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Virtual Irish Centre for Crop Improvement

ENHANCING FOOD VALUE OF MICROALGAE

IMPACT OF BREXIT

LABOUR ON DAIRY FARMS

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Crop improvement in support of sustainable production

Ireland's cropping systems underpin agri-food enterprises through the provision of high-quality livestock feed/material for processing. The strategic importance of the crops sector is further supported by its potential to contribute significantly to the environmental sustainability of Irish food production systems. In contrast to dairy, cattle and sheep, Ireland's tillage systems emit the lowest average greenhouse gasses (GHGs) (<2T CO_2/ha) and ammonia (<10kg NH_3/ha), and are the most resource efficient in regards to nitrogen (>60%) and phosphorous (>80%).

Yet, while the expansive role the cropping sector can play in supporting sustainable food production is clear, the sector faces challenges that are undermining its long-term viability. For example, European legislation is reducing the availability of crop protection products, which could reduce net margins by up to 50% in wheat and 65% in barley. In the absence of varieties with more robust resistance to biotic/abiotic stresses, growers will lose competitiveness, with economically viable cereal production limited to the highest-yielding sites. In response, continued innovation and investment in crop improvement strategies is essential if we are to improve the resilience and value of our crops. There is also a need to diversify crop production in Ireland and move away from commodity crops to higher-value alternatives. Through initiatives such as the Department of Agriculture, Food and the Marine (DAFM)-supported Virtual Irish Centre for Crop Improvement (VICCI) project, we have been able to build the requisite capacity with our national and international partners with a view to identifying/developing improved varieties with increased resource use efficiency.

This issue of *TResearch* contains several articles describing some of the exciting progress that has been made, and underlines the role crop improvement strategies can make in supporting sustainable production strategies. At a time when agricultural production is under the spotlight in regards to its environmental footprint, increasing the resilience and efficiency of varieties is key to developing novel production systems with the ability to support enhanced farm-level sustainability across all sectors in Irish agriculture.

Ewen Mullins
Head of Crop Science Department
Teagasc

Barra a fheabhsú chun tacú le táirgeadh inbhuanaithe

Buntacaíonn córais churaíochta na hÉireann le fiontair agraibhia trí bheathú/ábhar beostoic ar ardchaighdeán a sholáthar lena phróiseáil. Tacaítear arís eile le tábhacht straitéiseach na hearnála barr mar gheall ar an acmhainn atá aici cur go suntasach lena inbhuanaithe atá córais táirgthe bia na hÉireann ó thaobh an chomhshaoil de. I gcodarsnacht leis na hearnálacha deirí, eallaigh agus caorach, is ó chórais churaíochta na hÉireann a thagann an líon is lú gás ceaptha teasa (<2 thona de dhé-ocsaíd charbóin in aghaidh an heicteáir) agus an méid is lú amóinia (<10 kg de thríhidríd nítrigine in aghaidh an heicteáir) ar an meán. Tá siad ar an gceann is éifeachtúla ar acmhainní ó thaobh úsáid nítrigine (>60%) agus fosfair (>80%) de freisin. Cé gur soiléir an ról leathan is féidir leis an earnáil curaíochta a imirt maidir le tacú le táirgeadh bia inbhuanaithe, is ann do dhúshláin roimh an earnáil, atá ag baint an bhoinn ó inmharthanacht fhadtéarmach na hearnála. Mar shampla, tá an fháil ar tháirgí cosanta barr á laghdú leis an reachtaíocht Eorpach agus d'fhéadfaí an glanchorrlach a laghdú faoi suas le 50% ó thaobh cruithneachta de agus faoi suas le 65% ó thaobh eorna de dá bharr sin. Gan cineálacha barr atá níos frithsheasmhaí fós in aghaidh strus bitheach/aibitheach a bheith ann, caillfidh saothróirí iomaíochas agus beidh an táirgeadh gránaigh atá inmharthana ón taobh eacnamaíoch de teoranta do na láithreáin is mó toradh. Chun freagairt dó sin, tá sé ríthábhachtach go leanfaí le nuálaíocht a bhaint amach agus le hinfheistíocht a dhéanamh i straitéisí um barra a fheabhsú ar mhaithe le hathléimneacht agus luach ár gcuid barr a mhéadú. Chomh maith leis sin, is gá dúinn táirgeadh barr in Éirinn a éagsúlú agus bogadh ar shiúl ó bharra ar tráchtearraí iad agus i dtreo roghanna eile lena mbaineann luach níos airde. Trí thionscnaimh amhail an tIonad Fíorúil Éireannach um Barra a Fheabhsú, rud a dtacaíonn an Roinn Talmhaíochta, Bia agus Mara leis, d'éirigh linn an cumas riachtanach a fhorbairt lenár gcomhpháirtithe náisiúnta agus idirnáisiúnta d'fhonn cineálacha feabhsaithe barr atá níos éifeachtúla ar acmhainní a shainaithint/a fhorbairt. San eagrán seo de *TResearch*, tá roinnt alt ina gcuirtear síos ar chuid den dul chun cinn corraitheach a rinneadh agus tarraingítear aird ar an difear is féidir le straitéisí um barra a fheabhsú a dhéanamh maidir le tacú le straitéisí um tháirgeadh inbhuanaithe. Ós rud é go bhfuil táirgeadh talmhaíochta i mbéal an phobail faoi láthair mar gheall ar an lorg comhshaoil a fhágann sé taobh thiar de, is gá athléimneacht agus éifeachtúlacht na gcineálacha éagsúla barr a mhéadú ionas gur féidir forbairt a dhéanamh ar chórais táirgthe nua a bhfuil an cumas acu tacú le hinbhuanaitheacht mhéadaithe ar leibhéal feirme ar fud na n-earnálacha uile de thalmhaíocht na hÉireann.

Ewen Mullins
Ceann na Roinne Eolaíochta Barr
Ceannoifig Teagasc

‘Meet the Investor’ at Teagasc

‘Meet the Investor’ is an annual event organised by the Bridge Network (a technology transfer consortium that the Teagasc Technology Transfer Office is a member of). This event puts early-stage technologies in front of a panel of seasoned investors. The aim is to simulate a real-life investor pitch and provide valuable feedback to the researcher and the relevant Technology Transfer Office on potential commercialisation strategies. The event this year was hosted by Cork Institute of Technology and the panel was composed of several investors from investoment funds, a senior development advisor from Enterprise Ireland, and the Entrepreneur-in-Residence at the Tyndall National Institute. At this year’s event, two potential Teagasc spin-outs pitched their business ideas to the panel.

The first Teagasc pitch for SeqBiome, a potential Teagasc-UCC spin-out, was presented by Marcus Claesson (APC, UCC). The concept for SeqBiome is the provision of a commercial microbiome analysis service. The panel’s feedback was very positive, highlighting the solid commercial basis for this potential venture for Teagasc, and offering some very significant thoughts on early-stage funding.

The second Teagasc pitch was led by Norah O’Shea, who presented her ReBot technology. ReBot is a visual robotic test platform system for powder reconstitution that was developed using Teagasc funding. In comparison to the currently available manual system, ReBot provides a wealth of advantages to industry, including standardisation, low variability, and the very exciting possibility of including powder reconstitution in Quality by Design systems. The panel immediately appreciated the real industry need for her robotic test system, with the majority of her Q&A session spent discussing the large range of other fields that her technology could be applied to.

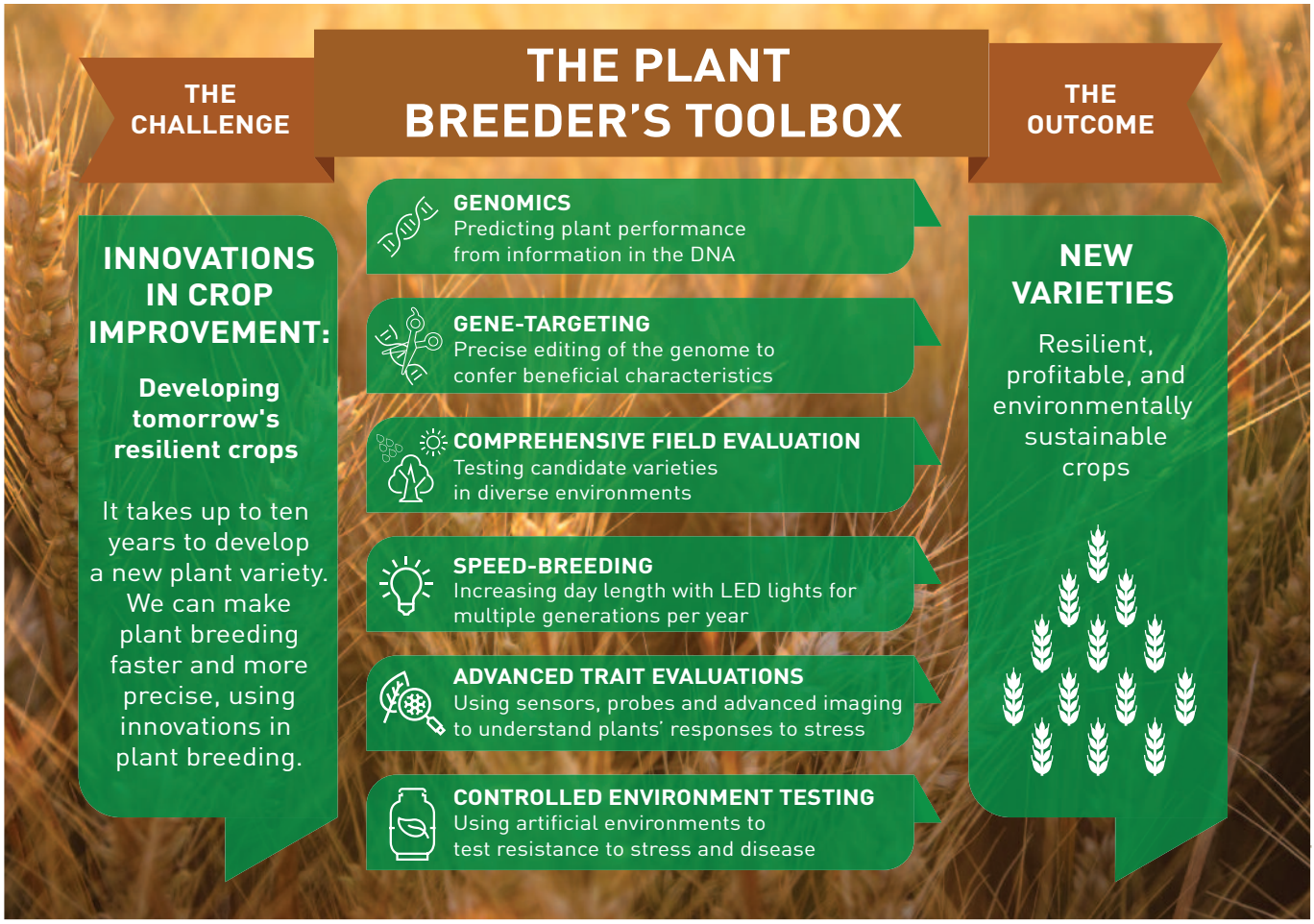
BabyBot – the prototype ReBot for testing powder reconstitution.

The researchers pitching at the event enjoyed the experience and found that it really helped them to view their respective technologies from a business/commercial perspective.

Researcher profile

Dan Milbourne

Dan Milbourne is a Senior Research Officer in the Teagasc Crop Science Department. He completed a BSc in Plant Science in University College Cork in 1996, before pursuing a PhD in the molecular genetics of resistance to late blight and cyst nematodes in potato at the Scottish Crop Research Institute (now the James Hutton Institute) in Dundee. He joined the Teagasc Crop Science Department in 2002. Dan is interested in developing practical approaches for the application of genomics-based approaches such as marker-assisted selection (MAS) and genomic selection (GS) in conventional plant breeding programmes for potato and forages at Teagasc. His work has enabled the routine use of MAS as a tool to select for disease and pest resistance within the Teagasc potato breeding programme, and this has resulted in the release of several commercial potato varieties exhibiting high levels of resistance to multiple pests and pathogens. More recently, he has collaborated with other researchers at Oak Park to develop GS-based approaches to improve selection for tuber quality in potato and forage quality, and seasonally distributed yield characteristics in perennial ryegrass. Dan also led Teagasc’s contribution to the international initiative to sequence the potato genome, the results of which were published in *Nature* in 2011. Dan co-ordinates the Department of Agriculture, Food and the Marine (DAFM) Research Stimulus Fund (RSF)-funded ‘Virtual Irish Centre for Crop Improvement’ (VICCI; featured in this issue), the goal of which is to exploit genome-based methods for the genetic improvement of crop species underpinning Irish agriculture, including cereals, forages, legumes and potatoes (www.vicci.ie). He is also a funded investigator in the recently established VistaMilk centre, where he leads a project to develop cost-effective approaches for GS in perennial ryegrass. Dan holds the position of Guest Professor at the Joint Academy of Potato Sciences at Yunnan Normal University in Kunming, China, and is an adjunct lecturer at NUI Galway. He is on the editorial board of the plant genetics and genomics section of the open access journal *Genes*. Between 2012 and 2018 he was Chairperson of the Potato Section of EUCARPIA (the European Organisation for Plant Breeding Research). In his spare time, he enjoys rediscovering the world with his four children, all of whom seem to be budding scientists.



Crops research in the *IJAFR*

The *Irish Journal of Agricultural and Food Research* (*IJAFR*) is an open-access peer-reviewed scientific journal published by Teagasc since 1961. Richie Hackett, a researcher at Teagasc Oak Park, recently published a paper in the *IJAFR* entitled 'Effect of nitrogen fertiliser application timing on grain yield and grain protein concentration of spring barley'. Richie explains: "Where the majority of nitrogen is applied to spring barley before the end of the tillering stage, altering the timing of applications or the proportion of the total applied in each application will have limited effect on grain yield or grain protein concentration". Researcher Steven Kildea, also at Oak Park, published a paper on 'Prevalence of QoI resistance and mtDNA diversity in the Irish *Zymoseptoria tritici* population'. Steven says: "The continued presence of Quinone outside Inhibitor (QoI) resistance at high frequencies in the Irish population will adversely impact the efficacy of all currently available QoI fungicides, and as such, they are not recommended for the control of *Z. tritici*. Given the high levels of gene flow also detected between the populations, it must be assumed that if resistance to additional fungicides targeting mtDNA encoded proteins was to develop, such as the QiIs, they would also spread quite rapidly within the Irish *Z. tritici* population. As such, measures that minimise the potential emergence of such resistances and subsequent selection must be implemented". Recent papers in the journal can be viewed, or new papers submitted, on the *IJAFR* website: http://bit.ly/IJAFR_Teagasc.

Winter barley at Oak Park (photo by Catriona Boyle).

Reaching out

Students at Carlow Educate Together at the 'Fascination of Plants' day.

Teagasc researchers have held a number of science outreach events recently. Researchers from Teagasc Oak Park ran a 'Fascination of Plants' day at Carlow Educate Together national school under the umbrella of the European Plant Science Organisation (EPSO). The goal of this activity is to get as many people as possible around the world fascinated by plants, and enthused about the importance of plant science for agriculture and sustainable production of nutritious food, as well as for horticulture, forestry and the production of plant-based products. Teagasc Walsh Fellow Katie Hetherington led a day-long workshop, with colleagues from Oak Park, where students got to experience DNA extraction and disease identification, see what plant-based products we use every day, and visit a 'plant zoo' to see how plants can adapt to their environments.

Well done to the Teagasc researchers from Moorepark, who demonstrated a series of fun-packed science experiments for over 130 students at the local Presentation Primary School in Fermoy. The themes were the 'Chemistry of Food' and 'Women in Science'. Many thanks to the event organiser, Bernard Corrigan, and fellow presenters, Sean Hogan, André Brodkorb, Alina Kondrashina, Daniela Freitas and Charlotte Oliver.

A farm walk was held on the farm of Karol Kissane, Ballylongford, Co. Kerry, for fifth-year agricultural science students from schools in the surrounding catchment area. This event was organised as part of the demonstration campaign for the EU Horizon 2020 NEFERTITI project. Teagasc, in association with the Irish Agricultural Science Teachers' Association (IASTA), hosted this 'You Can Farm' event, with over 130 students attending. The purpose of this interactive event was to promote dairy farming as a positive career, demonstrate different pathways to becoming a dairy farmer, and to increase overall knowledge of the industry. Redmond McEvoy, NEFERTITI project advisor with Teagasc, explains: "There are many reasons to become a dairy farmer. You are your own boss and there is the potential to achieve a great income from dairy farms across Ireland. Dairy farming offers an outdoor, healthy lifestyle, and there are multiple opportunities out there on dairy farms at the moment".

Teagasc researchers win at BSAS awards

Laura Boyle, a researcher in Teagasc Moorepark, took home the coveted RSPCA British Society of Animal Science (BSAS) award at the BSAS 2019 conference. Laura was chosen in recognition of her longstanding research into the welfare of dairy cows and pigs, and her contribution to developing carcass lesions as indicators of animal welfare.

Laura has been a passionate researcher and advocate for livestock welfare for almost 25 years, focusing her efforts on dairy cows and pigs in particular, as well as on ethics in animal research. She organised the successful 'Challenges in Scientific Research with Large Animals' session at the 2018 Dublin BSAS Annual Conference, and will be co-leading a forthcoming international conference on animal welfare in Ireland in 2020.

Speaking about her award, Laura said: "I am honoured and humbled to receive this prestigious award. I hope to use the recognition it affords me to progress both the science and the cause of animal welfare in Ireland and abroad. In an era of increasingly polarised views about animal production, I'm particularly keen to use my background in agriculture and animal welfare to bridge the gap between farmers and society".

BSAS award winner Laura Boyle.

Tomas Tubritt, a Teagasc Walsh Fellow in Moorepark, won the President's Prize at the event.

One Health European Joint Programme

Over 280 national and international delegates attended the One Health European Joint Programme Annual Scientific Meeting at Teagasc Ashtown recently, which examined the key issues related to foodborne pathogens and antimicrobial resistance in a One Health context.
The One Health European Joint Programme is helping to strengthen co-operation between its 40 partners (including the Med-Vet-Net Association) from 19 EU member states. It is aimed at improving and enhancing approaches to detect, monitor and prevent zoonotic micro-organisms and antimicrobial resistance in animals, the environment, the food chain, and humans. These research centres, most of which have national reference laboratory mandates on foodborne zoonoses, will form an organised network whose aim is to promote scientific progress in the areas of foodborne zoonoses, antimicrobial resistance and emerging risks. The programme has been built upon the principle of co-funding from the participating institutes and the European Union (Horizon 2020, the EU Framework Programme for Research and Innovation). As the largest European Joint Programme investment, it will cost €90 million, with 50% of its funding coming from the European Commission and 50% from the participating member states. The international One Health concept recognises that human health is highly dependent on animal health and the environment, and that the foodborne contaminants in particular that affect human health, animal health and the environment are closely intertwined. The European Joint Programme (EJP) on One Health has brought together a research community across Europe of medical, veterinary and environmental health scientists to work together in interdisciplinary teams with an international approach to address the threats of food-borne disease, antimicrobial resistance and emerging threats to human health from animals or the environment.

Johnstown Castle Estate opens for visitors

Johnstown Castle Estate in Wexford was established as the seat of the Esmondes in the 12th century, confiscated by Cromwell in the 1600s, and eventually gifted to the Irish State in 1945. It was a Department of Agriculture research station until 1960 when it was taken over by An Foras Talúntais (now Teagasc). The Irish Heritage Trust was awarded a tender to refurbish and manage the estate for a 10-year period in 2015. Teagasc remains the owner of the Johnstown Castle Estate and continues to operate an environmental research centre on site. As part of the refurbishment of the neo-gothic castle, one of the rooms has been maintained as a laboratory and there is an 86 metre underground servants' tunnel. The Johnstown Castle Estate visitor attraction also incorporates the Irish Agricultural Museum, spectacular lakes famed for their array of water fowl, and walled gardens. For more details on how to visit Johnstown Castle Estate, see: http://johnstowncastle.ie/.

Sustainability key message at dairy beef open day

A key message of the dairy beef open day event that took place at Teagasc Johnstown Castle Environment Research Centre recently was maximising production and farm efficiency from grass while reducing the effect of production on the environment. "Irish livestock systems will need to meet stringent environment targets that will require increased knowledge and technology," explained John Finn, Teagasc Johnstown Castle Enterprise Leader. The event displayed the latest research from Teagasc on environmentally sustainable farming that also contributes to production efficiency. "This includes effective nutrient management, low emissions slurry spreading, and use of protected urea that contributes to soil fertility, protection of water quality and lower greenhouse gas emissions," said John. Head of Teagasc Livestock Systems, Padraig French, said: "There are approximately one million dairy male calves and dairy-beef cross calves now available for beef production in Ireland. Beef farmers should evaluate dairy-beef production as an opportunity to potentially improve the profitability of their business". The systems and economics village at the open day included comprehensive comparisons of different dairy beef production systems and finishing regimes, including profitability analysis. In the genetics village, details of the new Dairy Beef Index (DBI) were given and attendees heard about the new dairy-beef programmes within Teagasc and the work being carried out by the Irish Cattle Breeding Federation (ICBF).

Dairy Beef Open Day at Teagasc Johnstown Castle.

Driving innovation in plant breeding

TEAGASC is part of the Virtual Irish Centre for Crop Improvement, which aims to develop specifically adapted crop varieties for the Irish sector.

The Virtual Irish Centre for Crop Improvement (VICCI) is a consortium of 15 principal investigators from Teagasc, University College Dublin, NUI Galway, Maynooth University and Trinity College Dublin (TCD). This consortium, established in 2014 through funding from the Department of Agriculture, Food and the Marine (DAFM), seeks to exploit advances in plant breeding-related sciences to enable the development of crop varieties specifically adapted to the future needs of the Irish agri-food sector.

A key driver

Plant breeding can be a key driver of profitability in agriculture. For instance, a report commissioned by the British Society of Plant Breeders outlines the fact that of the 2.1 tonnes per hectare yield increase (from 6.2 to 8.3 tonnes per hectare) experienced in UK wheat crops between 1982 and 2008, 1.9 tonnes per hectare (90%) was directly attributable to the release of new, higher-performing varieties in that period. Based on the 2008 UK harvest area of 2.1 million hectares, this resulted in an additional production of 3.9 million tonnes per annum when compared to 1982, with an associated gross value increase of between £373 million and £445 million per annum based on either feed or bread-making prices for grain.

This direct benefit was accompanied by downstream impacts: the development of UK-adapted wheat varieties with better milling characteristics over this period enabled a 57% increase (1.7 million tonnes) in UK-grown wheat used for milling, while imports of milling wheat fell by 20%. This amply demonstrates the potential of plant breeding to benefit both primary and downstream profitability in the agri-food sector.

An unusual slowdown

Despite the historical efficacy of plant breeding, the 21st century has seen a dramatic slowdown in the rate of genetic gain in major crops (e.g., maize, rice and wheat), which averaged at between 2% and 3% yield gain per annum between 1960 and 1990, but is projected to drop to half, or even less than a quarter of these levels between now and 2050. However, against the backdrop of this drop-off, huge strides have been made in biotechnology-based sciences with the potential to address the problem. Advances in areas such as genomics, transcriptomics, metabolomics, and high-throughput phenotyping not only allow the elucidation of the control of many key characteristics that are required for successful varieties, but offer routes to fast-track their development. Large-scale commercial breeders now routinely use approaches such as marker-assisted selection (MAS) and genomic selection (GS) to cut variety development time and incorporate difficult to breed for characteristics into varieties.

VICCI is using the above approaches to underpin the development of varieties that address four key challenges in Irish tillage and forage agriculture: fertiliser use; crop protection; abiotic stresses; and, the potential to replace imported crop products with Irish-grown alternatives. It would be impossible to address all of these topics for all of the crops and scenarios important to Irish agriculture, so VICCI research has focused on addressing specific challenges in six species:

- nitrogen use efficiency (NUE) in wheat, barley and ryegrass;
- disease resistance in wheat, oats, barley, potatoes and beans;
- cold tolerance in ryegrass;
- waterlogging stress in barley and ryegrass; and,
- frying quality in potatoes.

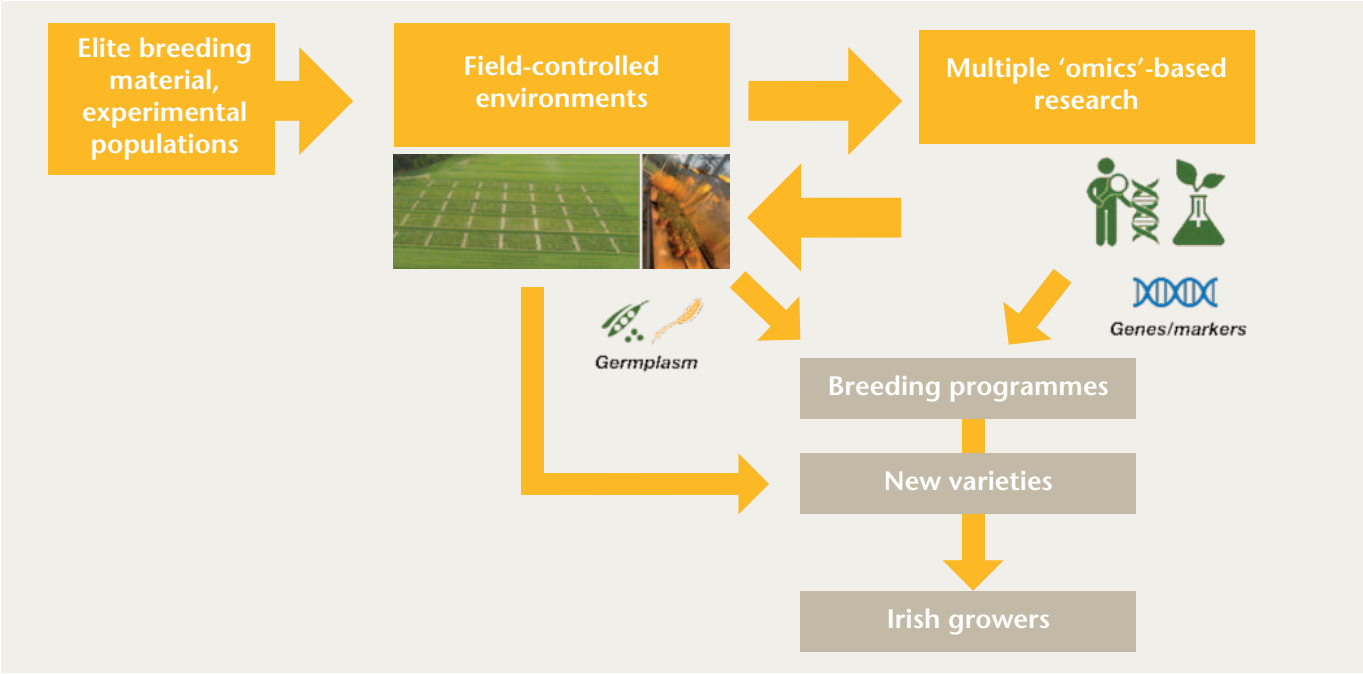


FIGURE 1: Model applied by VICCI to address challenges in Irish tillage and forage agriculture.

In order to address the challenges, VICCI broadly operates using the model outlined in **Figure 1**. Identifying relevant germplasm that can be used as parental material in breeding programmes is a key first step in the project, but rather than undertaking the expensive and lengthy process of developing collections of breeding germplasm, VICCI is collaborating with domestic and international partners who have already developed and characterised such populations.

The benefits of collaboration

VICCI partners are combining field, glasshouse and controlled environment trials to identify plants exhibiting desirable characteristics relevant to Ireland, with a multi-layered 'omics'-based approach to identify the genes and pathways in these plants that are controlling the characteristics. Subsequently, we develop and validate tools such as genetic markers that will provide cost-effective selection for these characteristics in breeding programmes. Making these tools available to breeding programmes that target the Irish market means that improved varieties will become available to growers. As it enters its fifth year, VICCI has had many tangible successes. In this special focus issue of *TResearch*, three sets of authors from VICCI give a series of snapshots of how VICCI research is advancing plant breeding innovation in the areas of disease resistance, abiotic stress tolerance, and developing crop varieties that are simultaneously adapted to Irish growing conditions and market expansion opportunities. Another notable success in VICCI has been the bringing together of Ireland's plant science and applied crop science communities. For example, this special issue of *TResearch* highlights a collaboration between scientists at Teagasc, Maynooth University and UCD that combines expertise in highly controlled field experiments, cutting-edge X-ray computer tomography (CT) imaging, and gene discovery and genetic marker development, to develop approaches to breed waterlogging-resistant winter barley varieties. VICCI activities have also developed new capacities and skillsets that are essential to allow the research community to effectively impact varietal development for Irish agriculture. Perhaps one of the biggest indirect benefits of VICCI has been the leveraging power that the consortium has given its participants. Since the project began, VICCI partners have successfully exploited both VICCI research, and the demonstrable existence of a co-ordinated crop improvement community, to participate in bidding for EU Horizon 2020 projects worth in excess of €10 million, further extending the potential of the VICCI community to impact variety development for Irish agriculture.

Acknowledgements

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A blotch on wheat production

Understanding wheat's response to septoria tritici blotch disease, the most destructive wheat disease in Western Europe.

Septoria tritici blotch (STB, caused by the fungus *Zymoseptoria tritici*) presents a significant threat to European wheat production, requiring substantial inputs of fungicide to exert adequate control and preserve yields for farmers. Within the EU, over 70% of annual EU fungicide usage in wheat is targeted towards STB, supporting a fungicide market worth ~€1.2bn per annum. In the absence of adequate control measures, STB can cause yield losses of up to 50% when susceptible wheat varieties are grown under weather conditions conducive to STB development. Unfortunately, our typical Irish climate is highly supportive of STB epidemics. Coupled with this is the loss of several chemistries due to the ability of *Z. tritici* to evolve resistance/tolerance to fungicides in a relatively short period.

A tough opponent

To date, three separate classes of fungicide have lost robust field efficacy against STB. In addition, the EU has recently removed the broad-acting fungicide chlorothalonil (CTL) from the registered list due to environmental concerns. CTL was a cornerstone of disease control strategies by mitigating the emergence of fungicide-resistant strains. As a result, Teagasc assessments indicate that the loss of CTL alone could reduce average net margins by up to 50% in wheat, with growers achieving national average yields at or just above break-even. In the short term, winter wheat production will only be a viable option for those with the lowest costs of production and with high-yielding sites. In the longer term, the future is bleaker because in the absence of CTL, a more rapid loss of efficacy of the remaining fungicides is expected due to high disease pressure.

It is clear that if winter wheat production is to remain a viable enterprise in the Irish tillage sector, the generation of novel varieties with durable genetic resistance to STB is the only viable option remaining. When integrated into an appropriate integrated pest management (IPM) strategy, such resistant material would have the potential to support profitable returns and maintain wheat within current rotations. Delivering such resistant material is, however, challenging, primarily due to the knowledge deficit that exists surrounding the STB-wheat interaction and specifically with regard to the genetic response to STB through the infection cycle. As part of VICCI, we have made significant strides in addressing the knowledge gap by elucidating the infection cycle and identifying signature genetic networks and genes that are the first response of the plant to STB infection.

STB-infected wheat plant.

A lot learned

Z. tritici spores quickly germinate upon landing on a leaf surface and gain entry into the leaf tissues by penetrating through the stomata (pores) in the leaf surface. However, for a period of time (up to 15 days) after this, there are no visible symptoms on the leaf surface, in spite of *Z. tritici* infection having occurred. Through research completed in VICCI, we now know that this 'latent period' is a critical aspect of the infection process. Indeed, extending the latent period will deliver a significant decrease in symptom development, and overall disease within the crop, which in turn reduces the necessity for high inputs of fungicide.

In parallel, we have also begun to interpret the genetic response of wheat to STB infection through the latent period. Using sequencing technology, we have identified the key host and pathogen genes involved in the early development of STB disease. Genome studies and cognate studies of the wheat metabolome (the metabolites produced in response to disease) have also given us great insights into the way that the disease evolves to attack new wheat varieties.

Separately, we have identified new pathways involved in wheat's defence against disease. This includes novel rapidly evolving genes, termed 'orphan genes' that are responsive to STB disease. Our findings also contradict some earlier studies, which suggested that the pathogen is relatively inactive during the early stages of disease: our genome studies suggest that there is significant cross-talk between the host and pathogen even as early as six hours after the pathogen infects the plant.

Identifying resistant genes

As part of these genome studies in VICCI, we have shown that the pathogen produces specific proteins that enable it to attack wheat varieties and, in parallel, wheat has evolved resistance proteins to help defend itself against this same attack. Different strains of the pathogen carry different attack genes, so called effectors. And wheat varieties differ in the resistance genes they carry and thus in the spectrum of pathogen strains that they can combat. Knowledge regarding the effectors present in Irish STB strains and the resistance genes present in the wheat varieties grown here is critical if we are to help breeders to tailor wheat varieties for the Irish tillage sector.

Breeders invest a lot of time and effort into introgressing resistance genes into new wheat varieties and thus it is very important that they have evidence that the selected genes have a significant quantitative effect on disease resistance. In VICCI, using gene silencing technology, we have validated the role of specific genes in STB disease resistance. VICCI has highlighted these genes as important targets for breeding STB-resistant wheat varieties.

STB disease has a very narrow host range and we hypothesised that this was because wheat carries genes that make it, unlike its relatives, susceptible to the disease. Through a collaboration with the John Innes Centre in the UK, we have identified two wheat lines with enhanced STB resistance and we are working with industry to map this resistance and introgress it into prebreeding material. While more time is required, it is clear that, armed with this new knowledge regarding the dynamic between wheat and STB disease, we are now in a much more informed position to help breeders develop wheat adapted to Irish disease pressures.

Acknowledgements

Additional authors: Carl Ng (School of Biology and Environmental Science, UCD), and Angela Feechan (School of Agriculture and Food Science, UCD). VICCI is funded by DAFM FIRM/Stimulus/CoFORD Grant 14S819.

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Innovations in breeding for import substitution

Research in VICCI is helping to develop varieties of potatoes and beans that will allow Irish producers to replace imported crops with Irish-grown ones.

Despite our capacity for crop production, Ireland still imports significant quantities of crop-based products to fill gaps in supply for various applications. This represents a potential diversification opportunity for Irish producers, who, with the right tools at their disposal, could displace some of these imports with Irish-grown alternatives. For instance, Ireland is a net importer of potatoes and beans. In both cases, imports are driven in part by a lack of varieties suited to both the targeted end use of the crop and our unique agro-climatic conditions.

Opportunities for import substitution

In 2018, CSO figures indicated that 72,000 tonnes of fresh potatoes were imported into Ireland. In addition to this, a further 120,000 tonnes of frozen potato products are imported annually, mainly to serve the frozen chip market. This represents an opportunity for import substitution using indigenously produced potatoes. Current varieties suitable for chip production can be difficult to grow in Ireland due to environmental, soil and management constraints. Thus, robust varieties that are adapted to the Irish agri-environment, suitable for chip production, and which possess good storage characteristics to support year round supply, would help to exploit this opportunity.

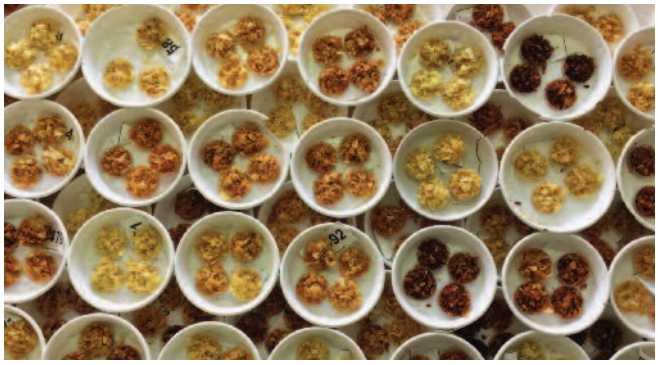
Ireland imports over three million tonnes of protein for animal feed annually, mostly soya, beans and maize. Faba beans constitute a potential home-grown alternative source of protein and are currently used mostly in coarse rations. Legume-friendly greening measures introduced as part of post-2014 Common Agricultural Policy (CAP) reforms, and the surge in feed demand brought about by the expansion of the dairy and beef herds following milk quota abolition, have resulted in an increase in bean acreage in Ireland.

Mild Irish winter agro-climatic conditions permit high yield potential over a wide range of sowing dates in faba bean production, and so-called 'spring' varieties can out-yield 'winter' varieties from autumn sowing when there is low disease pressure, suggesting that UK- and northern Europe-bred varieties are not well targeted to the Irish environment. However, there is currently no dedicated breeding programme focused on developing faba bean varieties adapted for optimal yield in autumn-sown Irish growing conditions, combining performance with improved disease resistance.

Potatoes for chipping

Potatoes for chipping are normally stored at 8°C; below this, reducing sugars accumulate leading to undesirably dark colours on frying. Unfortunately, sprouting occurs above 8°C, necessitating the use of sprout suppressants such as chlorpropham. These are being phased out, and it is therefore necessary to develop potatoes that can be stored below 8°C without accumulating sugars. Fry colour and low temperature sugar accumulation are under polygenic control and therefore challenging to breed for, particularly when they need to be combined with other traits such as yield and disease resistance. This is where new approaches such as genomic selection (GS) can assist traditional breeding. GS is a form of marker-assisted selection that simultaneously estimates genetic marker effects across the entire genome to calculate breeding values. These breeding

Faba bean isolation cage at Oak Park.



Variation in potato chip fry colour.

values can then be used to select individuals for advancement in the breeding cycle without direct phenotyping.

During VICCI, we evaluated fry colour on over 650 candidate varieties from the Teagasc potato breeding programme, after harvest and at various time points during storage at 4.5°C and 8°C (with sprout suppressant). Nearly 10,000 tubers were sliced into crisps, fried, and analysed for fry colour. This "training population" was also DNA-sequenced to identify approximately 50,000 single nucleotide polymorphism (SNP)-based molecular markers. We evaluated various statistical algorithms and determined factors affecting predictive ability of the SNP markers, enabling the identification of subsets of as few as 100 markers that were capable of predicting fry colour and resistance to low temperature sweetening with high accuracy. These are being used to develop a cost-effective genotyping assay to enable GS for these traits in the early stages of the Teagasc potato breeding programme when direct measurement of them is impractical.

Breeding better beans

As part of VICCI, Teagasc has collaborated with the University of Reading to establish a recurrent selection breeding scheme to improve yield and disease resistance for faba beans in Irish growing conditions. A founder population combining yield, quality and disease resistance characteristics, from which better adaptation to late autumn sowing under Irish conditions, along with many more desirable traits, can be selected, was established at Reading by intercrossing diverse faba bean varieties and inbred lines from a number of sources. These included UK elite field bean varieties and broad beans, sources of *Ascochyta* resistance, European lines carrying zero tannin and low-vicine/convicine traits, and Hungarian, Chinese and Egyptian germplasm as sources of diversity. Recurrent rounds of selection for yield are underway at Reading. High-yielding lines from the second round of selection in the UK were established in isolation cages in Oak Park in 2017, to allow crossing and selection under autumn-sown Irish conditions. One cage was maintained under standard commercial faba bean cultivation practice, while fungicide treatments were withheld from the "untreated" cage in order to exercise selection under enhanced disease pressure. Field-based selection for disease resistance will be complemented by screening for resistant progeny of selection in artificial inoculations, with *Ascochyta* and chocolate spot isolates. Survivors of these inoculated screens will be returned to the main recurrent selection population to contribute enhanced levels of disease resistance. Preliminary data from trials show that seed yield per plant is responding to selection, indicating that it should be possible to develop high-performing autumn-sown lines for Ireland. The definitive test of selection response will entail replicated field trials planned for the final year of the project, where yield and disease resistance of the new VICCI selected lines will be compared to the progenitor lines and current recommended varieties.

Conclusion

Real world output in the form of improved Irish-adapted varieties is an important goal for VICCI. These breeding initiatives in potato and beans have the potential to achieve this goal in the near future, supporting diversification and expansion of the Irish tillage sector.

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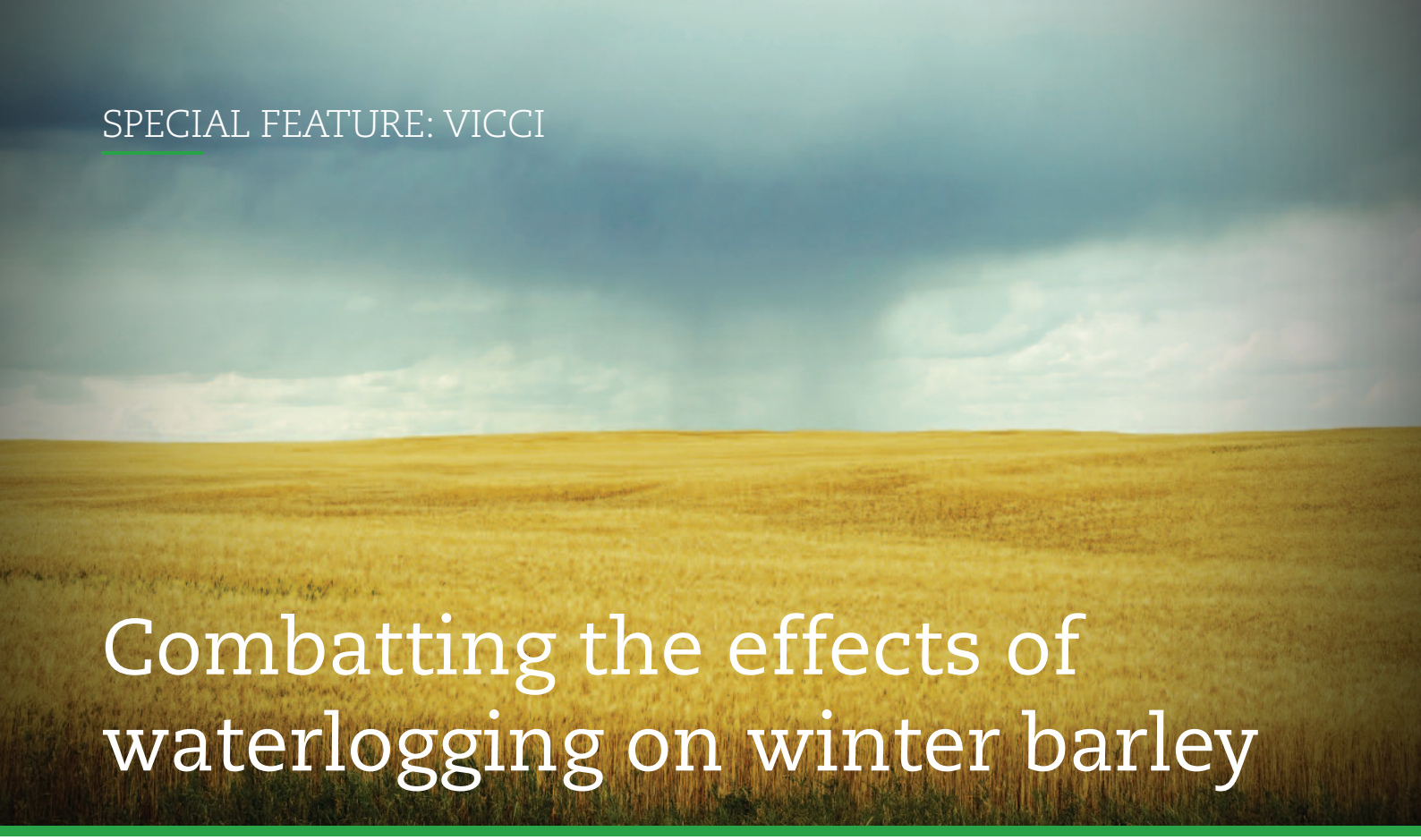

Combatting the effects of waterlogging on winter barley

As flooding events increase, TEAGASC researchers are looking at genotypic differences among winter barley cultivars with the aim of reducing the impact of waterlogging.

Flooding is becoming an increasingly challenging problem in Ireland due to global climate change-associated increases in annual rainfall. Flooding is a complex abiotic stress, which creates a low oxygen (hypoxic) environment for the plant. With increasing severity of flooding, the environment can become anoxic (no oxygen). Hypoxia and anoxia reduce available energy for the plant, decrease the rate of photosynthesis, limit nutrient uptake, and increase toxic metabolite production from the soil microbiome. These conditions are detrimental to the plant and result in crop death, as well as yield and total biomass loss. Recent climate reports predict rainfall increases of 15-20% in Ireland by 2100, highlighting the need for a solution to flooding stress. Because many crops are highly sensitive to flooding, the development of new cultivars with increased tolerance to waterlogging is essential to ensure stable crop yields.

We set out to investigate the genotypic response of winter barley towards waterlogging stress as experienced under typical early spring conditions in both field (**Figure 1**) and controlled climate chamber experiments. A barley association mapping family panel from the James Hutton Institute, which has been used in several association mapping projects in the UK, was used for our experiments. Through these activities, a set of approximately 400 winter barley cultivars has been assembled to represent the elite breeding pools of north western Europe, combined with some key progenitors and cultivars from Mediterranean Europe. The set contains nearly all the lines that completed at least two years of UK National List trials in the period 1993-2006. Inclusion of other cultivar sets extended the collection to older cultivars and other key production regions of Europe.

We observed, in flooding field trials, significant reductions in total biomass, grain biomass and height in winter barley. A 45% reduction in biomass was observed under waterlogged conditions, with total crop death resulting from the most severe treatments applied. This highlights the severe consequences of flooding stress for Irish barley production.

Mapping flooding tolerance

Phenotypic characterisation of chlorosis, necrosis and wilting allowed us to identify tolerant and sensitive cultivars. We developed a phenotypic scoring system that enabled us to select a subset of cultivars for further characterisation, under controlled conditions, of a range of shoot and root traits that may contribute to flooding tolerance, as well as molecular events. Significant reductions in chlorophyll pigment correlating with chlorosis of the leaves due to flooding were observed. This was coupled with an increase in carotenoid pigment. To further understand the underlying molecular responses to flooding in barley, we carried out RNA sequencing experiments and observed significant transcriptomic reprogramming. To further understand the extent of this reprogramming, we carried out bioinformatics analyses to functionally group these genes. As expected, our results highlighted the involvement of genes implicated in flooding responses, including alcohol dehydrogenases, pyruvate decarboxylase, sucrose synthases, and ethylene response factors, which highlights the validity of our datasets.

FIGURE 1: Flooding in field – year 2. Images of the blocks were taken using a DJI phantom 4 on January 26, 2018.

Interestingly, through a detailed analysis of roots, we found significant aerenchyma formation in flooded plants, with better-developed aerenchyma in tolerant barley cultivars. Aerenchyma are interconnected gas-conducting intercellular spaces that provide plant roots with oxygen under hypoxic conditions. Importantly, we have demonstrated the use of X-ray computed tomography (CT) scanning for identifying aerenchyma in intact roots. Using this technology for aerenchyma identification represents an innovative technical advance and highlights its potential application for future research and plant breeding.

New methods will assist in identifying flooding stress traits

Modern agriculture faces many issues, but there are none more pressing than global climate change. As we approach increasing climate variability, we must adapt our farming systems, and crop species and cultivars, to cope with atypical climate conditions, including tolerance to flooding. Modern plant breeding allows us to improve our crops at accelerated rates. Unfortunately, as flooding tolerance is a complex trait and reproducible screening approaches for flooding tolerance are technically challenging to set up, testing for flooding tolerance has as not yet entered as a criterion into breeding programmes and national list trial testing. With our work, we have shown that there is huge genotypic scope for barley improvement towards flooding stress as a trait, and we have also developed approaches and methods to evaluate this trait reliably, including visual markers (**Figure 2**), tissue phenotyping approaches (X-ray CT), molecular transcription-based approaches and marker genes.

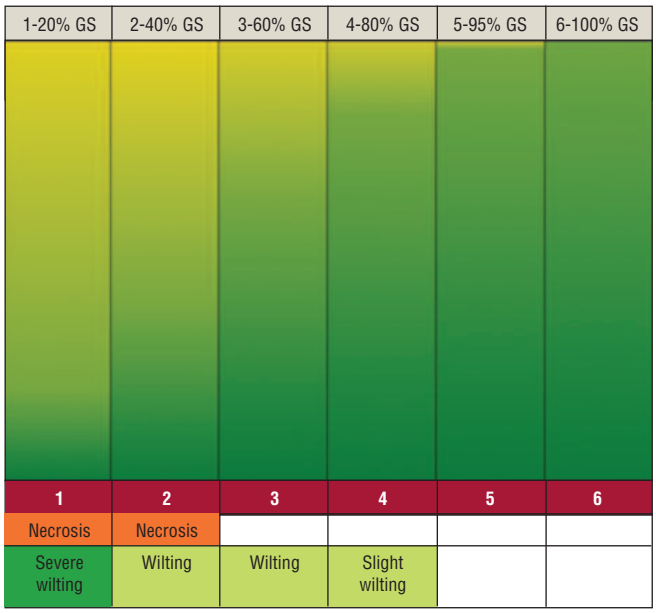

FIGURE 2: Scoring chart used for phenotyping. A colour gradient represents the percentage leaf green space (GS) indicating chlorosis in sensitive cultivars (score 1) to tolerant cultivars (score 6). The presence of necrosis on the leaves signifies sensitive cultivars. Wilting occurs on scores 1 to 4. Score 6 represents a tolerant cultivar with no phenotypic response to flooding. Score 6 is also the common phenotype of control plants.

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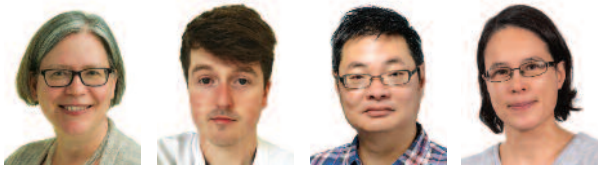

Learning through international collaboration

In addition to the funding offered under the Walsh Fellowship Scheme, TEAGASC offers a small number of overseas training awards for students to travel to laboratories in universities and research institutes abroad to develop international collaborations, as well as furthering their science education and training.

In 2018, Megan O'Brien received a Teagasc Overseas Training Award to conduct research in the Institute of Agriculture at the University of Tennessee (UT) in Knoxville, USA. Gina Pighetti, the head of the laboratory, has an international reputation in mammary physiology and immunology, and has conducted extensive research on bovine mastitis. As a second-year PhD student, Megan was ideally placed to take the results she has generated in Teagasc and develop them in line with the findings from the US lab.

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Interleukin 8

Megan's PhD is focused on a critical gene, which, when turned on, calls in immune cells, known as neutrophils, to fight infection. In agricultural terms, when these neutrophils are called into the mammary gland, the cow develops a high somatic cell count (SCC). However, neutrophils are important in all infections, including those outside the mammary gland, such as in the uterus, lungs and digestive tract. It is all the more relevant, therefore, that Megan's work focuses on characterising two different versions of this gene that were discovered in earlier work by the research group in Teagasc.

This work dovetails with the work done in the US lab, as the gene that Megan works on, known as interleukin 8, activates an immune response by binding to a receptor that has been characterised by Pighetti.

The proteins produced by these two genes orchestrate the immune response and determine if a cow can efficiently fight infection. Changes (or mutations) in these genes can contribute to a changed immune response, resulting in cows with a higher (or lower) SCC.

Megan is a member of Kieran Meade's research group in Teagasc, Grange, which has shown that mutations in the interleukin 8 gene result in two distinct versions (called haplotypes), and these versions are carried in approximately equal frequencies by Holstein-Friesian cattle. Interestingly, the Jersey breed only carries haplotype two of this gene.

Mastitis research at the University of Tennessee

The Teagasc training award presented Megan with the opportunity to conduct an experiment to investigate what combination of these genes may improve the outcome of a mastitis infection.

Over 120 cows from the herd at UT's dairy farm in Little River were genotyped for both genes. Blood samples were then taken

FIGURE 1: Megan taking a blood sample for genotyping from the tail of a Holstein-Friesian cow of the dairy herd at the University of Tennessee's Little River Farm.

FIGURE 2: Poster presentation at the Conference of Research Workers in Animal Disease 2018 held at the Marriott Downtown Magnificent Mile in Chicago, Illinois.

(**Figure 1**) and stimulated with a bacterial ligand known as LPS to imitate a bacterial infection and elicit an innate immune response. Megan has now shipped these samples back to Ireland for detailed analysis in Teagasc, Grange. A dataset, previously collected by Pighetti's group, also allowed Megan to link her version two of the interleukin 8 gene to more severe clinical outcomes during mastitis infection.

While in the US, Megan also presented a poster on her work at the Conference of Research Workers in Animal Diseases (CRWAD) held in Chicago, Illinois (**Figure 2**) and met with leaders in the field in the US dairy industry.

The Teagasc training award presented Megan with the opportunity to conduct an experiment to investigate what combination of these genes may improve the outcome of a mastitis infection.

Thanks to the Teagasc Overseas Training Award, Megan has enhanced our collective scientific knowledge on the genetics underlying the immune response to mastitis, a disease that requires a collaborative, global partnership approach to overcome. Ultimately this work will contribute toward the selection of cattle with a superior immune response to better fight infection.

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Balanced breeding – the dairy-beef index

TEAGASC, ICBF and AbacusBio researchers have developed a dairy-beef index to identify and breed beef bulls for use on dairy females.

The expanding dairy herd, coupled with improving reproductive performance, will necessitate that a greater proportion of slaughtered cattle in Ireland originate from dairy herds. Hence, a tool that ranks beef bulls for use on dairy females is required, and must provide a balance between the desires of the dairy farmer and those of the beef farmer. Such a ranking system should rank bulls on estimated genetic potential to efficiently produce a high-value carcass, while having minimal repercussions on the milk, health and reproductive performance of the dairy female. The technical name for such a tool is a breeding index. The breeding index can be used by dairy farmers to select suitable beef bulls for use on their dairy females, but can also be used by beef bull breeders to breed the next generation of beef bulls demanded by dairy producers.
A trait must fulfil three prerequisites to be considered for inclusion in a breeding index:

1. It must be important (either economically, socially or environmentally).
2. It must exhibit inter-animal genetic variability.
3. It should be measureable (ideally early in life and at a low cost) or correlated with a trait that is measureable.

Categories of sub-indices, a selection of possible traits within each of those categories, and the percentage of observed inter-animal variability that is due to transmissible genetic effects, are summarised in **Table 1**. While routine genetic evaluations are already in place for many of these traits (e.g., calving difficulty, carcass weight), the animal geneticists at both Teagasc and the Irish Cattle Breeding Federation (ICBF) are actively developing genetic evaluations for other traits (e.g., calf vigour, environmental hoofprint). Moreover, with time, new traits will be added to the list. For example, the Irish national dairy cow breeding index, the Economic Breeding Index (EBI), today includes almost four times as many traits as it did when it was launched in 2001.

Finding the optimal balance of traits

Once genetic evaluations exist, the next step in the development of an optimised breeding objective is the derivation of how much relative emphasis to place on individual traits. Obviously minimal calving difficulty is crucial, but a breeding index with a high emphasis on calving difficulty will, on average, select bulls with poor carcass characteristics. Finding the optimal balance between traits is key, but is also the most contentious issue in animal breeding.
The weighting factors currently used in all Irish cattle and sheep breeding indices are economics based; the intensifying interest in social licences could challenge this dogma and necessitate alternative strategies to derive weight for public good traits. Notwithstanding this, the economic weighting factors placed on the current traits within the dairy-beef index are informed by costs and prices experienced on farm. For example, the economic value attributable to carcass weight is simply the value

Table 1: Potential traits for consideration in a dairy-beef index and the contribution of genetic differences to the observed inter-animal variability.

Sub-index	Trait	Genetic emphasis (%)
Calving	Calving difficulty	10
	Gestation length	35
	Calf mortality	2
	Calf vigour	3
Efficiency	Feed intake	33
	Environmental hoofprint	20
	Age at slaughter	13
Carcass	Carcass weight	35
	Carcass conformation	35
	Carcass fat	35
	Ability to meet carcass specifications	10
	Meat quality	16
Societal	Docility	20
	Polled	100

of an additional kg of carcass sold in the marketplace. The overall cost of a difficult calving includes costs associated with increased labour requirements, veterinary costs, and the likelihood of reduced subsequent cow performance such as reduced milk production, compromised reproductive performance, and even risk of death.

The relative emphasis placed on the eight traits within the dairy-beef index launched in January 2019 is summarised in **Figure 1**. Some 65% of the emphasis relates to calving performance (i.e., calving difficulty, gestation length and calf mortality); these traits reflect the desirable attributes from the perspective of the dairy farmer. The remaining emphasis is on carcass merit (26%), feed intake (8%) and docility (1%), which reflect animal characteristics sought after by the beef farmer and processors.

Where to from here?

Traits currently not explicitly included in the dairy-beef index include, among others, calf vigour and health, lifetime methane emissions, novel measures of meat quality and nutritive value, and saleable red meat yield. Research is currently underway to generate routine genetic evaluations for these traits. Given the high heritability of most of the traits within the dairy-beef index, individual animal genetic merit should be a good reflection of future performance. Research is well underway in the development of an index informative for the sale and purchase of cattle; such an index would not include the traits associated with calving performance, since the animal has already expressed those traits (i.e., it is already born).

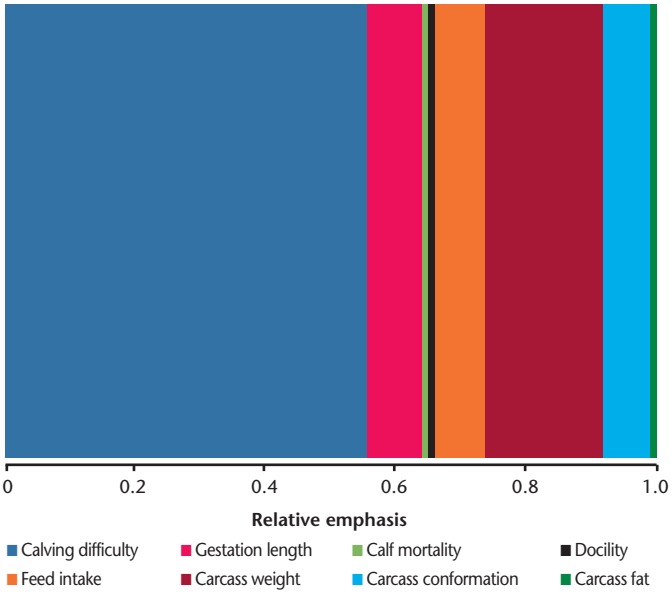

FIGURE 1: Relative emphasis on the component traits of the dairy-beef index.

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Antimicrobial use and resistance in Irish pig farms

TEAGASC researchers have compiled the first nationwide dataset on antimicrobial use in Irish pig production and will now investigate the dynamics of antimicrobial resistance at farm level.

The World Health Organisation, World Organisation for Animal Health, and the Food and Agriculture Organisation of the United Nations have included antimicrobial resistance (AMR) in the list of the biggest threats to human health. There is growing concern that the use of antibiotics in animal production may have a role in the emergence and dissemination of antimicrobial-resistant organisms relevant to human health. The spotlight often falls on intensive production sectors, such as pig production, because a high level of antimicrobial use (AMU) is assumed in these sectors. Until now, data on current AMU was not available in Ireland. Project AMURAP (Antimicrobial Use and Resistance in Animal Production), a Department of Agriculture, Food and the Marine (DAFM)-funded collaborative project between Teagasc and UCD, has collected the first nationwide database on AMU in Irish pig production, setting the baseline for future reference. Starting in summer 2019, the project will measure the evolution of AMR throughout the pig's life cycle.

How are antimicrobials used in pig production?

AMU data for the year 2016 was collected from 67 farrow-to-finish pig farms, representing one-third of the pigs in Ireland. The majority (89.2%) of antimicrobials used in pig production were administered in medicated feed, mostly to weaner pigs, to treat or prevent disease. The average total use of antimicrobials per farm was 108.5mg/kg liveweight sold (lwt; weight of all animals sent to slaughter), or 161.9mg/PCU, where PCU or 'population correction unit' is an estimate of weight at treatment defined for each species. **Figure 1** depicts the antimicrobial consumption for 2016 in six European countries, including all routes of administration. The total antimicrobial consumption in Irish pig farms was lower than in the UK, but much greater than reference countries such as Sweden, the Netherlands or Denmark.

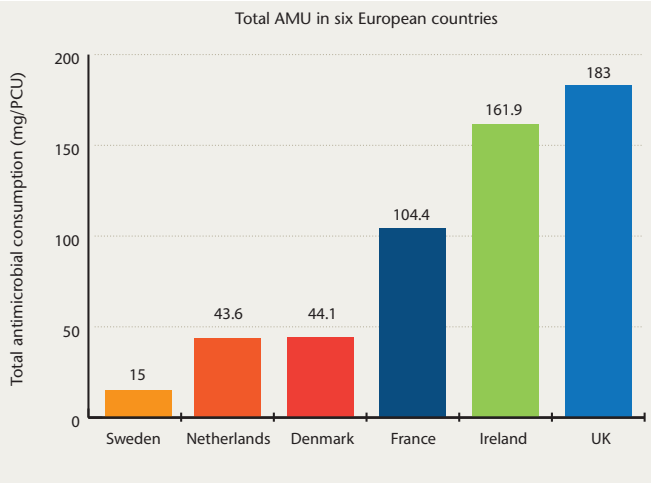

FIGURE 1: Total antimicrobial consumption in six European countries in mg/PCU in 2016. The population correction unit (PCU) is an estimate of weight at treatment defined for each species. For each country, the weight of antimicrobials consumed was taken from the respective national reports (Sweden – Swedres Svarm, 2016; the Netherlands – Sda, 2016; Denmark – DANMAP 2016; France – Anses, 2016; UK – VMD, 2017). The PCU for each country was taken from the European Surveillance of Veterinary Antimicrobial Consumption *report for 2016 (ESVAC, 2018).*

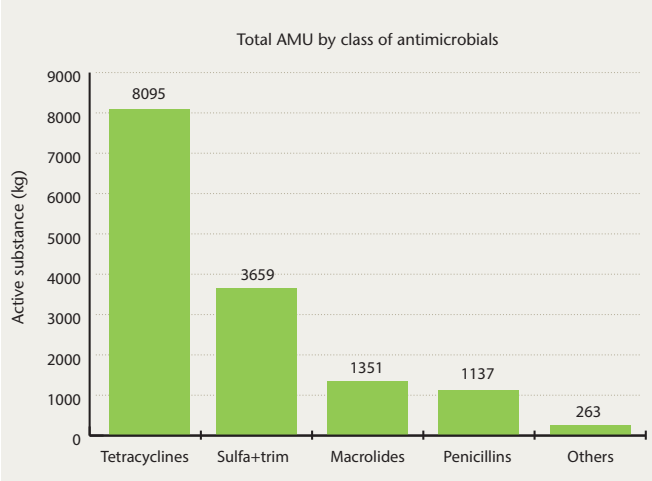

FIGURE 2: Total antimicrobial consumption by weight of active ingredient (kg) across all routes of administration on 67 Irish farrow-to-finish pig farms, 2016.

The World Health Organisation defines antimicrobials that are most important for treating human disease as "critically important antimicrobials" (CIAs). Only 0.39mg/kg lwt of AMU in pigs was comprised of CIAs. AMU breakdown by class of antimicrobials is shown in **Figure 2**.

Comparison of farms

Teagasc researchers put together a report summarising the information gathered on each farm, and compared the values obtained to the other Irish farms surveyed. This practice is known as benchmarking and it allows farmers to compare their data to that of their peers. **Figure 3** is an example of a benchmarking report where the farm in question is above the national average.

Relating AMU to AMR

Besides setting the baseline reference for future AMU estimates in Ireland, these data are useful to better understand the links between patterns of AMU and the development of AMR. Previous research indicates that AMR peaks after weaning and decreases thereafter. However, further research is needed to understand the dynamics of resistance at farm level, and to help identify points in the production chain where interventions to control the development of resistance might be most effective. In AMR investigations, zoonotic bacteria (infectious agents that spread between animals and humans) such as *Salmonella spp.*, are studied due to their links to public health while *Escherichia coli*, which live normally in the gut, are studied due to their ability to transfer AMR to other bacteria. Project AMURAP will follow batches of pigs in high- and low-user farms, and measure AMR throughout the pig's life cycle. Particular attention will be paid to resistance against the critically important antimicrobials for human medicine. The project aims to provide a better understanding of how AMR evolves through the production period, how it is affected by AMU, and to identify patterns of use that present the highest risk for the development of resistance. Thus, farmers will have improved knowledge of the strategies available to minimise the risk of AMR while maintaining good health status in their herds.

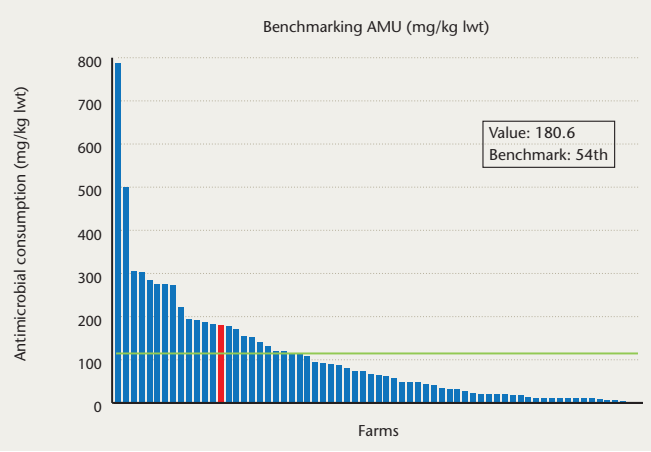

FIGURE 3: Benchmarking total in-feed antibiotic use in Irish pig farms. The red bar represents the farm benchmarked against its peers and the green horizontal line represents the national average.

Conclusions

- The pig sector is the first in Ireland to publish information on the use of antibiotics.
- Almost all antimicrobials used in pig production are administered in feed.
- AMU in pig production is greater than for other sectors, but it is lower than expected and the use of CIAs is low.

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Designing more attractive dairy farm workplaces

Labour shortages are having a major impact on dairy farming in Ireland. TEAGASC researchers are engaging with stakeholders to identify strategies to address this.

Inadequate availability of skilled farm labour has been identified as a major issue that is currently impacting the sustainability of dairy farming enterprises, and it is anticipated that this will worsen in the coming years. Attracting new and young people into the dairy industry is essential to achieve succession on farms, enhance innovation, and promote successful and profitable dairying (McKillop *et al.*, 2018). The shortage of skilled workers combined with an increased workload is contributing to a deteriorating work/life balance for many farmers. The growing economy in Ireland means that dairy farming is facing increased competition for employees from other industrial sectors. Contributing issues from the farm perspective include work organisation, farm facilities, and work practices. Although contributing factors have been identified, it is imperative to identify strategies to overcome the labour challenges facing the industry. One approach that was considered was to engage with key informants, record their views, and analyse the data.

Methodology

A mixed methods research approach was used to explore farm labour issues. This was achieved by conducting an in-depth focus group discussion (three hours), held on the day after the International Agricultural Workforce Conference (July 2018). There were 34 participants, including farmers (ten), industry organisation representatives (nine), advisors (six), educators (two) and researchers (seven: three national and four international). The group was randomly divided into smaller groups of five to seven people. Three open-ended questions relating to farm labour were developed and presented to the groups:

1. What are the current work/labour challenges on Irish dairy farms?
2. What do you anticipate as being the two main labour issues on Irish dairy farms in five to ten years?
3. What is working well on Irish dairy farms currently with respect to workload and employees, and why?

A range of participatory learning and action techniques such as flexible brainstorming, clustering of ideas, and direct ranking were used (de Brún *et al.*, 2017). The data collected were coded into themes and analysed.

Informants' views

What are the current work/labour challenges on Irish dairy farms?

Significant challenges to labour efficiency on dairy farms were identified:

- poor working environment (poor management of employees, low levels of training provided to employees, poor standard of facilities);
- seasonality of workload;
- poor perception of industry (long hours and low wages); and,
- low availability of skilled workers.

What do you anticipate as being the two main labour issues on Irish dairy farms in five to ten years?

The workshop participants considered that the future challenges facing the industry will be broadly similar to those challenges currently being faced by farmers, so new challenges are not envisaged, but the current challenges are seen to be very significant.

FIGURE 1: Key factors that are working well on farms regarding managing labour demand and providing a good working environment for employees. (Graphic reproduced courtesy of the Irish Farmers Journal.*)*

What is working well on Irish dairy farms currently with respect to workload and employees, and why?

A number of key factors that are currently being practised on farms, and working well in attracting and retaining employees, were identified (**Figure 1**).

Most of the points illustrated in **Figure 1** of 'what is working well' on Irish dairy farms largely address the current challenges. The solutions are known, but the challenge now is how to take action and implement them.

The shortage of skilled workers combined with an increased workload is contributing to a deteriorating work/life balance for many farmers.

Conclusion

Farming can be a very enjoyable and rewarding career, as indicated by the responses gathered from the informants. There are, however, challenges that need to be addressed to ensure its long-term sustainability:

1. The high level of labour demand on farms may be compounded for both the farmer and employee by the seasonality of the milk production system, and facilities and practices conducted on the farm. Changes in employee management, shorter hours, better wages, and provision of training could increase the availability of skilled labour.
2. The labour demand/availability challenges are likely to continue in the long term and therefore need to be addressed.
3. A range of mechanisms was identified as working well on farms in addressing the challenges. Thus, the new advanced challenge is to develop a strategy to implement these mechanisms. A multi-actor approach may be required, and the People in Dairy Action Plan will be essential in realising this.

Acknowledgments

The authors acknowledge the contribution of Pat Clarke and Sean McCarthy in facilitating the workshop, and Paidi Kelly and Tom O'Dwyer for their input in designing the workshop.

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Ensuring a future for forestry

Pest risk analysis carried out by TEAGASC researchers is helping to ensure the future of forestry in Ireland and further afield.

The introduction of pests and diseases (collectively referred to as pests) to new regions globally is on the increase. This is directly linked to the globalisation of trade. Plants and plant products are now moving further and faster than ever before, and they are bringing their pests with them. The consequences of outbreaks can be devastating. The arrival of the bacterial pathogen *Xylella fastidiosa* to Europe is one such example. This pest, which attacks a wide variety of plant species including grapevines, olive trees and ornamental shrubs, is estimated to have caused €1.2 billion of damage since its arrival in 2013. In Ireland, the arrival of the ash dieback pathogen *Hymenoscyphus fraxineus* led to the destruction of over 2.1 million trees.

Sitka spruce (*Picea sitchensis*) is a highly productive forest tree, and the most commonly grown commercial forest tree in Ireland, making up over 50% of the Irish forest estate. One reason Sitka spruce thrives in Ireland is that it has been established here in the absence of the most important pests found in its native range of the Pacific Northwest of North America. Despite its great quality wood and fast growth rate, Sitka spruce is not grown extensively for commercial production in North America. Pests such as the Sitka spruce weevil (*Pissodes strobi*) attack trees so extensively in its native range that they develop multiple forks and become commercially unviable. With forestry contributing an estimated €2.3 billion to the economy each year, it is imperative that Irish Sitka spruce production is protected from such damaging pests.

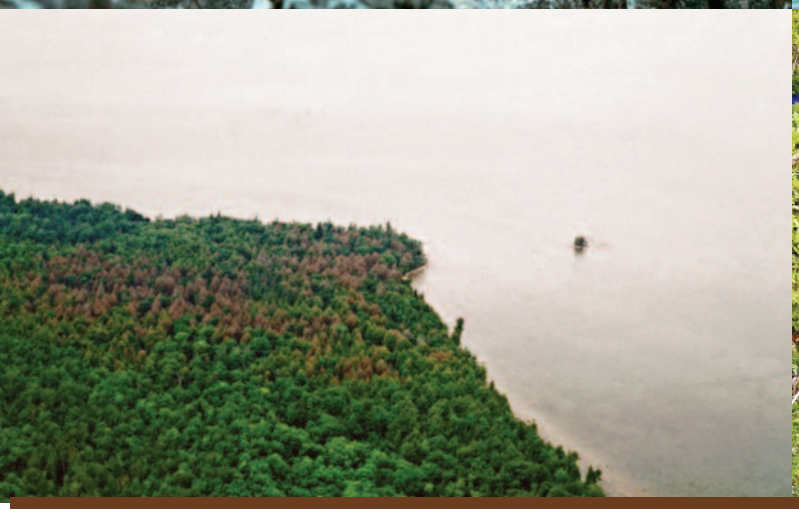
Recognising this, the Department of Agriculture, Food and the Maine (DAFM) funded the FORM (FORest Management) project, with a specific work package to address potential risks to Sitka spruce. The first step to protecting Sitka spruce was to identify those pest risks. An in-depth literature search was undertaken to identify pests of all species of the genus *Picea* globally. Over 1,300 known and potential pests of Sitka spruce were identified.

Prioritising risks and the role of pest risk analysis

In order to protect the country from the introduction of new pests, regulations exist around the importation of plants and plant products. International trade laws require that such regulations are "technically justified". The internationally recognised way to technically justify such regulations is via the use of pest risk analysis (PRA). This is a technical document that analyses the likelihood of pests entering and establishing in a defined area, e.g., the island of Ireland. It then estimates the potential magnitude of economic, environmental and social impacts to that area. Finally, PRA will identify measures that can be taken to reduce the risk of the pest via regulation. PRA may analyse the risk of an individual pest, or it can analyse the risk that trade in a particular commodity poses, analysing all pest risks associated with that commodity – also known as "pathway" PRA.

Ireland had no PRA scheme, and as part of the FORM project a scheme was developed and the first Irish PRAs produced. A pathway PRA analysed the pest threats to Sitka spruce that could






Top left: The hemlock looper moth (photo: Jerald E. Dewey, USDA Forest Service, Bugwood.org).
Top right: Hemlock looper caterpillar (photo: Connecticut Agricultural Experiment Station, Connecticut Agricultural Experiment Station, Bugwood.org).
Above left: Hemlock looper damage to a forest in the US (photo: USDA Forest Service – Northeastern Area, USDA Forest Service, Bugwood.org).
Above right: Imported moss that may harbour undesirable pests.

enter on the "plants for planting" pathway, and over 220 pests were analysed for their likelihood of entry and potential impacts. This exercise was invaluable as it helped to identify which pests posed the greatest threat to Ireland. It also identified a number of trades that could be subject to further regulations in order to provide protection against a range of pests.

Hemlock looper: the hidden threat in our hanging baskets?

The hemlock looper (*Lambdina fiscellaria*) is a North American moth, the caterpillar of which is a forest pest that can cause extensive defoliation and mortality of coniferous trees. A PRA carried out for this species identified a previously unknown pathway of entry. This moth species likes to lay its eggs in the mosses and lichens that cover trees in the lush North American forests. It was discovered that such mosses and lichens are harvested directly from the forest and are being exported to the EU for use in ornamental displays and hanging baskets. When this occurs, the eggs of the hemlock looper may be inadvertently gathered up with the mosses and introduced into new regions. The PRA for hemlock looper has been sent to the European and Mediterranean Plant Protection Organisation (EPPO) for consideration, as part of the process to regulate this pest and protect not only Ireland but the whole of the EU from this potentially highly damaging species.

Ensuring a healthy future for our forests

The Sitka spruce pest list will be an invaluable tool for protecting our forestry. This pest list has now been shared with other organisations in Europe working to protect forest health, including a collaborative project among the Nordic countries, which are investigating risks to coniferous forestry in Northern Europe. The establishment of a PRA scheme for Ireland is an essential step, not only to ensuring a healthy future for our forests, but also for plant health across the island. Ireland for the first time has the ability to write PRAs and provide the necessary evidence direct to the EU to support the regulation of pests and pathways.

Acknowledgements

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Novel technologies to eradicate microbial biofilms

TEAGASC research has shown a number of new technologies with the potential to help fight microbial biofilms.

Microbial biofilms

Biofilms are significantly important in environmental, industrial, and clinical contexts. They are complex microbial multicellular communities formed on most biotic and abiotic surfaces, and are responsible for 80% of chronic human infections leading to hospitalisation and death. Microbial biofilm has been an active form of research since the first definition of biofilm in 1968 by Bill Costerton and co-workers. Bacterial biofilms (**Figure 1**) are defined as: "A microbial derived sessile community characterised by cells that are irreversibly attached to a substratum or interface or to each other, are embedded in a matrix of extracellular polymeric substances that they have produced and exhibit an altered phenotype with respect to growth rate and gene transcription" (Donlan and Costerton, 2002).

They are one of the most persistent states for bacteria, which can withstand severe environmental conditions and have significantly elevated tolerance to antimicrobial agents. The resistance of the bacterial biofilms is mainly attributed to multiple mechanisms: inability of antimicrobial agents to penetrate the biofilm matrix; ability of the bacteria to survive starvation conditions; the physical and genetic heterogeneity of biofilm microenvironment; and, the presence of the non-active persister cells within the biofilm community. To counteract these challenges, there is need for an advanced disinfection technique/methodology that could help eradicate microbial biofilms and help control food- and healthcare-associated human infections. Non-thermal plasma (**Figure 2**) and acoustic airborne are emergent technologies, which have attracted attention for their enhanced microbial safety, non-thermal nature and fast processing. The Ultrafilm project will offer an innovative solution to eradicate biofilms, which could help develop a new sustainable technology to solve serious economic and health problems. The project's importance is emphasised in the current climate of increasing tolerance and resistance of biofilms to standard decontamination methods and agents.

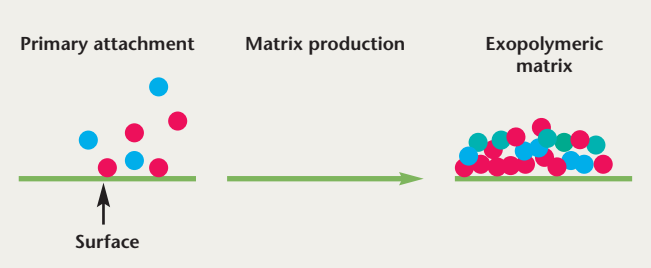

FIGURE 1: Bacterial biofilm on surface.

Atmospheric cold plasma

A wide range of applications of atmospheric cold plasma have emerged in the last two decades, which offer the possibility of inactivating a range of microbial populations and are the subject of intensive research. Atmospheric cold plasma generates a diverse array of reactive species, UV, high electric fields and charged particles, which individually or in synergy are capable of contributing significantly to bacterial inactivation. The results from bacterial biofilm populations inoculated on stainless steel coupons treated with high-voltage (240V) atmospheric cold plasma are presented in **Figure 3**. Plasma treatments for three minutes considerably reduced *Listeria innocua* and *Escherichia coli* by 2.8 and 3.6 Log_{10} CFU/ml, respectively. Further, treatment for five and ten minutes reduced the bacterial population below the detection limit (1 Log_{10} cfu/ml).

Ultrasound

Ultrasound is well known to have a significant effect on various processes in the food industry. Substantial literature is available

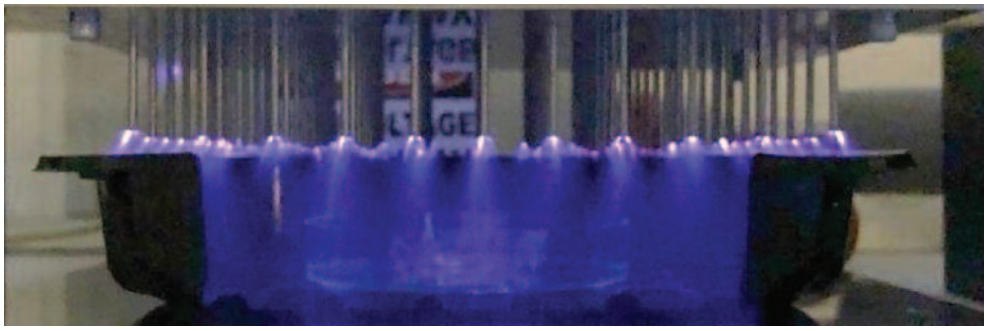

FIGURE 2: Plasma leap system, with the system voltage of 240V, 2500Hz frequency treatment, with biofilm coupon placed in a petri dish at the centre of the system.

describing the application of contact type ultrasound for drying, defoaming and decontamination of various microorganisms, whereas relatively little is known about the acoustic non-contact ultrasound and its application against microbial biofilms. Application of high ultrasonic stresses along with acoustic pressure is known to induce a rapid series of contractions and expansions in bacterial cells, leading to various morphological changes such as formation of pores, thinning and disruption of cell membranes. Airborne acoustics operated at 35kHz for 15 minutes has demonstrated 1.6-2.4 log reductions in bacterial biofilm populations formed on stainless steel coupons (**Figure 3**). Bacterial biofilms have complex structures and chemical compositions, which may vary among bacterial strains. It is necessary to optimise the treatment parameters to enhance treatment efficacy. A number of significant gaps, such as understanding the mechanism of action, characterisation and in-depth interaction to treat bacterial biofilms are elusive and still remain to be fully addressed. For biofilms, the study will focus on the synergistic effects of airborne acoustics in combination with cold plasma technologies to accelerate and eradicate microbial biofilms more effectively.

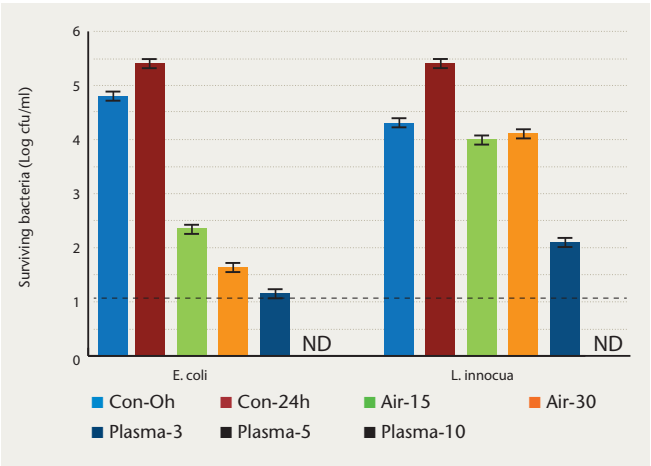

FIGURE 3: Surviving populations of E. coli *and* L. innocua *96h biofilm after airborne acoustics (15 and 30 minutes) and plasma treatments (three, five and ten minutes) estimated by colony count assay. The dotted line indicates a detection limit (1 Log_{10} cfu/ml). ND: Not detected (below detection limit). Vertical lines on the column indicate standard deviation.*

Conclusion

Many traditional food processing techniques are reaching their optimum performance, while consumer demands grow, and food and environmental regulations tighten. The unique physics and chemistry found with atmospheric cold plasma and airborne acoustics could offer agri-food industries a new technology-driven tool for supporting a sustainable food industry. Further studies on synergistic microbial effects using these technologies could help develop effective bio-decontamination technology to solve serious economic and health issues associated with biofilms.

Acknowledgment

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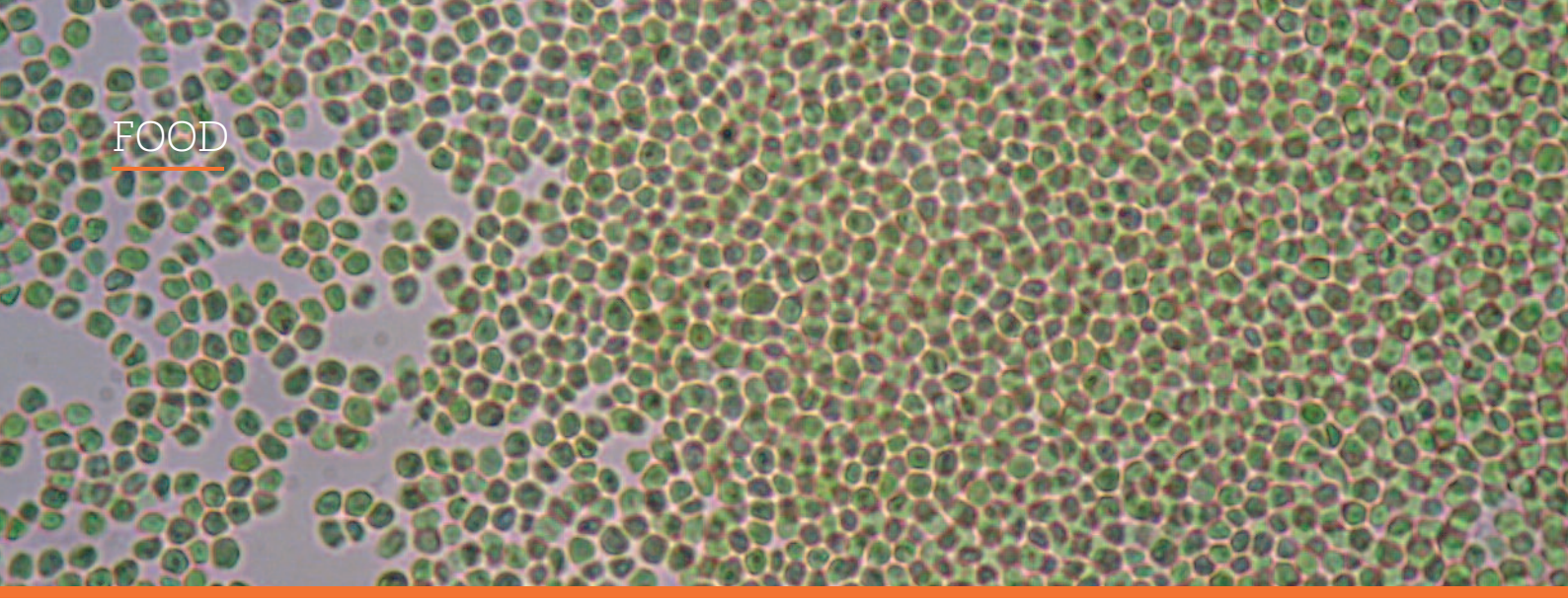


Enhancing the food value of microalgae

As part of an EU project, TEAGASC researchers are examining types of microalgae, which are among the richest and most sustainable sources of nutrients.

It is now believed that more than 4,000 species of microalgae exist and just a few hundred of these have been investigated, which suggests that they are one of the most unexplored groups in the world. Thus, more research needs to be done to assess the relatively unknown reservoir of novel compounds, and the full potential of these organisms. Microalgae have been established as a good source of proteins and other high-value compounds such as carbohydrates, lipids, vitamins, pigments, minerals and bioactive compounds. In this regard, although the microalgae industry is growing very quickly, more attention needs to be paid to the by-products after protein extraction to make the most of the initial biomass.

Relevance of microalgae

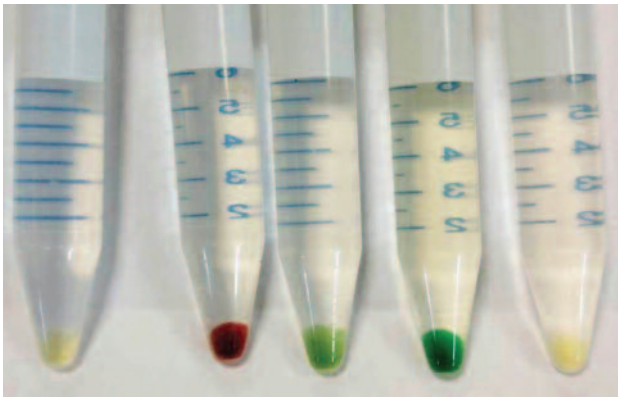
Microalgae represent one of the most promising sources of new food products and applications but there are also other factors that make the microalgae business very attractive:

- microalgae present a higher yield rate of biomass production than traditional crops of vascular plants;
- they have high adaptability to be grown in different conditions (e.g., marine and freshwater);
- they present the flexibility to be produced using different systems (e.g., naturally in lakes, open ponds, photobioreactors);
- microalgae can be cultivated everywhere, even on non-cultivable lands (e.g., desert, seashore);
- they are a photosynthetic microorganism, so they reduce atmospheric CO_2;
- if the entire conditions of production are controlled, there is no seasonality and variability of the final product is almost null; and,
- microalgae can be used to remove excess nutrients from water (e.g., phosphorus, nitrogen and potassium), reducing the cost of production.

In spite of all these advantages, just a few microalgae have been harvested and commercialised as "generally recognised as safe" (GRAS) in the United States, and in Europe a couple of strains of microalgae have been approved as novel food and/or novel food ingredients. In Ireland, *Chlorella vulgaris* (chlorella) and *Arthrospira platensis* (spirulina) are the best known. They can be found easily at a reasonable price in health food stores and consumed in different formats, tablets and powder being the most common. The popularity of these two microorganisms is so high that they were classified recently as 'superfoods' (Castello *et al.*, 2018, van den Driessche *et al.*, 2018) along with blueberries and kale, among other products. But what does superfood mean? Superfood is a non-scientific term commonly used for marketing purposes in the media and in blogs, where people attempt to describe food with a high content of vitamins, minerals and antioxidants. The closer scientific term to define such edible products is "functional foods", which can be effective in preventing or treating different diseases due to the presence of bioactive compounds. In particular, chlorella is a single unicellular alga with powerful health properties due to its high content in protein, amino acids, pigments and antioxidants, which may help prevent several illnesses. It is estimated that about 5,000 tons are cultivated per year. On the other hand, spirulina production is a bit higher, at around 12,000 tons per year. Spirulina could be one of the most complete foods, containing abundant protein (about 60% of the total content), vitamins, pigments, good fatty acids and minerals. Also, it has a total phenolic content that is sometimes even higher than the most consumed vegetables and fruits, enhancing human health.

EnhanceMicroAlgae

Researchers at Teagasc have shown that the application of novel extraction techniques such as ultrasound, enzymes and microwave-assisted extraction techniques can enhance the extraction of proteins and other bioactives from microalgae. EnhanceMicroAlgae (High added-value industrial opportunities for microalgae in the Atlantic Area – Enhance Microalgae) is an ongoing project with a budget of €2.45 million, aiming to make the most of microalgae in the Atlantic Area, with several partners based in Spain, Portugal, France, the UK and Ireland. The objective is to enhance the value of this resource by transferring the latest developments in this field to the business sector, thereby facilitating production of large biomass volumes, using new species and optimising production processes in line with different final products such as fatty acids, pigments and polyphenol extraction for human nutrition, led by Teagasc.



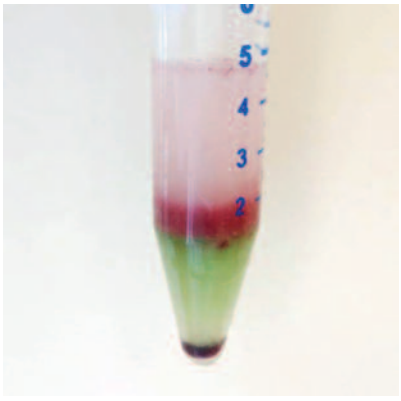


FIGURE 1 (left): Extraction of fatty acids from different microalgae strains.

FIGURE 2 (right): Pigments extracted from Porphyridium purpureum.

Fatty acid supplements

Fatty acids are essential for living organisms, and good polyunsaturated fatty acids (PUFAs) can be sourced from fish oil. PUFAs are beneficial in reducing the risk of coronary heart disease and might be beneficial in the treatment of certain autoimmune diseases such as multiple sclerosis, among other benefits. However, the use of fish oil as a source of PUFAs has some drawbacks:

- fish are being depleted due to overexploitation of fish reserves;
- fish can accumulate toxic compounds such as heavy metals, which can be transferred to the fish oil;
- fish oil has an unpleasant smell and taste;
- the PUFAs extracted are instable due to oxidation, losing their good properties; and,
- it is not a suitable product for the vegan and vegetarian market.

As a result of these disadvantages, research into new matrices to find alternatives is being carried out. Fish are rich in PUFAs due to their diet. Hence, lines of research are driven by microalgae that are the first link of the fish trophic chain and a very rich source of PUFAs. At Teagasc, we are using new, less-investigated strains, such as *Nannochloropsis oculata*, *Scenedesmus obliquus* and *Porphyridium purpureum*, to enhance the extraction of fatty acids (**Figure 1**).

Antioxidants, pigments and polyphenols

Nowadays, there are concerns due to problems associated with the unsafe effects of artificial colourants. There is a wide range of microorganisms pertaining to different families of microalgae (diatoms, green algae, golden algae and blue-green algae cyanobacteria) and each one produces different pigments that may have antioxidant activity and can be used as a natural source to replace synthetic colourants in the food, cosmetic, nutraceutical, and pharmaceutical industries. **Figure 2** depicts the extraction of two pigments from *P. purpureum*.

The task of Teagasc regarding the characterisation of bioactive compounds in microalgae is carried out in nutraceutical facilities. The work will be done following antioxidant guided tests; the initial microalgae biomass will be extracted and divided into different fractions, using techniques such as dialysis, flash chromatography, etc. The fractions that present higher antioxidant activity will be the remarkable ones to be further studied.

Acknowledgements

The EnhanceMicroAlgae project is funded by EU INTERREG Atlantic Area: https://enhancemicroalgae.eu.

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A gut feeling about body fat

TEAGASC research shows that loss of body fat causes the growth of the intestine and increases its capacity to absorb nutrients. This presents new approaches for weight management.

The intestine is a vital organ for sustaining life because it controls how much we eat and, of the nutrients ingested, how much are absorbed into the blood for delivery to target organs. Nutrient absorption is achieved by specific transporters expressed in the intestinal cells. The intestine also allows some nutrients to freely pass into the blood. Because the intestinal cells have to continuously divide to sustain these activities, there is a substantial energy usage by the tissue, which is known to be met by breaking down of some of the nutrients absorbed by the intestinal cells. While this coupling between the external nutrient supply and intestinal cellular activity is well known, and has been exploited to control the growth of the intestine by varying the diet, in this article we highlight an alternate, less well-known pathway that can also be used to control the growth of the intestine. Based on our recent work, published in the official journal of the World Obesity Federation (Nilaweera and Speakman, 2018), we propose that depletion of fat stores inside the body also causes the growth of the intestine, and that this occurs via a signalling mechanism involving the brain (**Figure 1D**).

Supporting evidence

Our body weight varies constantly, sometimes daily, but more noticeably over long periods following intake of high-energy diets coupled with reduced physical activity. While this would increase body weight, a reduced calorie intake and/or increased physical activity would have an opposite response. The change in body weight arises largely due to corresponding variation in fat stores in the body. As part of our ongoing research to understand the mechanisms controlling body weight, we wanted to know how this variation in fat stores impacts on other organs in the body. To this end, we looked at data from interventions that cause fat loss: dietary whey protein intake; calorie restriction (or dieting); cold exposure; lactation; and, bariatric surgery (where surgical changes to the gastrointestinal tract cause reduced food intake, and fat loss) (Nilaweera and Speakman, 2018). We extended this review of data to include different animals such as mammals, birds and reptiles. By going through our own data related to some of these interventions, and those of others, it became clear that there is a link between loss of body fat and the growth of the intestine, involving changes in the brain.

We proposed that animals, including humans, have evolved this internal mechanism (fat-brain-intestine pathway) to control the growth of the intestine to survive periods of food shortage, where loss of fat would signal to increase the size of the intestine. The enlarged intestine would then be able to absorb nutrients efficiently upon ingestion of a meal consumed during the period of food scarcity, and use the energy in the food to survive this challenging period and replenish the depleting fat stores.

Relevance to society, policy makers and industry

The UN has declared a "Decade of Action on Nutrition, 2016-2025" in recognition of the need to eliminate all forms of malnutrition, specifically over-nutrition and under-nutrition. Developing interventions that can control the growth of the intestine may provide a way to address these grand challenges.

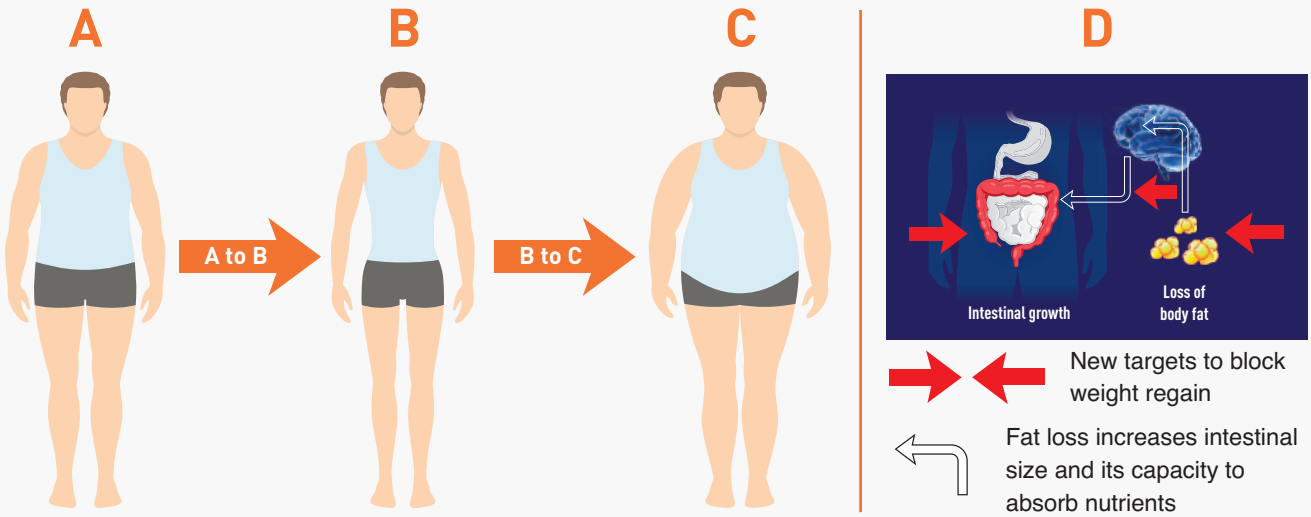

FIGURE 1: A loss of body weight occurs during dieting (A to B) but weight regains when dieting stops and a shift towards pre-diet meal intake resumes (B to C). Current data support the model (D) whereby loss of body fat causes the growth of the intestine and its capacity to absorb nutrients, which appears to underlie at least in part the weight regain during post dieting phase.

Over-nutrition

The world is experiencing an obesity epidemic arising from over-consumption of high-energy, palatable foods. While dieting is a popular way to lose weight and body fat, maintaining the lost body weight is a difficult task when dieting stops and a shift to pre-diet meal intake resumes. The link between fat loss and intestinal growth proposed by us provides an understanding of why the change in the diet post weight loss enhances weight gain so quickly (**Figure 1**). Is there a way then to sustain lost body weight?

Our recent work shows that intake of whey protein isolate (WPI) in sufficient quantities causes the gut to shrink (McAllan *et al.*, 2015), as well as affecting the mechanisms involved in nutrient absorption in the intestine, including the gut microbiota (Nilaweera *et al.*, 2017). This work will pave the way for the creation of better weight loss/weight maintenance interventions.

Under-nutrition

Alongside the obesity epidemic, which affected 600 million adults worldwide in 2014, there were 462 million underweight individuals resulting from poor nutrition (WHO records). This could arise because of physical inability to consume food (for instance in old age), chronic illness (cachexia), or psychological reasons (anorexia).

For these affected individuals, the solution is not simply giving access to more food. Thus, by targeting key components of the fat-brain-intestine signalling pathway that are sensitive to nutrients (Nilaweera and Speakman, 2018), it would be possible to promote the growth of the intestine and increase its capacity to absorb nutrients in underweight individuals with limited desire to consume nutrients (**Figure 1**).

Acknowledgments

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John R. Speakman (Not pictured)
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The Munster Institute in Cork, where most of the poultry instructresses of this era would have trained.

Women in Irish agricultural history

The role of women in the Irish poultry industry is a fascinating example of the history of women in Irish agriculture, and illuminates the need for greater collaboration between men and women in the sector.

Three students of NUI Galway's MA in Gender, Globalisation and Rights worked with Teagasc researchers and Teagasc's Steering Committee for the History of the Irish Agricultural Advisory Services to examine historical records documenting the role of women in Irish agricultural history. The records are in the library of Ireland's Department of Agriculture, Food and the Marine (DAFM), and are the Annual Reports of the County Committees of Agriculture (ARCCA) for 1901-1980. The project sought to answer the question: how have women been involved in Irish agriculture historically? It sought evidence specifically of a number of types of 'feminisation' (**Table 1**). The literature on the role of women in agriculture discusses how women's participation in agriculture may be optimised by leveraging and exploiting women's traits and work styles. This optimisation benefits both women and society generally, and increases the potential for innovation.

Integrative and substitutive feminisation

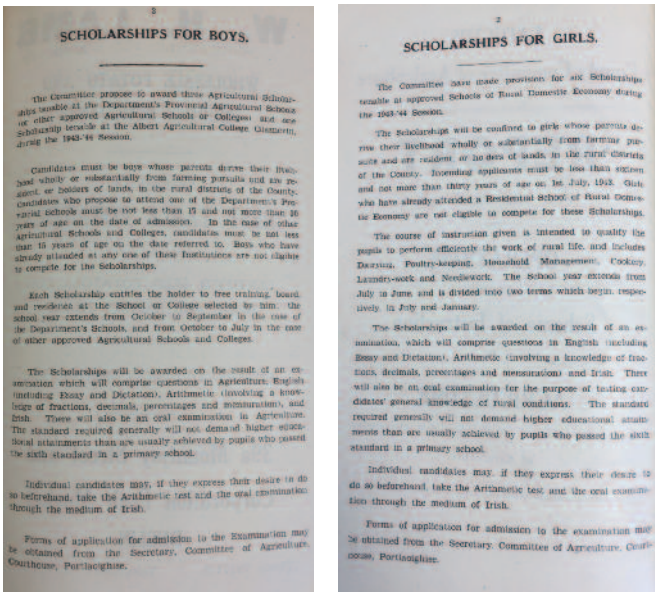
Poultry and egg production was associated with and operated almost exclusively by women, but it was integrated as a small-scale activity ('pin money') on male-owned farms. According to the ARCCA for Galway, the Hatcheries Act (1947) "introduced a radical change to the system of poultry-keeping", leading to its masculinisation. This substitution of women by men was explained by their lack of property ownership and professional organisation. According to the Cork ARCCA, by the end of the 1940s the poultry sector was highly male dominated, and women participated mainly as workers. However, what had not changed was women dominating the occupation of poultry instruction (**Figure 1**). Laois ARCCA showed that poultry instructresses worked daily irrespective of weather conditions, were not entitled to holidays, and were initially paid £150 per annum, which was £50 more than male horticultural instructors, although the latter enjoyed different employment terms. As they had to resign upon marriage, many women were not employed for long.

Progressive and competitive feminisation

Poultry instructresses were highly innovative in designing strategies for breeding, packaging and marketing for their clients so that they could progress their businesses. For instance, after the world poultry exhibition in Britain in 1903, they advised their clients of the importance of having trap nests and pedigree stock. A particularly entrepreneurial instructress, Nora Keating in Galway, noted that her turkey scheme "was most successful" and the "chicks" were of "superior quality", while cautioning that it was "premature to speak of markets" lest an inferior product gave "Galway a bad name". Eventually, the sector proved remarkably successful, leading to the exporting of stock. Mary E. Daly noted that of all agricultural sectors, "poultry was one that progressed". There was an impression that instructresses were successful because they were "wives" and "mothers"; hence, they could understand the temperaments of the birds. However, progressive business acumen is evident from the data. It is notable that Keating – who outstepped the integrative/substitutive boundaries – was dismissed from her

Table 1: The feminisation framework: how women may become involved in agriculture.

Type	Definition	Example
Integrative	Women 'slotting into' roles designated to them by society	Particular types of farm work (e.g., poultry-keeping, young calf care), often unpaid and without ownership of farm assets/land
Substitutive	Women undertaking roles disdained or rejected by men	Poultry-keeping/dairy farming before it became policy supported/industrialised
Competitive	Women vying for equal opportunity, engaging in the same type of work as is typically dominated by farm men, and often imitating the established male style	A woman managing one of the largest dairy herds in Ireland, a role occupied frequently by men. Agricultural education was supportive to her gaining the respect of peers and entering the occupational category of 'dairy farmer'
Progressive	Women following enterprise/career development paths considered uniquely associated with women, carving out a different path in agriculture	Examples given in the international literature are: high nature value/organic agriculture; on-farm diversification; high value-added agriculture/food processing. Note: these activities are becoming more frequently engaged in by men
Reconstitutive or collaborative	Women entering into collaborative relationships with men, with both parties committed to principles and actions of gender equality	Farm partnerships or other collaborative farming ventures involving farm women and men



SCHOLARSHIPS FOR BOYS.

The Committee propose to award three Agricultural Scholarships tenable at the Department's Provincial Agricultural Schools or other approved Agricultural Schools or Colleges and one Scholarship tenable at the Albert Agricultural College Glasnevin, during the 1943-'44 Session.

Candidates must be boys whose parents derive their livelihood wholly or substantially from farming pursuits and are resident, or children of lands, in the rural districts of the County. Candidates who propose to attend one of the Department's Provincial schools must be not less than 15 and not more than 16 years of age on the date of admission. In the case of other Agricultural Schools and Colleges, candidates must be not less than 15 years of age on the date referred to. Boys who have already attended at any one of these Institutions are not eligible to compete for the Scholarships.

Each Scholarship entitles the holder to free training, board and residence at the School or College selected by him. The school year extends from October to September in the case of the Department's Schools, and from October to July in the case of other approved Agricultural Schools and Colleges.

The Scholarships will be awarded on the result of an examination which will comprise questions in Agriculture, English (including Essay and Dictation), Arithmetic (involving a knowledge of fractions, decimals, percentages and mensuration), and Irish. There will also be an oral examination in Agriculture. The standard required generally will not demand higher educational attainments than are usually achieved by pupils who passed the sixth standard in a primary school.

Individual candidates may, if they express their desire to do so beforehand, take the Arithmetic test and the oral examination through the medium of Irish.

Forms of application for admission to the Examination may be obtained from the Secretary, Committee of Agriculture, Courthouse, Portlaoighise.

SCHOLARSHIPS FOR GIRLS.

The Committee have made provision for six Scholarships tenable at approved Schools of Rural Domestic Economy during the 1943-'44 Session.

The Scholarships will be confined to girls whose parents derive their livelihood wholly or substantially from farming pursuits and are resident, or children of lands, in the rural districts of the County. Intending applicants must be less than sixteen and not more than thirty years of age on 1st July, 1943. Girls who have already attended a Residential School of Rural Economy are not eligible to compete for these Scholarships.

The course of instruction given is intended to qualify the pupils to perform efficiently the work of rural life, and includes Dairying, Poultry-keeping, Household Management, Cookery, Laundry-work and Needlework. The School year extends from July to June, and is divided into two terms which begin, respectively, in July and January.

The Scholarships will be awarded on the result of an examination, which will comprise questions in English (including Essay and Dictation), Arithmetic (involving a knowledge of fractions, decimals, percentages and mensuration) and Irish. There will also be an oral examination for the purpose of testing candidates' general knowledge of rural conditions. The standard required generally will not demand higher educational attainments than are usually achieved by pupils who passed the sixth standard in a primary school.

Individual candidates may, if they express their desire to do so beforehand, take the Arithmetic test and the oral examination through the medium of Irish.

Forms of application for admission to the examination may be obtained from the Secretary, Committee of Agriculture, Courthouse, Portlaoighise.

FIGURE 1: Different scholarships for girls and boys. (Source: Laois ARCCA, 1942-1943.)

post. Her actions represented both progressive and competitive feminisation, in the ways in which she created new pathways with a style that was then perceived as ostensibly male.

Collaboration between men and women

A substitutive and integrative role for women in Irish agriculture was highly evident in the historical data. There was some evidence of a progressive and competitive role, but no evidence of a collaborative, reconstitutive role involving both women and men. Understanding the historical scene – its norms, challenges and missed opportunities – illuminates the need for greater collaboration between men and women in Irish agriculture, which, according to recent Teagasc research, has strengthened in the sector over the past decade in particular.

Acknowledgments

Larry O'Loughlin, Chairman of Teagasc's Steering Committee for the History of the Irish Agricultural Advisory Services; Áine Macken-Walsh, Agrifood Business and Spatial Analysis (AFBSA), Rural Economy and Development Programme (REDP); Paolo Defant, Jen Byrne and Esther Brady, DAFM library; and, Peter Foynes, Cork Butter Museum.

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Measuring sustainability of agricultural emissions

The TEAGASC National Farm Survey 2017 Sustainability Report contains a wealth of information about gaseous emissions on Irish farms, which is crucial in measuring and improving sustainability.

The recently published Teagasc 2017 Sustainability Report outlines the sustainability performance of dairy, drystock and tillage farms through data collected by the Teagasc National Farm Survey. Sustainability reflects the economic and social well-being of those involved in farming, and also encompasses agriculture's interaction with the environment. On the environmental side, agriculture is the largest contributor to greenhouse gas (GHG) emissions of any sector in the Irish economy at just over 33%. Moreover, Ireland's emissions of ammonia come almost exclusively from the agriculture sector. Ireland is a party to international agreements designed to limit emissions, with challenging reduction targets in place for both gases over the next decade. Hence, this article focuses on the gaseous emissions aspect of environmental sustainability, while at the same time acknowledging that stakeholders should be concerned with all three pillars (economic, social and environment) of sustainability.

Approach to measurement

One of the challenges in both measuring and improving farm sustainability is that every farm is unique. Farms differ in term of size, what they produce, and their production intensity. These factors all influence the level of emissions of GHGs or ammonia from individual farms. Therefore, while reporting the total emissions from individual farms is relevant, greater granularity, focusing on emissions per hectare or emissions per unit of product, provides a more relevant farm assessment. GHGs emitted by dairy, cattle, sheep and tillage farms can be converted to a common currency of CO_2 equivalents (using Intergovernmental Panel on Climate Change [IPCC] methodology), which allow comparisons to be drawn across these farm types. A three-year rolling average is used to iron out the impact that variable production conditions, or positive and negative price shocks, can have on emissions from one year to the next.

Results

GHG emissions

Due to the more intensive nature of production, GHG emissions per hectare from the average dairy farm are two and four times higher than on the average drystock and tillage farms, respectively. Emissions on non-dairy farms have tended to remain static over the period examined, whereas emissions on dairy farms have trended upwards, reflecting the growth in activity that has happened with milk quota removal. However, when GHG emissions are expressed relative to the revenue generation capacity of the farm (layering environmental and economic sustainability together) the narrative changes (**Figure 1**). Due to their superior revenue-generating capacity and consequent economic sustainability, on average dairy farms produce close to half of the GHG emissions per Euro of output generated compared to cattle farms. Similarly dairy farms generate only about two-thirds of the emissions per Euro of output compared to sheep farms. However, as noted in the detailed report (Buckley *et al.*, 2019), on the basis of kg of product produced (milk, liveweight beef and sheep) the carbon footprint of production has been declining over the study period across all farm types.

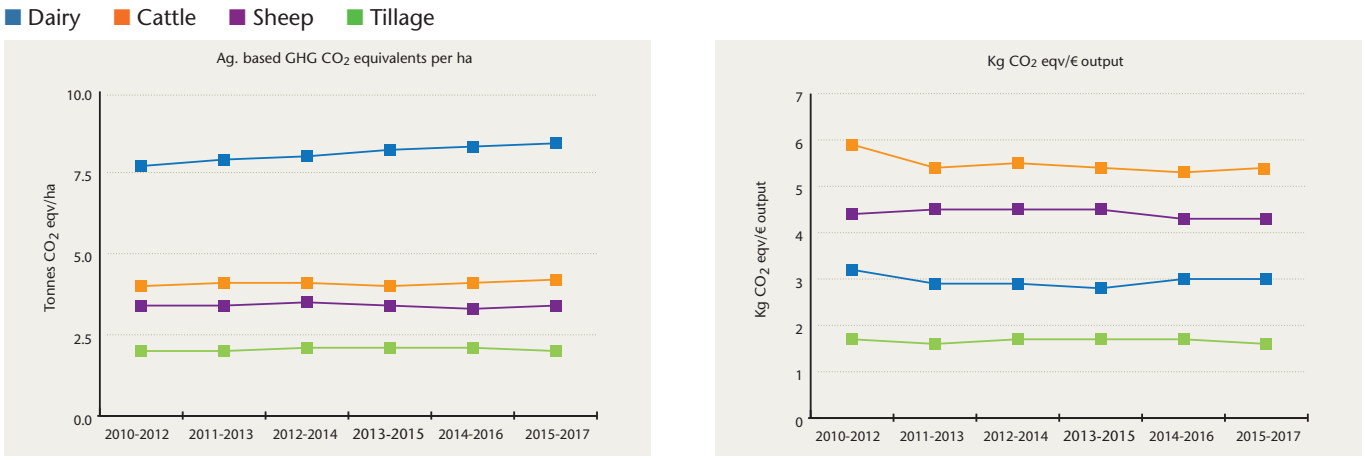

FIGURE 1: Comparison of GHG emissions based on CO_2 equivalent per hectare, and on CO_2 equivalent per Euro output.

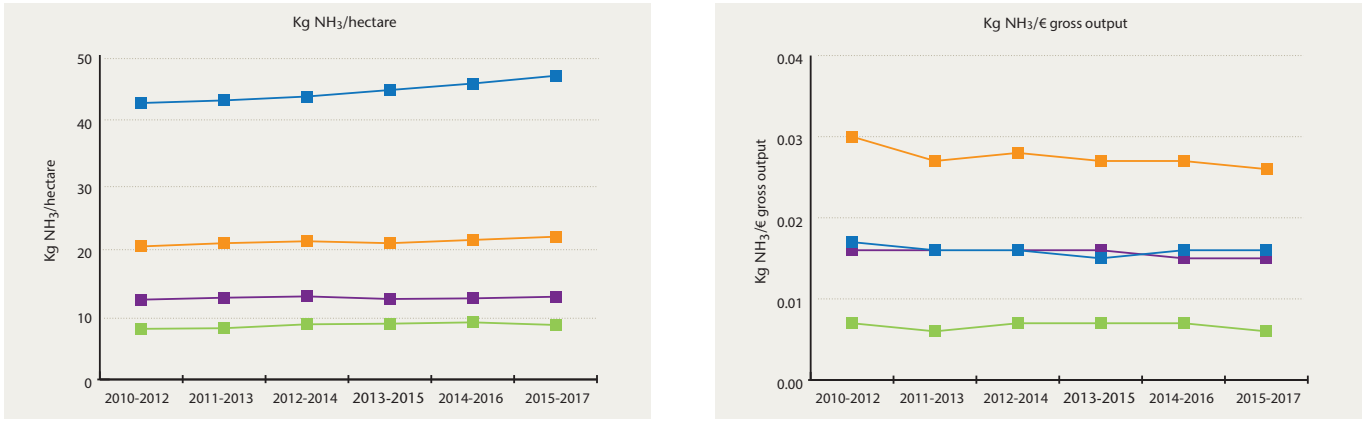

FIGURE 2: Comparison of ammonia emissions based on NH_3 equivalent per hectare, and on NH_3 equivalent per Euro gross output.

Ammonia

As with GHG emissions, dairy farms have the highest level of ammonia emissions on a per hectare basis. Per-hectare dairy farm ammonia emissions are on average two, 3.5 and five times higher than the average emissions on cattle, sheep and tillage farms, respectively. Non-dairy farm ammonia emissions have again remained relatively static on a per hectare basis over the study period, whereas ammonia emissions on dairy farms have been trending upwards since EU milk quota abolition. However, when ammonia emissions are expressed relative to the associated revenue generated on farms, a somewhat different picture emerges. Cattle farms are the highest emitters of NH_3 per Euro of gross output generated, 1.8 times higher than dairy and sheep farms, and four times higher than tillage farms (**Figure 2**). However, it again should be noted than on a kg of product produced basis (milk, liveweight beef and sheep) the ammonia footprint of production has been declining over the study period.

Overall, the sustainability report illustrates that an incremental improvement in GHG and ammonia emission intensity in recent years has been achieved on Irish farms, and there is a trade-off between economic and environmental sustainability. However, the sector needs to make significant progress in emissions mitigation if internationally agreed absolute emissions reduction targets are to be achieved.

Acknowledgements

Additional authors of this report include Emma Dillon, Kevin Hanrahan, Brian Moran, and Mary Ryan, Agricultural Economics and Farm Surveys Department, Teagasc Rural Economy and Development Programme.

Reference

Buckley, C., Donnellan, T., Dillon, E., Hanrahan, K., Moran, B. and Ryan, M. (2019). 'Teagasc National Farm Survey 2017 Sustainability Report'. Available at: https://www.teagasc.ie/media/website/publications/2019/2017-sustainability-report-250319.pdf.

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Getting functional with cheese

Research from TEAGASC has shown that if manufacturers wish to make claims about the health benefits of functional cheese, they should emphasise that taste has not been affected.

Both Food Harvest 2020 and Food Wise 2025 have recommended a substantial growth in Irish cheese production, from an added value perspective. Some of this growth can be achieved through the development of radical cheese innovations. Researchers in Teagasc and University College Cork have examined the factors influencing Irish and UK consumers' acceptance of cheese product concepts varying in function and health claim.

Ancient food to novel functions

Cheese is an ancient food, with archaeological evidence of its production dating back to 7,000BC. It is an excellent source of many essential nutrients such as calcium, phosphorous and protein, and can make a meaningful contribution to a healthy diet. Furthermore, cheese is a product that can lend itself to fortification with vitamins, minerals or functional ingredients, resulting in new 'health-enhanced' cheese products with significant market potential.

Meeting consumer needs in NPD

Radical new product development (NPD) requires significant investment and, because of high product failure of between 60 and 80% of product launches, it may be considered too risky by some cheese manufacturers. However, these high failure rates can possibly be attenuated through a deep understanding and targeting of appropriate consumer segments. Indeed, it is widely acknowledged that consumer orientation in product development activities is necessary for market success. In fact, by applying a consumer-oriented NPD process, the likelihood of market success increases. International consumer markets are of particular importance to Irish dairy manufacturers in regards to sustaining and growing their business. Hence NPD should also account for the needs of international consumers, such as the British (the UK accounted for 22% of our dairy exports in 2017, of which 41% was cheese and nearly half of this was cheddar). Notwithstanding the issues surrounding Brexit and proposed tariffs, the UK is very likely to remain a significant export market for Irish cheese. Thus, it is essential to have extensive up-to-date consumer insights and market knowledge to respond effectively to changing consumer food preferences.

Consumer assessment of novel cheese concepts

The aim of this research was twofold: firstly to examine consumers' current attitudes towards cheese; and, secondly to determine consumer responses to a range of health-enhanced cheese products. In particular, the research was interested in consumers' health evaluations of a set of proposed cheese products (varying in fortification and health claim) and their willingness to try such cheese options. Data were collected using an online survey of a representative sample of 600 adult cheese consumers from Ireland and the UK. Respondents' current cheese usage practices and attitudes to cheese were sought. Furthermore, evaluations on the healthiness of and willingness to try a range of eight full-fat and eight low-fat realistic cheese concepts were sought. The concepts were rated on a scale of 1 to 7. Higher scores indicate more positive health evaluations (perceived

Table 1: Mean consumer scores for willingness to try and the perceived healthiness of full-fat cheese concepts varying in fortification and claim.

Fortification	Claim	Willing to try	Perceived health
No fortification	No claim	5.27	3.90
Vitamins	No claim	4.45	4.32
Protein and vitamins	No claim	4.42	4.41
Protein	No claim	4.39	4.18
Protein and vitamins	Muscle claim	4.38	4.49
Protein	Muscle claim	4.34	4.35
No fortification	Child development	4.16	4.55
Vitamins	Child development	4.03	4.53

healthiness) and increased willingness to try.

Attitudes to cheese were generally positive. Over 90% indicated that they always have a supply of cheese in their fridge, with 63% preferring full-fat cheese and nearly half indicating that they regularly cook with cheese. In addition, 43% indicated that they considered cheese to be a healthy food product and 28% indicated that they regularly consume cheese as a snack.

Furthermore, cheese is a product that can lend itself to fortification with vitamins, minerals or functional ingredients, resulting in new 'health-enhanced' cheese products with significant market potential.

Consumer acceptance of regular full-fat cheese and functional full-fat cheese concepts are presented in **Table 1**. Compared to all of the other full-fat cheese concepts, full-fat cheese with no fortification and no claim had the highest willingness to try score but the lowest perceived healthiness score. This consumer willingness to try decreased when the cheese concepts had added fortification or had an associated health claim. Conversely, the concepts with both fortification and health claim had the highest perceived healthiness score. Cheese concepts with a child development claim had the highest perceived healthiness scores of all the concepts. A similar pattern was observed for the low-fat cheese concepts, whereby fortification and claim decreased willingness to try but increased the perceived healthiness of the products. Although consumers perceived most of the cheese products with fortification and claims as healthier, there was a lower willingness to try. This may be a result of diminished perception of sensory satisfaction and taste in a modified food concept.

There was no difference in willingness to try the concepts between Ireland and UK consumers. However, Irish consumers were more likely to rate the healthiness of cheese concepts with added vitamins and minerals and/or with health claims significantly higher than UK consumers. Demographic differences were observed across the concepts, with lower-fat products more appealing to the younger female demographic and protein cheese having a strong appeal for fitness-oriented and younger consumers. The concepts with health benefits were positively received among parents.

With respect to NPD and functional cheese with claims, using an established and accepted concept from another food domain may be a good point of entry to the market. There is a need for clear and effective communication of less familiar concepts. Most importantly, it should be emphasised that taste has not been compromised when the currently accepted product has been modified.

Acknowledgements

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Deal or no deal?

What would a no deal Brexit mean for UK import tariffs, and what would be the impact on Irish agriculture?

In April of 2019, the EU granted the UK a membership extension to October 31, 2019, to allow the UK parliament further time to approve the withdrawal agreement (WA) negotiated between the UK Government and the EU. The WA is an essential step towards a smooth Brexit. Among other things, the WA makes provision for a transition period where, on leaving the EU, the UK's current trading relations with the EU would not change. The transition period would provide more time to negotiate the future trading relationship between the UK and EU, while also allowing trade between the UK and EU to continue unimpeded by tariffs or other non-tariff barriers.

Should the UK fail to ratify the WA in the coming months, one of many possible outcomes is a no-deal Brexit. In a no-deal Brexit, there would be no transition period. From a trade perspective this would mean that overnight the UK and EU would be required to treat each other as Most Favoured Nations (MFN) under the rules of the World Trade Organisation (WTO). The UK and EU would be required to levy tariffs on one another's imports. The tariffs the EU would levy are already in application with existing third countries. In contrast, the UK's no-deal MFN tariff schedule on imports from third countries has only recently become clear following an announcement by the UK Government in March 2019.

Given the value of Ireland's exports to the UK, the nature of the UK's MFN tariffs in the event of a no-deal Brexit is very important.

In a no-deal Brexit, there would be no transition period. From a trade perspective this would mean that overnight the UK and EU would be required to treat each other as Most Favoured Nations (MFN) under the rules of the World Trade Organisation (WTO).

The UK is a major net food importer, meaning that it does not produce enough food to feed its own population. The UK has substantial imports of, among other things, beef, pig meat, poultry meat, dairy products, fruit and vegetables. Much of the UK imports of these agri-food goods come from EU member states. A key difficulty for the UK of adopting the EU WTO MFN schedule as the model for its tariff schedule is that this would raise the tariff-paid import price of a range of agri-food commodities, and this in turn would result in higher consumer prices for food in the UK.

As a contrast, the UK could choose to set all of its WTO MFN tariffs to zero, but this would open UK farmers to competition from low-cost agri-food exporters around the world. This could prove quite damaging to profitability and production in the UK farm sector, likely increasing the UK's dependence on imports still further. In calibrating its newly independent trade policy position, the UK Government has been explicit that it is seeking to "… minimise costs to business and consumers, while protecting vulnerable industries".

UK WTO MFN tariff schedule

In setting its WTO MFN tariffs for agri-food commodities, the strategy adopted by the UK Government was pragmatic, striking a balance between protecting the incomes of UK farmers and limiting the impact of a no-deal Brexit on UK food price inflation.

For sectors where the UK is not internationally competitive, but where it has a significant export capacity (e.g., sheep meat) the UK selected the highest tariffs (equal to existing EU MFN tariff levels). For sectors where the UK is less internationally competitive, but where it does not have a significant export capacity (beef and poultry), the UK chose moderate tariffs with some access to the UK market at zero tariffs offered by way of tariff-rate quotas (TRQs). Finally, for sectors where the UK is either more internationally competitive, or not a significant producer and/or exporter, tariffs were set at either relatively low (dairy, pig meat) or zero levels (cereals).

The *ad valorem* equivalents of the announced UK WTO MFN tariff schedule in the event of a no-deal Brexit, calculated using data at the tariff line level on UK imports in 2018, are shown in **Figure 1**.

Implications for Irish trade with the UK

From an Irish perspective, the UK's no-deal tariff schedule, while inferior to a comprehensive free trade agreement between the EU and UK (or no Brexit at all), is still preferable to an outcome where the UK adopts a schedule of tariffs equivalent to the EU's WTO MFN tariff schedule. However, the proposed UK no-deal tariff schedule would still impede Irish exports to the UK.

The no-deal UK tariff schedule is comparatively benign for dairy products, but remains prohibitively high for lamb. For beef, the over-quota tariffs are high enough to make full tariff-paid exports of beef from Ireland unattractive in price terms on the UK market. While the UK schedule includes a system of TRQs at zero tariff, these TRQs are smaller than existing volumes of beef imports into the UK. In addition, these TRQs would be available on a first come, first served, basis to a range of exporters globally. While Irish beef dominates current UK beef imports, Australia, Brazil, Canada, the US and Argentina could profitably export beef to the UK at lower prices than would be feasible for Irish exporters. Overall, the no-deal UK tariff schedule would have the largest implications for the Irish beef sector, which would lose its preferential (high price) access to the UK beef market. The UK currently accounts for over half of all Irish beef exports. Therefore, the negative consequences for the Irish beef sector would be considerable. A substantial reduction in the farm gate price of Irish beef would be inevitable, until such time that alternative markets could be secured offering prices close to those previously available from exports to the UK.

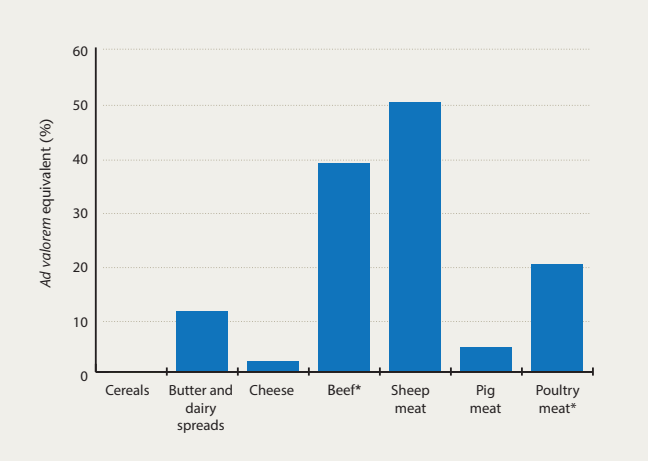

FIGURE 1: UK tariff schedule expressed in ad valorem *equivalent. (Source: authors' estimates based on announced temporary UK no-deal tariff schedule.)*

** Beef and poultry tariffs are those due on imports outside of the announced UK* erga omnes *TRQ.*

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JULY

July 3 (8.30am-5.00pm) *Teagasc Moorepark, Fermoy, Co. Cork*

MOOREPARK 2019 – IRISH DAIRYING – GROWING SUSTAINABLY

The theme of this year's Teagasc National Dairy Open Day event is 'Growing Sustainably'. The continuing expansion of the Irish dairy industry provides opportunities to increase the profitability of family farms, while also further developing climate smart dairy farming systems. Future expansion will require close alignment of national agricultural and environmental targets, with a particular focus on carbon emissions, water and air quality, and biodiversity. Moorepark '19 will highlight the various technologies and practices available to underpin future farm and sector profitability and sustainability.

Twitter: #Moorepark19
https://www.teagasc.ie/news--events
Contact: margie.egan@teagasc.ie

AUGUST

August 26-29 *Teagasc Moorepark, Fermoy, Co. Cork, and University College Cork*

EUROPEAN CONFERENCE ON PRECISION LIVESTOCK FARMING

The ECPLF brings together the worldwide specialists in precision livestock farming. It will provide a forum to exchange knowledge and experience through an open discussion and to support progress in precision livestock farming. The conference will incorporate: an industry forum; networking event; farmers' workshop; business models seminar; and, specific parallel conference sessions. Scientists and industry participants from several sectors – pharma, nutrition, technology, ICT, etc. – are expected to attend. This event is being hosted by Teagasc Moorepark.

https://www.ecplf2019.com/
Contact: bernadette.obrien@teagasc.ie

SEPTEMBER

September 2-3 *Teagasc Food Research Centre, Ashtown*

INTERNATIONAL STAKEHOLDER WORKSHOP ON BEST PRACTICE FOR THE CONTROL OF HUMAN PATHOGENIC MICROORGANISMS IN PLANT PRODUCTION SYSTEMS

This workshop, bringing together researchers, regulators and growers, will be hosted by the HUPlant COST action (CA16110), which is focused on examining the impact of plant microbiomes on human health. This workshop will examine critical control points in agricultural practices to ensure product safety, with a particular focus on interventions used across Europe, the regulatory landscape and undertaking risk analysis. A specific horticulture industry-targeted event will be held on the second day to disseminate the workshop outputs.

Contact: fiona.brennan@teagasc.ie or kaye.burgess@teagasc.ie

September 27 *Cork City (multiple venues)*

CORK DISCOVERS – A WORLD OF RESEARCH

This is a series of free and exciting interactive events for all ages. Come and join us to explore topics ranging from archaeology to zoology, and learn how research impacts on your daily life. Cork Discovers is funded by the European Union's Horizon 2020 programme as part of European Researcher's Night. This initiative celebrates researchers and the valuable contributions that they make to our society, with over 100 researchers participating in events in the UCC campus and other venues in Cork City last year. This year's event promises to be even more exciting!

http://corkdiscovers.org/
Contact: kim.reilly@teagasc.ie

NOVEMBER

November 5-7 *Clayton Whites Hotel, Wexford*

CATCHMENT SCIENCE 2019

This international conference focuses on achieving quality water in diverse and productive agricultural landscapes under a changing climate. The themes are: soil analysis and nutrient management; drivers, controls and time lags – meeting the expectations; options for management approaches in reducing nutrient loss risk; long-term in-situ monitoring and modelling of water quality; impacts of multiple stressors on aquatic ecology; decision support tools; integrated management, stakeholder engagement and catchment economics; knowledge transfer; and, water governance and policy implementation. The event includes a poster session, gala dinner and field visits.

https://www.teagasc.ie/news--events
Contact: pererik.mellander@teagasc.ie

November 10-17 *Locations nationwide*

FESTIVAL OF FARMING AND FOOD – SFI SCIENCE WEEK AT TEAGASC

This festival is a celebration of the science underpinning sustainable agriculture and food production in a series of events aimed at a broad audience ranging from primary school students up to open events for the general public. Attendees will learn about a wide variety of topics and how they apply to their everyday lives including sustainability of animal and plant production, healthy soils and biodiversity, the development of rural areas, food for health, food product development and improvement, and food safety. There will plenty of opportunities to participate in hands-on experiments and demonstrations.

http://www.sfi.ie/engagement/science-week/
Contact: catriona.boyle@teagasc.ie

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