gaurav Rajauria

Animal Nutrition Technologist, School of Agriculture and Food Science, University College Dublin, Lyons Research Farm, Celbridge, Co. Kildare

#### Brijesh Tiwari

Principal Research Officer, Teagasc Food Research Centre, Ashtown, Dublin 15

#### Torres Sweeney

Professor, School of Veterinary Medicine, Veterinary Sciences Centre, University College Dublin, Belfield, Dublin 4

Correspondence: torres.sweeney@ucd.ie





# Trends in fertiliser use

**TEAGASC** National Farm Survey data shows how fertiliser use changed over the space of 11 years on Irish farms.

This research examines long-term developments in farm and crop scale fertiliser use across the Republic of Ireland. The analysis is based on over a decade's worth of data collected by the Teagasc National Farm Survey covering the years 2005-2015. This is a period when the Republic of Ireland has been bound by EU Nitrates Directive regulations governing fertiliser use. Longer-term studies of this kind are of particular value since the data provides a better picture of trends at farm level than is available from short-term analysis. Data showing short-term trends in fertiliser usage can be affected by fertiliser price levels and weather variations, and are a less reliable indicator of longer-term developments.

## Methodology

The data used for this analysis is taken from the Teagasc National Farm Survey (NFS). The NFS is based on a nationally representative random sample of the farming population. The 2015 results are based on a sample of 898 farms, which represents 84,259 farms nationally. Results are presented for average quantities of nitrogen (N), phosphorus (P) and potassium (K) applied at farm level on grassland and arable farms between 2005 and 2015. Trends in fertiliser use by nitrates zone, land use class, farm system, stocking rate and agri-

environmental scheme participation are part of the overall research project (Teagasc, 2018). Results were validated by comparison with published annual sales data of N, P and K from the Department of Agriculture, Food and the Marine (DAFM) and it was found that the NFS data closely tracks national fertiliser sales of N, P and K over the study period.

## Results and conclusions

Results indicate that average N, P and K fertiliser application rates on grassland tended to be between 11% and 16% lower at the end of the study period compared to the start, with more dramatic declines in application rates noticeable in the mid-study period (23-52%) (**Figure 1**). The years of lowest grassland fertiliser use (2008-09) coincided with the period of higher fertiliser prices, while higher than average period application rates in 2013-2014 were associated with the aftermath of a national fodder shortage. Higher application rates of N, P and K on grassland were generally associated with farms in nitrates zone A, farms of wide land use potential, dairy farms and farms with higher stocking rates. Similarly, average fertiliser application rates across the main cereal crops (wheat, barley, oats) were lower in the higher price period of 2008-09. Comparing 2005 with 2015 showed that N application rates on the main cereal crops actually



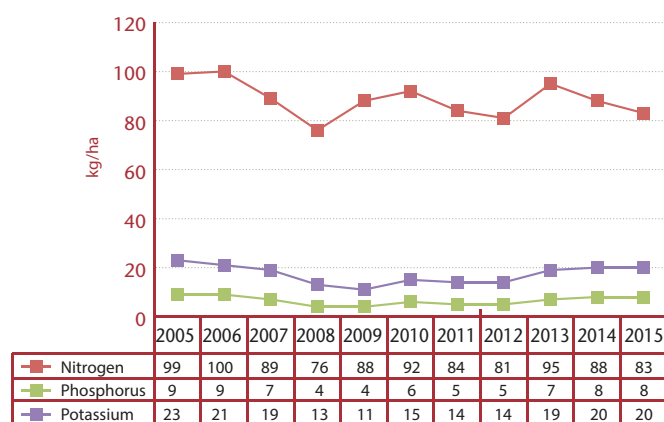


FIGURE 1: Average fertiliser applications on grassland area.

increased by about 10%. P application rates on the main cereal crops in 2015 were broadly in line with usage levels in 2005. K application rates showed the largest increase, up 33% in 2015 relative to 2005, as shown in **Figure 2**. Agri-environmental scheme membership had a large impact on fertiliser usage. Fertiliser application rates on grassland were on average 34-38% lower for farms participating in an agri-environment scheme and 3-15% lower for cereal production.

A concern raised by the research is that a minority of farms are engaged in ongoing application of lime from year to year. Adequate liming is essential to achieve optimum soil pH levels in order to maximise the effectiveness of fertilisers. It is notable that on average just over 20% of farms used lime year on year over the study period. The lowest rate of liming was evident in 2006, at just 16% of the farm population, and the highest liming rate over the period was recorded in 2013 at 26% of total farms. Higher rates of liming were associated with dairy farms (see **Figure 3**) but also on farms of wide land use potential and farms with higher stocking rates.

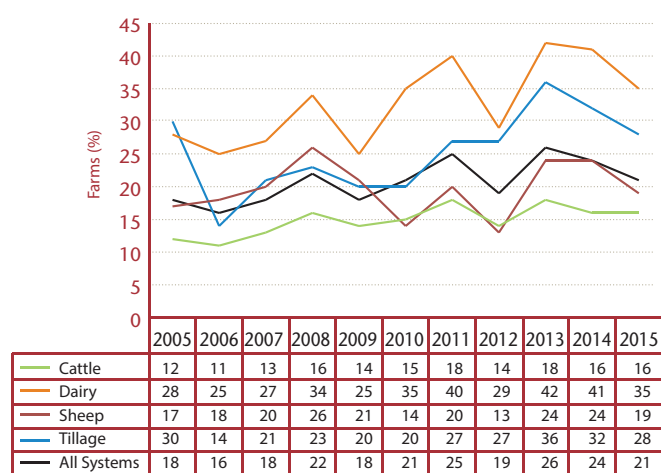


FIGURE 3: Percentage of farms using lime by farm system.

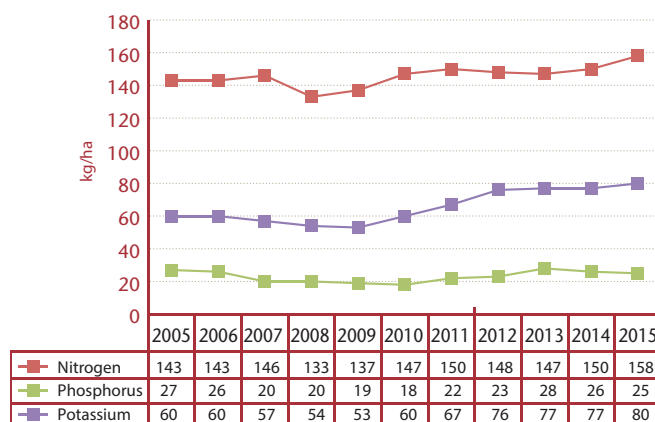


FIGURE 2: Average fertiliser applications on main cereal crops.

### Acknowledgements

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### Authors

#### Cathal Buckley

Research Officer, Agricultural Economics and Farm Surveys Department, Teagasc, Athenry, Co. Galway  
Correspondence: [cathal.buckley@teagasc.ie](mailto:cathal.buckley@teagasc.ie)

#### Emma Dillon

Research Officer, Agricultural Economics and Farm Surveys Department, Teagasc, Athenry, Co. Galway

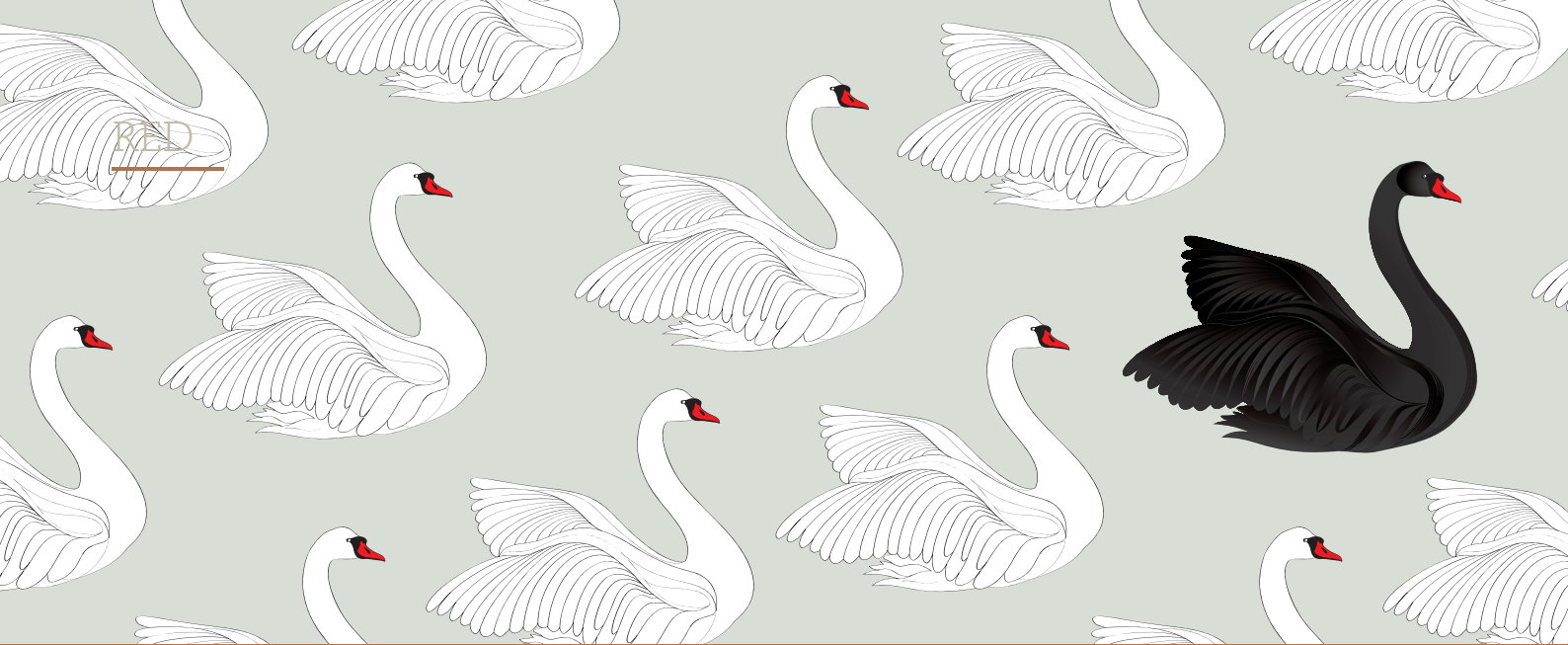
#### Brian Moran

Technician, Agricultural Economics and Farm Surveys Department, Teagasc, Athenry, Co. Galway

#### John Lennon

Technologist, Agricultural Economics and Farm Surveys Department, Teagasc, Athenry, Co. Galway





# Food supply chain integrity

Researchers at **TEAGASC** and UCC are looking into the challenge of food fraud and food threat, and investigating approaches to dealing with these issues.

What do black swans and the Irish food industry have in common? This question is currently being investigated in a *safe*food-funded project, involving Teagasc and University College Cork. 'Black swan events' are low-probability but high-impact events, and are of mounting interest in the context of food supply chain integrity. This is because all food businesses are exposed to threats and vulnerabilities. These have always existed, but are of growing concern due to increasing supply chain complexity. The fact that supply chain disruptions are more likely to be publicly announced ensures that this is an area of importance to industry, as well as to regulators and public health agencies. If these kinds of threats are not prevented or adequately responded to, they may result in illness and death, as well as in economic and reputational damage to individual companies, and indeed the wider food industry. Given that exports from the Irish agrifood sector are worth more than €12.5bn on a whole-island basis, these challenges cannot be ignored.

## Food fraud and food threat

It is important to distinguish between familiar food safety and food quality events, and less familiar food fraud and food threat events (**Figure 1**). In the former case, because they occur frequently and are accidental, risks and likelihoods are identifiable, enumerable, and quantifiable. In addition, such events, being internal to the processing unit and recurrent, are amenable to data collection on their context, causes, and overall likelihood. They can be controlled to an acceptable level by identifying the most important (or critical) risks, and initiating responses that reduce the likelihood and consequences of those risks. Hazard Analysis and Critical Control Points (HACCP) is the primary example of such a risk model and control process. By contrast, food fraud and food threat events are the result of intentional actions by perpetrators who identify and exploit vulnerability in the supply chain. Because such events are relatively infrequent, data about them are limited, often due to sensitivities and reputational concerns on the part of the victims.

Thus, the primary focus of countermeasures should be on the identification of vulnerabilities, with the emphasis placed on prevention rather than on mitigation.

## Perceived level of exposure

The aims of our current research are to assess the food industry's perceived level of exposure to food fraud and food threat, to examine approaches taken to deal with food fraud and food threat risks in other jurisdictions (the UK, the Netherlands, the US and Denmark), and to determine the feasibility and benefits of integrating such approaches into food supply chains in Ireland. The research will be undertaken in stages including a literature review, expert interviews and an online survey. The interviews and survey are underway with the questionnaire sent to almost 1,000 Irish firms, and interesting findings have already emerged from the literature review.

## Think like the perpetrator

First, the literature has identified a need to think like the perpetrator of such activities in identifying risks and designing responses. Offenders are focused on market signals such as price spikes or an increasing demand for a commodity. Analysis of data relating to price and demand can therefore help to identify vulnerabilities. The literature also emphasises that the potential opportunity to undertake such activity is dependent on supply chain factors, including: its complexity and the level of collaboration and information flow along the chain; the availability of test and detection technology; and, knowledge of how to adulterate. Accordingly, wrongdoers may analyse such factors to identify areas where potential profits (in the case of fraud) or potential damage (in the case of threats) are high, the chances of detection are low, or the consequences of such action, if detected, are low. Strategies to combat such activities thus seek to enhance horizon scanning to detect candidate products and ingredients, to ensure negative consequences for wrongdoers, and to improve visibility and information sharing along the supply chain.



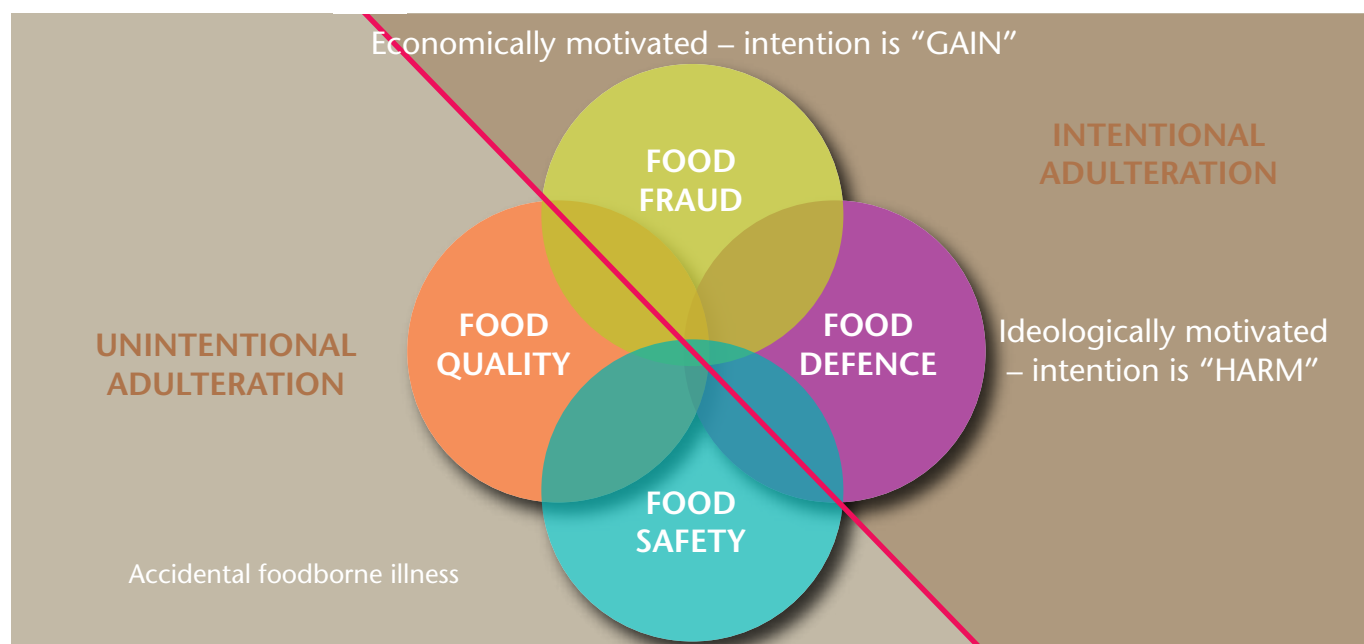


FIGURE 1: Food fraud in the context of the Global Food Safety Initiative.

### Increase risk of detection

Second, in relation to prevention, the aims are to increase the risk of detection, reduce the opportunity for profit, and increase negative consequences for the perpetrator. One preventive action is to ensure that adequate penalties are in place. The familiar quality control and assurance processes, which, for example, can result in contractual penalties or reputational loss, fall short when dealing with food fraud and food threat. In the EU the central law is Regulation (EU) 2017/625. It updated an earlier Regulation (EC) 178/2002 in the wake of the horse meat fraud by adding provisions against “fraudulent or deceptive practices along the agri-food chain” and requires national authorities to take account of “potential risks and the likelihood” of such events occurring. Public prosecutions to enforce such regulations are important to create a less attractive environment for perpetrators. The role of ‘private’ law (i.e., industry-developed standards) is an important response by supply chain actors. Such standards and accreditations – of which the Global Food Safety Initiative (GFSI) is the most influential – require processes and tests that producers and auditors can use to identify and resolve vulnerabilities. When such certification becomes a requirement for doing business, non-conformant businesses are excluded from many contracts. In essence, therefore, ‘private’ law makes the business environment less attractive for potential offenders.

### Information flow is key

Finally, for response strategies to be effective, information flow between supply chain stakeholders is crucial. Ongoing efforts to develop rapid testing methods have enhanced surveillance and detection of food fraud and food threats. Furthermore, databases developed by public agencies (e.g., the European Food Fraud Network (EFFN)) and commercial concerns (e.g., the United States Pharmacopeial Convention (USP) and Fera Science Ltd) allow better information sharing. Despite these developments, our review suggests a need for food chain actors to utilise these databases to a greater degree so as to embed the resulting knowledge into their processes.

### Further information

A seminar to share all project results will take place on December 6, 2018. Further information will be available at: [www.teagasc.ie/news—events/](http://www.teagasc.ie/news—events/). Please contact the authors for access to the questionnaire if you wish to contribute to the study or visit: [https://cubs.eu.qualtrics.com/jfe/form/SV\\_bl9lwyUuH8DvCg5](https://cubs.eu.qualtrics.com/jfe/form/SV_bl9lwyUuH8DvCg5).

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### Authors

#### Alan Sloane

Lecturer, Department of Food Business and Development, University College Cork

#### Maeve Henchion

Principal Research Officer, Department of Agrifood Business and Spatial Analysis, Teagasc Food Research Centre, Ashtown, Dublin 15  
Correspondence: [maeve.henchion@teagasc.ie](mailto:maeve.henchion@teagasc.ie)

#### Seamus O'Reilly

Senior Lecturer, Department of Food Business and Development, University College Cork

#### Hanna Sheerin

Research Officer, Department of Agrifood Business and Spatial Analysis, Teagasc Food Research Centre, Ashtown, Dublin 15



## AUGUST

August 19-24

Convention Centre Dublin

**INTERNATIONAL ASSOCIATION FOR PLANT BIOTECHNOLOGY CONGRESS**

The plenary themes and topics at this congress are: food and nutritional security; public understanding of science; new plant breeding techniques; plant microbiome; plant pathology; *in vitro* culture and morphogenesis; abiotic and biotic stresses; plant nutrionics; and, novel bioproducts and biopharmaceuticals. Teagasc is a sponsor of this international event, which includes a study visit to the Teagasc Oak Park Crop Research Centre in Carlow.

<http://iapb2018.com/> Contact: [iapbhome@gmail.com](mailto:iapbhome@gmail.com)



August 30-31

National University of Ireland Galway

**166TH EUROPEAN ASSOCIATION OF AGRICULTURAL ECONOMISTS SEMINAR**

This seminar is jointly hosted by Teagasc, NUI Galway and the FLINT Consortium. Sustainability has become one of the dominant themes for the development of the

agricultural industry. In a development setting, sustainable agriculture is central to sustainable development goals. There are numerous dimensions to sustainability including measurement, economic, environmental and societal impact, behaviour and extension, value chains, marketing and policy levers. The EAAE Seminar on 'Sustainability in the Agri-Food Sector' will provide an opportunity to present and discuss progress in the analysis of sustainability in agriculture and extension approaches to incentivise farmers to adopt sustainable farm management practices.

<http://bit.ly/EAAE2018> Contact: [dilovar.haydarov@teagasc.ie](mailto:dilovar.haydarov@teagasc.ie)

## SEPTEMBER

September 11

Killashee Hotel, Naas, Co. Kildare

**NATIONAL CROPS FORUM**

Organised by Teagasc tillage specialists, the Forum will look at the new varieties available this year and also the outlook for grain prices. The Forum will also look at how tillage farmers can profitably supply the substantial fodder market for the future, with a particular emphasis on the challenges of producing grass for livestock farmers.

[www.teagasc.ie](http://www.teagasc.ie) Contact: [michael.hennessy@teagasc.ie](mailto:michael.hennessy@teagasc.ie)



September 11-12

Inis Mór, Aran Islands, Galway

**ARANLIFE CONFERENCE**

The conference will detail the AranLIFE approach to implementing a multi-farmer programme in a high nature value (HNV) farmland area, which was locally led and incorporated a results-based element. The project team will

outline the works completed and overall findings and there will be field visits to a number of sites. The second day of the conference will include discussions on future policy and how the findings of AranLIFE (an EU LIFE-funded project) could be incorporated into policy in similar HNV areas. The conference will be of interest to any organisations/individuals working in semi-natural farmland and groups considering developing their own local-led programme.

<https://www.aranlife.ie/> Contact: [aranlifeproject@gmail.com](mailto:aranlifeproject@gmail.com)



September 28

University College Cork

**EUROPEAN RESEARCHERS' NIGHT - CORK DISCOVERS**

Teagasc is delighted to be involved in European Researchers' Night, a Europe-wide event, dedicated to raising public awareness of the positive role of research in society, on Friday September 28. This year 27 countries and over 300 cities will be involved, making it a truly international celebration of the positive impact of research on the modern world. The Cork Discovers Night is funded through the Marie Skłodowska-Curie Actions call under the European Commission Horizon2020 programme. The event is being co-ordinated by University College Cork with Teagasc and Cork City Council as partners.

[www.teagasc.ie](http://www.teagasc.ie)

Contact: [orlaith.nichoncubhair@teagasc.ie](mailto:orlaith.nichoncubhair@teagasc.ie)

## OCTOBER

October 1-2

Rochestown Park Hotel, Cork and Teagasc,

Moorepark Research Centre, Fermoy, Co. Cork

**FOCUSED MEETING 2018: MICROBIOMES UNDERPINNING AGRICULTURE**

Microorganisms play a fundamental role in agriculture and food production, representing a key and indispensable resource that underpins the agri-food sector. Microbiota in these systems perform an array of pivotal functions essential to system health, sustainability and productivity. This conference will focus on the diverse roles played by microorganisms in agricultural systems, and on exploring what microbiome research can offer to agriculture.

[www.teagasc.ie](http://www.teagasc.ie)

Contact: [fiona.brennan@teagasc.ie](mailto:fiona.brennan@teagasc.ie)

October 5

Environmental Protection Agency, Johnstown

Castle Estate, Co. Wexford

**TEAGASC WALSH FELLOWSHIPS PROGRAMME 25TH ANNIVERSARY SEMINAR**

This event will showcase a selection of the Walsh Fellows from across the Teagasc five programme areas and will also include presentations from previous Walsh Fellowships Seminar winners, who will share their experiences of the Walsh Fellowships Programme. A guest panel will discuss the future of postgraduate training and the role of the PhD in Ireland.

[www.teagasc.ie](http://www.teagasc.ie)

Contact: [Hilary.King@teagasc.ie](mailto:Hilary.King@teagasc.ie)

[walsfhellowships@teagasc.ie](mailto:walsfhellowships@teagasc.ie)

## NOVEMBER

November 11-18

Multiple locations nationwide

**FESTIVAL OF FARMING AND FOOD – SFI SCIENCE WEEK AT TEAGASC**

A series of events will be held catering for primary, second and third level and the general public. The open public events are taking place at Teagasc Ashtown Food Research Centre and The River Court Hotel, Kilkenny. Attendees will learn about a wide variety of topics and how they apply to their everyday lives including: food for health; food product development and improvement; food safety; sustainability of animal and plant production; healthy soils and biodiversity; and, the development of rural areas.

<https://www.sfi.ie/events/festivals/> Contact: [catriona.boyle@teagasc.ie](mailto:catriona.boyle@teagasc.ie)

For a full list of Teagasc food industry training events see: [www.teagasc.ie/food/food-industry-development](http://www.teagasc.ie/food/food-industry-development)

For presentations from previous Teagasc events see: [www.teagasc.ie/publications](http://www.teagasc.ie/publications)