TResearch

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Empowering farmers through marketing models

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Understanding the history of a North American species

SHEEP EMISSIONS
Calculating the environmental impact of farming

A piece of the Action

Teagasc has launched its Climate Action Strategy 2022-2030, including new measures to reduce emissions

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teagasc
Agriculture and Food Development Authority

Welcome

The Teagasc Climate Action Strategy 2022-2030 – 'Supporting Farmers for Climate Action' – was launched in December by the Minister for Agriculture, Food and the Marine, Charlie McConalogue, TD.

The strategy is based on three pillars: the Signpost Advisory Programme; a Sustainability Digital Platform; and a virtual National Centre for Agri-Food Climate Research and Innovation. Pat Dillon, Teagasc's Director of Research, explains how the strategy is focused on reducing greenhouse gas (GHG) emissions from agriculture in an interview on pp10-12.

Ireland is the largest net exporter of sheep meat within the European Union. However, as with all food production systems, sheep systems can have negative environmental effects, including (GHG) emissions. In an article on pp28-30, Jonathan Herron and colleagues describe their research using life cycle assessment to calculate the environmental performance of sheep systems in Ireland and to determine the effect of recommended practices.

In our *Look Ahead* column on p34, Declan Bolton looks at the potential of waste materials as natural fertilisers. Climate change, the energy crisis and the drive for agricultural sustainability have moved anaerobic digestion centre stage in this area. Declan explores the critical steps of anaerobic digestion, pasteurisation and storage in ensuring a safe end-product.

You will notice in this issue that we have included icons alongside articles where there is a clear link to the urgent actions in our Climate Action Strategy. We will continue to do this in subsequent issues. These actions are: Reduce Nitrogen Emissions, Reduce Methane Emissions, Increase Carbon Capture, Enhance Biodiversity, Increase Diversification, Enhance Adaptation, Circular Food System, and Supporting Policy.

Catriona Boyle
Editor, *TResearch* magazine, Teagasc

Sheol an tAire Talmhaíochta, Bia agus Mara, Charlie McConalogue, TD, Straitéis Gníomhaithe ar son na hAeráide de chuid 2022-2030 – 'Ag Tacú le Feirmeoirí do Ghníomhú ar son na hAeráide'.

Tá an straitéis bunaithe ar thrí cholún: an Clár Comhairleach Comharthaí; Ardán Digiteach Inbhuanaitheachta; agus Lárionad Náisiúnta fíorúil um Thaighde agus Nuálaíocht Aeráide Agraibhia. In agallamh ar leathanaigh 10-12, míníonn Pat Dillon, Stiúrthóir Taighde Teagasc, an chaoi a bhfuil an straitéis dírithe ar astaíochtaí gás ceaptha teasa (GHG) ón talmhaíocht a laghdú.

Is í Éire an t-onnmhaireoir glan is mó de chaoireoil san Aontas Eorpach. Mar sin féin, amhail gach córas táirgthe bia, is féidir le córais chaoirigh tionchar diúltach a bheith acu ar an gcomhshaol, lena n-áirítear astaíochtaí (GHG). In alt ar lch 28-30, déanann Jonathan Herron agus a chomhghleacaithe cur síos ar a gcuid taighde ag baint úsáide as measúnú saolré chun feidhmíocht comhshaoil na gcóras caoraigh in Éirinn a ríomh agus chun éifeacht na gcleachtas molta a chinneadh.

Inár gcolún Look Ahead ar lch 34, breathnaíonn Declan Bolton ar chumas ábhar dramhaíola mar leasacháin nádúrtha. Tá an díleá anaeróbach i lár an aonaigh sa réimse seo mar gheall ar an athrú aeráide, an ghéarchéim fuinnimh agus an feachtas ar son na hinbhuanaitheachta talmhaíochta. Scrúdaíonn Declan na céimeanna ríthábhachtacha a bhaineann le díleá anaeróbach, paistéaradh agus stóráil chun táirge deiridh sábháilte a áirithiú.

Tabharfaidh tú faoi deara san eagrán seo go bhfuil deilbhíní curtha san áireamh againn in éineacht le hailt ina bhfuil nasc soiléir leis na gníomhartha práinneacha sa straitéis um ghníomhú ar son na haeráide. Leanfaimid den mhéid sin a dhéanamh in eagrán ina dhiaidh sin. Is iad seo a leanas na gníomhartha: Astaíochtaí Nítrigine a Laghdú, Astaíochtaí Meatáin a Laghdú, Gabháil Carbóin a Mhéadú, Bithéagsúlacht a Fheabhsú, Éagsúlú a Mhéadú, Oiriúnú a Fheabhsú, Córas Ciorclach Bia, agus Beartas Tacaíochta.

Catriona Boyle
Eagarthóir, iris *TResearch*, Teagasc

TResearch is an official science publication of Teagasc. It aims to disseminate the results of the organisation's research to a broad audience. The opinions expressed in the magazine are, however, those of the authors and cannot be construed as reflecting Teagasc's views. The Editor reserves the right to edit all copy submitted to the publication.

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Contents

A sweeter way to treat equine parasites

The winners of the Teagasc Special Award at the BT Young Scientist and Technology Exhibition 2023 recently visited the equine facilities at Teagasc Kildalton College, Co Kilkenny.

Transition year students Aine Shortall and Kate Whyte from Moate Community School, County Westmeath, visited the college along with their teacher Irene O'Sullivan. Both students are keen horse riders. Indeed, Aine competes for Ireland in show jumping.

Their project, "A sweeter way to treat equine parasites", looked at creating a solution to anthelmintic resistance in horses. They trialled different herbs to reduce populations of parasites such as lungworm, redworm and liver fluke in horses. They created a nutritious horse treat containing common herbs – slippery elm, fennel, thyme and mint – to act as a natural equine worm treatment.

The students fed the horses a treat each day for five days and measured the faecal egg count over a two-week period. They found that the combined treat, including all four herbs but with a greater quantity of mint, was the most effective treatment, with a decrease of 92% in the faecal egg count.

Teagasc staff (from left): Rosemary Gaffney, Catriona Boyle and Tim Ashmore welcome Aine Shortall and Kate Whyte to Kildalton College

The students said that, as horse owners, they were motivated to find a chemical-free alternative for treating equine parasites. They were advised by their teachers Irene O'Sullivan and Mairead Cusack. Orla Keane, a Research Officer at Teagasc Grange, advised the students on the methodology.

The three pillars of the Teagasc Climate Action Strategy

Teagasc is increasing its resources devoted to climate-related research and knowledge transfer to support farmers and the industry in responding to the challenge of climate change. The strategy is built around three pillars:

1 Signpost Advisory Programme

A targeted programme will support climate and sustainability actions on farms. It will provide enhanced advisory and training support to farmers.

10,000 Target number of participating farmers by end of 2023.

2 Sustainability Digital Platform

A digital platform will support whole farm sustainability assessments. It will allow each farmer and their advisor to understand their current emissions. Real-time data analysis will help plan and prioritise actions to reduce emissions and enhance removals. This work is being carried out in collaboration with ICBF and Bord Bia.

3 Virtual Climate Centre

A virtual National Centre for Agri-Food Climate Research and Innovation will help deploy almost-ready and early-stage technologies. It will provide scientific and technological solutions to lead the sector towards climate-neutrality by 2050.

24 Number of new staff who will join the virtual centre.

▶▶▶ *Read more about Teagasc's Climate Action Strategy in our interview with Director of Research Pat Dillon on page 10.*

Photograph: Dylan Vaughan Photography

Trails and Tales for Science Week

Frances McHugh, Teagasc Forestry Advisor, is pictured (centre) with a group at the Trails and Tales event at Woodstock Gardens and Arboretum, Inistioge, Co. Kilkenny, as part of Teagasc's Festival of Farming and Food during Science Week. Also in the picture are attendees Terry Platt from Killeshin, Co. Carlow; Siobhan McGee from Rathnure, Co. Wexford; Rachel Keirse, Crop Science Department, Teagasc; and Denis Lahiff, Curraghamore, Co. Kilkenny.

Frances took the group on a looped walk of the forest, explaining all about the benefits of forestry, from carbon sequestration to biodiversity, not to mention the benefits to our wellbeing. Over 20,000 people attended Teagasc's Science Week events in November, both online and in-person.

Climate Action Strategy launch

The Teagasc Climate Action Strategy 2022-2030 – 'Supporting Farmers for Climate Action' – launched in December by the Minister for Agriculture, Food and the Marine, Charlie McConalogue, TD.

Pictured with Minister for Agriculture, Food and the Marine Charlie McConalogue TD (second from left) and Director of Teagasc Frank O'Mara (far right) are Teagasc climate scientists (from left) James Rambaud, Rachael Murphy, Giulia Bondi, Dominika Krol and Sinead Waters

Speaking at an event at the Teagasc campus in Ashtown, Dublin, Charlie said: "The key to the agriculture sector meeting its climate ambitions is innovative science-based research. This is the ace up our sleeve and I know that the new Climate Action Strategy by Teagasc will be a key component of what we need to do over the next decade."

Teagasc Director Frank O' Mara adds: "Our ambition is to deliver a world-leading Climate Advisory Service for farmers and an accelerated research programme to address emissions reduction and carbon offsetting. We are mobilising collective resources of Teagasc, ICBF and Bord Bia to build a unique Sustainability Digital Platform. We are doing this from a strong base, building on existing strong platforms: the Signpost Programme, state-of-the-art facilities, and committed and talented staff."

News in brief

Engage@Teagasc

Teagasc Technology Transfer Office had a busy year in 2022 in facilitating the commercialisation of Teagasc intellectual property, having negotiated five licences with four Irish companies. These include **patented plant protein and microencapsulation technologies** licensed to two Irish SMEs, with ambitious plans, in the Food for Health and Smart and Sustainable Food Production and Processing areas. Impact from licensing can be significant, including job creation, new or enhanced products and services to market and added revenues. With Teagasc having over 30 active licences, and contributing to over 25 new product and service launches in the past 10 years, this illustrates the key role the **Engage@Teagasc** team plays in driving impact from Teagasc research.

Upcycled Food Foundation

Kamaljit Moirangthem (pictured), a Teagasc Research Leader fellow, is one of eight recipients worldwide of **the Kerry Upcycled Food Foundation Fellowship for 2023**. The foundation is dedicated to preventing food loss and waste across the entire supply chain. Kamaljit, a Marie Skłodowska Curie Fellow at Teagasc and the University of Helsinki in Finland, says: "Upcycling means repurposing side streams or waste that was previously not destined for human consumption. I am looking at the role of bioprocessing in upcycled food development – in other words, using microbes or microbe-derived aids, such as enzymes, to make upcycled food or ingredients. I'm also looking into increasing consumer acceptance of upcycled foods."

Teagasc success in Horizon Europe

Horizon Europe is the EU's key funding programme for research and innovation, with a budget of €95.5 billion. It tackles climate change, helps to achieve the UN's Sustainable Development Goals and boosts the EU's competitiveness and growth. Since the launch of the Horizon Europe programme in 2021, Teagasc is placed **7th across Europe** in terms of total funding secured in Cluster 6, which focuses on **food, bioeconomy, natural resources, agriculture and environment**.

Celebrating women's role in sustainability

The 2023 **International Day of Women and Girls in Science** celebrated their role in the Sustainable Development Goals of the UN. **Dominika Krol**, a Senior Research Officer in Teagasc, measures greenhouse gases from various agricultural activities and looks at ways to reduce their impacts by adopting mitigation practices and technologies.

Screening seaweeds for positive health benefits

The SeaHealth Project aims to provide new insight and technical know-how for the seaweed processing sector to develop high-value functional prebiotic ingredients from raw biomass.

Teagasc's SeaHealth project is screening seaweed extracts that have the potential to positively impact the human gut microbiome if ingested.

The gut microbiome is the community of bacteria, fungi and viruses that inhabit our gut. An imbalance in the beneficial versus harmful bacteria ratio (dysbiosis) of the gut microbiome may affect our health.

Gut bacteria influence metabolism, absorption of nutrients, our immune status and our nervous and neuroendocrine systems. The positive impacts of a healthy gut microbiome are the result of antibacterial activity of good gut bacteria such as *Bifidobacteria* and *Lactobacilli* against pathogens in the gut and the production of health-beneficial short chain fatty acids (SCFA) that signal the immune and neuroendocrine systems. This interaction has been called "the gut microbiome-immune system-brain axis".

Bacteria require specific nutrients to grow. They consume components such as dietary fibres and polyphenols, which humans cannot digest in the stomach. Fibre is composed of complex polysaccharides that occur naturally in plants, while polyphenols are produced to protect plants from environmental stresses and herbivores. These components are considered 'prebiotics' due to their growth-enhancing benefits towards good health-promoting bacteria in the gut.

In the SeaHealth project, polysaccharides and polyphenols from Irish and Australian seaweeds were extracted and fed to an *in vitro* gut created using human intestinal bacteria. The abundance of bacteria and the amount of beneficial SCFA that the bacteria produced was assessed after 24 hours, following the addition of whole, dried seaweed, polysaccharide or polyphenol extracts.

Evaluating the potential of seaweeds

New knowledge concerning the use of seaweeds including *Ecklonia radiata*, *Phyllospora comosa* and *Ulva ohnoi* has been generated and disseminated to industry and the scientific community. The prebiotic potential of seaweeds and seaweed extracts was evaluated using 16s RNA gene sequencing of human stool-derived bacterial populations following *in vitro* fermentation and analysis of the

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$20.78 billion

Estimated value of the global prebiotic ingredients market by 2030 – based on a predicted annual growth rate of 13.25% from a 2021 value of $6.78 million.

Source: Prebiotic Ingredients Market – Global Industry Analysis, Size, Share, Growth, Trends, Regional Outlook, and Forecast 2022–2030

health-beneficial SCFA produced by bacteria.
The study found that the abundance of beneficial bacteria was significantly increased by the inclusion of whole dried seaweed, polysaccharide and polyphenol extracts compared with the known prebiotics inulin and *epigallocatechin gallate* (EGCG – a polyphenol).

The beneficial bacteria that were enhanced included *Lactobacilli*, *Bifidobacteria* and *Streptococcus*, which produce lactic acid; and *Eubacteriaceae*, *Akkermansia*, *Butyricicoccus*, *Blautia*, *Roseburia*, *Barnesiella* and *Faecalibacteria*, which produce SCFA. Compared with the inulin and EGCG-fermented samples, the production of SCFA (particularly butyric, acetic and propionic acids) by bacteria was up to three times greater in samples fermented with whole dried seaweed, polysaccharide or polyphenol extracts.

Prebiotic ingredients: market drivers

There are four main factors driving accelerated growth in the global prebiotic ingredients market:

1. **Increased incorporation of prebiotics into foods and beverages.**
2. **Consumer awareness of the importance of gut and immune health.**
3. **Demand for reduction in calories, sugar and fat in foods using fibre-replacement.**
4. **Growing demand for prebiotic ingredients for the dairy product industry.**

Broad benefits to industry

Potential functional food ingredients were identified in farmed biomass and other currently underused sustainable seaweed resources to minimise any environmental impacts. This could help generate growth, access new markets and increase value-added output for the seaweed processing and ingredients sectors.

Raw, unprocessed seaweed biomass is a low-value commodity. New knowledge generated by the research project – such as optimised procedures for isolation, and the extraction and stabilisation of high-value algal polyphenolic and polysaccharide functional ingredients – will be shared. The development of new health-beneficial products could provide novel prebiotic ingredients that are nutritionally balanced and may benefit the gut.

Project outputs will provide technical know-how and understanding of consumer attitudes, supporting further use and development of functional food ingredients from raw seaweed biomass. This could potentially lead to further research in this area.

Seaweeds have unique polysaccharides and polyphenols that differ from those in terrestrial plants and are a sustainable source of potentially prebiotic compounds to ameliorate dysbiosis of the gut. Prebiotic effects found *in vitro* have the potential to exert similar effects *in vivo* if consumed as a food ingredient. Clinical trials would be required, however, to evaluate bioaccessibility, bioavailability and safety. T

FUNDING

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If the CAP fits...

Pillar I Common Agricultural Policy (CAP) support represents a significant proportion of income for certain cohorts of the farming population. Researchers at Teagasc set out to examine what the changes to how the support is distributed mean.

Research undertaken by economists in Teagasc suggests that the changes to the Pillar I Common Agricultural Policy (CAP) will not significantly impact the number of farms that are economically viable.

Fiona Thorne, one of the authors of the report, says: "The change in incomes that result from the Pillar I CAP reform are, in general, small relative to the scale of the income changes required to shift farms from being economically unviable to economically viable."

As part of the CAP reform process, the new CAP strategic plan for Ireland came into operation from 1 January 2023. New research by Teagasc examines the impact of the reforms to the implementation of Pillar I under the new agreed CAP strategic plan for Ireland, 2023-2027. The analysis did not consider the changes to Pillar II under the recently approved CAP Strategic Plan.

Key changes of new Strategic Plan

Pillar I CAP support in Ireland's National Strategic Plan includes:

- Capping: further continuation of capping of payments
- BISS: a ring-fenced percentage of the direct payments ceiling to be paid as a Basic Income Support for Sustainability (BISS)
- Eco Schemes: an allocation of 25% of the direct payments ceiling to eco-schemes reflects the strong environmental ambition of the CAP programme
- CRISS: redistribution of funds by front-loading direct payments through the Complementary Redistributive Income Support for Sustainability (CRISS) scheme
- Internal convergence: continuing convergence of payment entitlement values – a process to redistribute and flatten the value of payment entitlements in Ireland

Cattle other farms, as well as dairy and tillage farms, will, on average, be worse off than before the Pillar 1 CAP reform

BearFotos/Shutterstock.com

- National Reserve: a minimum ring-fenced sum for generational renewal (3%).

In general, specialist dairy farms tend to have a lower reliance on Pillar I direct payment support as a source of Family Farm Income (FFI) compared with other farm systems, while specialist cattle systems – such as cattle rearing and cattle other – tend to be the most reliant on direct income support.

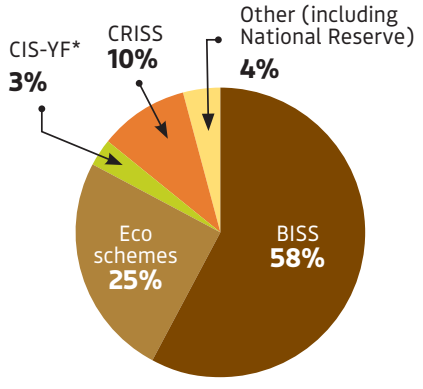
"Based on data from 2019," says Fiona, "other things being equal, a 10% reduction in the combined Basic Payment Support scheme and Greening payments [schemes from the Pillar I support from CAP 2015-2019] received by specialist dairy farms would reduce FFI on these farms by 7%. However, a 10% reduction in these supports provided to cattle farms would lead to an FFI reduction of approximately 25%."

Conducting the research

Teagasc National Farm Survey (NFS) data from 2019 was the main source of information used in this analysis. The NFS surveyed a sample of 878 farms representing a farm population of 92,190 farms. 'Small' farms – those with a standard farm output of less than €8,000 – are excluded from the annual NFS sampling frame.

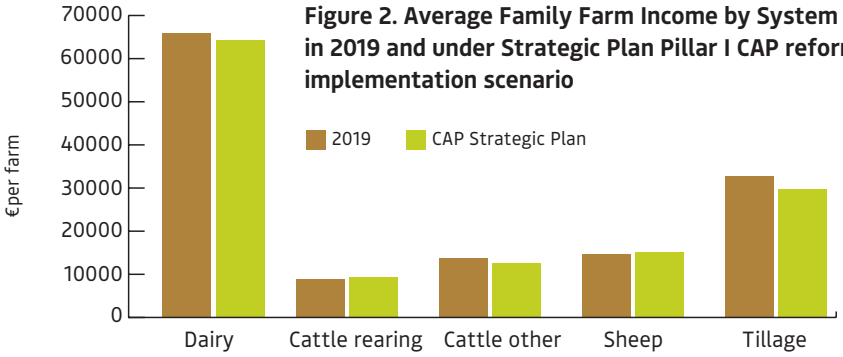
The Teagasc analysis was based on the CAP Strategic Plan 2023-2027 submitted by Ireland and agreed by the European Commission in 2022. The analysis assumes an average BISS of €156.18 per ha, with all farmers receiving at least 85% of this level by 2027; an eco-scheme payment of €77 per ha; and a CRISS payment of €43 on the first 30 hectares of each holding. The mandatory inclusion of a convergence strategy for Pillar I payments in this CAP reform implies reduced levels of income support for some cohorts of the population, while providing additional levels of income support to other cohorts.

Figure 1. A summary of the decomposition of the Pillar I CAP budget for Ireland.



*Complementary Income Support for Young Farmers

Figure 2. Average Family Farm Income by System in 2019 and under Strategic Plan Pillar I CAP reform implementation scenario



Distributional impact of the reform

The results (Figure 2) show that the simulated effect on FFI at a farm level as a result of the Pillar I CAP reform depends on an individual farm's starting position in terms of its Basic Payment Scheme level and Greening payment per hectare (both components of the CAP scheme 2015-2019), and the importance of Pillar I direct income subsidies in the farm's overall FFI.

For the average farmer, the change in income that would be experienced as a result of the CAP reform of Pillar I payments is relatively small. Figure shows that, on average, dairy, tillage and cattle other farms will be worse off than they were before the reform was implemented, with sheep and cattle rearing farms gaining on average as a result of the implementation of the reform.

Only a small proportion of specialist tillage farms gain in terms of direct income support receipts or FFI under the CAP reform analysed. However, in contrast to the implications of the scenario for dairy farm incomes, a considerable proportion of specialist tillage farms would experience a rededication in income effects of at least 10% under the CAP reform scenario.

Unlike dairy and tillage farms, the implications for specialist sheep farms are more mixed when the proportion of sheep farms represented by those in income gain and loss categories is examined. Just over half of specialist sheep farms represented by the Teagasc NFS would gain in terms of a change in FFI when the reform, as analysed in the Teagasc report, is fully implemented.

The pattern of income gains and losses is different for the two specialist cattle systems. The proportion of farms losing in terms of changes in FFI under the reform is greater for cattle other (mainly finishers) farms than it is for cattle rearing farms, where a slightly greater proportion of the farms represented by the NFS see gains in income due to the CAP reform.

A greater number of 'small' farms gain in income rather than lose under the CAP reform relative to income in the status quo.

Fiona concludes: "Focusing on the proportion of output produced by gaining and losing farms, the value of output produced by farms gaining under the reform was less than the value of output produced by the farms experiencing losses in income as a result of the CAP reform.

"The implication is that farmers who benefit from the changes to Pillar I payments tend to produce less agricultural output." T

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Reduce Nitrogen Emissions

Reduce Methane Emissions

Steering farmers on a sustainable journey

Since 1850, there has been an increase of 1.1˚C in global temperatures. This rise is being propelled by increases in greenhouse gases (GHG) in the atmosphere, mainly produced when we burn fossil fuels and through industrial processes, together with emissions associated with land use. Irish agriculture is the largest contributor of Ireland's GHG emissions. This reflects the economic and historical importance of agriculture, relative to other industries in the Irish economy.

Here, Pat Dillon, Director of Research at Teagasc, explains how Teagasc's Climate Action Strategy 2022-2030 is focused on reducing GHG emissions from agriculture.

Our climate is changing rapidly and is transforming our world. As such, the Irish government has set targets to reduce greenhouse gas (GHG) emissions from agriculture by 25% by 2030 and strive for climate neutrality by 2050. Teagasc has developed a roadmap to support these aims, without reducing the competitiveness of the Irish agri-food sector.

Approximately one-third of the technologies required to reduce GHG emissions by 25% are available currently. To make sure these are implemented at farm level, a strong advisory and education programme is key – and this has been prioritised in our new Climate Action Strategy, announced in December 2022.

Pat Dillon is Director of Research at Teagasc, with research interests including sustainability, economics, farm systems, animal breeding and grassland management. Prior to his current role, Pat was Head of the Animal and Grassland Programme. He has initiated and led major research initiatives, contributing significantly to industry knowledge through more than 100 scientific publications, with almost 70 as senior author.

Here, Pat outlines Teagasc's new Climate Action Strategy, reflecting on how research and innovation must be made accessible to all farmers.

Pat, can you explain Teagasc's new Climate Action Strategy?

There are three pillars to the Strategy. First, we are implementing a new Signpost Advisory Programme, which will be available to all farmers to support farms' climate and sustainability actions. We aim to reach 50,000 farmers by 2030.

This is important to the implementation of technologies that are already available and the new ones that will become available. The Signpost Advisory Programme will be the advocate for these technologies.

As part of this programme, we have a network of 120 demonstration farms that include all the main farming enterprises where we will carry out detailed measurements. These will be used to translate research into practice and will be used for open days, workshops and training.

The second pillar is a new Sustainability Digital Platform, which will be developed in collaboration with Irish Cattle Breeding Federation (ICBF) and The Irish Food Board (Bord Bia). This will be a new online tool aimed at facilitating a whole-farm sustainability assessment. It will allow farmers to 'count' their farm carbon emissions and removals.

Thirdly, we are establishing a National Centre for Agri-food Climate Research and Innovation. This will be a virtual centre to accelerate and coordinate climate research and innovation, while providing leadership nationally and internationally. Teagasc recognises the importance of collaborating with other universities and entities and we want to strengthen these connections.

How does this new strategy differ from your focus on climate-related action up until now?

Until recently, most of the climate-related research was the responsibility of the Teagasc Crops, Land Use and Environmental

Director of Research Pat Dillon says new and existing technologies will be key to achieving emissions reduction targets

> **Teagasc is significantly increasing its resources devoted to climate related research and knowledge transfer.**

Programme. Now it's part of all Teagasc research and advisory programmes. Our overarching strategic goal in the Statement of Strategy is to 'make sustainability front and centre of all Teagasc activities'.

Teagasc has allocated 24 new research staff to work specifically on climate-related research. In addition, all new core funded research projects are required to have a climate-related aspect.

Where are you investing to support the strategy?

Teagasc is significantly increasing its resources devoted to climate-related research and knowledge transfer. We are investing €12.7 million in upgrading labs and facilities in our environment research centre in Johnstown Castle. This is because we recognise that research is the backbone of everything we do to combat climate change.

There is a lot of uncertainty about the quantities of carbon being sequestered by our mineral soils and emitted by our peat soils. Currently, we are using default values from a Europe-based model. The National Agricultural Soil Carbon Observatory has been established to reduce this uncertainty.

A total of 30 flux towers have been established all around the country, covering all soil types and farming systems to measure actual carbon sequestration and emissions. In a European context, Ireland will have the biggest consignment of flux towers in relation to the size of the country, providing the real data we need.

Between Teagasc, ICBF and University College Dublin, we have purchased 20 GreenFeed machines. These machines were developed in the United States and measures the amount of enteric methane a ruminant animal emits on a daily basis. The machines take a sample of breath – 90% to 95% of enteric methane is expelled from the rumen in the breath. These GreenFeed will be used to verify the quantity of enteric methane that is being emitted daily from Irish grazing ruminants and develop feeding strategies to reduce emissions.

What is Teagasc's roadmap to reduce GHG emissions from agriculture by 25%?

Teagasc envisages three phases in the transition to reducing GHG emissions by 25% by 2030.

Phase 1 involves the adoption of technologies currently available, such as protected urea and low emission slurry spreading, increased soil fertility and replacing chemical nitrogen with biological fixed legume nitrogen.

Replacing calcium ammonium nitrate with protected urea for the chemical nitrogen used will reduce nitrate oxide emissions by approximately 70%. All our research shows that protected urea is equally efficient in terms of biological actions.

Phase 2 will see the roll-out of almost-ready technologies. These include reduced age at slaughter, new low-emitting nitrogen fertilisers and the use of feed additives in indoor feeding systems. ▶

Marie Kearney, Teagasc Advisor, Cork East, discusses low emission slurry spreaders with Signpost farmer Jack Kearney; (below) a GreenFeed machine measures methane from a cow's breath

Photography: Mark Moore

Finally, Phase 3 involves technologies that require significant further research, such as the use of feed additives at pasture, breeding lower-methane-emitting animals, and use of slurry additives.

Can you expand on Teagasc's research into lower-carbon systems?

Diversification into organic farming, biomethane production and afforestation has the potential to develop lower-carbon systems.

Currently, approximately 3% of useable land area in Ireland is devoted to organic farming; this is low when compared to an average of 9.1% for the rest of the EU. The Climate Action Plan 2023 has a target to increase this to 10% or 450,000 ha by 2030. This will help to reduce chemical nitrogen and pesticide use resulting in associated environmental benefits. Teagasc is supporting this programme at both an advisory level – with eight new advisers – and research level (through a new research programme).

Biomethane is a renewable gas made from biological feedstocks that includes animal manures, grass and grass silage. The Climate Action Plan 2023 has committed to deliver 5.7 TWh of indigenously produced methane, based on agricultural feedstocks by 2030. This will provide a diversification opportunity for farmers and a land-use alternative to livestock.

25%

Target set by the Irish government for the reduction of greenhouse gas emissions from agriculture in Ireland by 2030.

Forestry and related products play an important role in mitigating climate change. Increased financial incentives have been introduced to increase the annual afforestation rates from approximately 2,000 ha per annum currently to 8,000 per annum from 2023 onwards.

Lastly, we have been developing a circular food system, which reduces food waste, promoting sustainable packaging and the role of plant proteins.

What are your specific goals or targets for the strategy – short-term and long-term?

Mainly, we aim to reduce GHG emissions by 5.75 Mt of CO_2 equivalent by 2030 and support the industry to become climate neutral by 2050.

What are the next steps for Teagasc?

The next immediate action for us will be establishing the Signpost Advisory Programme and, by the end of 2023, having 10,000 farmers registered.

We aim to launch version 1 of the Sustainability Digital Platform in 2023 using data from the 120 demonstration Signpost farms. In 2023 also, the National Centre for Agri-Food Climate Research and Innovation will be established, while publishing the new GHG Marginal Abatement Cost Curve will be one of its first significant outputs.

Are there challenges – current or anticipated – related to climate change or sustainability that you think will be an increasingly hot topic for the farming sector?

Reducing chemical nitrogen use by between 27–30% by 2030 as outlined in both the Food Vision Dairy and Beef 2030 reports; this will be a huge challenge. Getting grassland farmers to switch from relying on chemical nitrogen fertiliser to managing white clover pastures to naturally fix nitrogen will require significant changes in grassland management. It's important that its adoption is successful.

Another increasingly hot topic will be reducing the age of slaughter of prime beef cattle by between three to four months. This will require significant changes at farm level in terms of grassland and silage management and using appropriate genetics.

Are there any changes or technologies you think will be helpful in reaching the sustainability goals?

Feed additives/inhibitors will become key. There is one existing feed additive that reduces enteric methane emissions by up to 30% with ruminant animals. The only thing is that this is for indoor feeding systems; we need an additive that will perform equally well with grazing livestock. Currently, we don't have such an additive. There is a lot of research being carried out currently in this area. We are collaborating with both national and international partners in this area of research, especially in New Zealand, as they also have a pasture-based system.

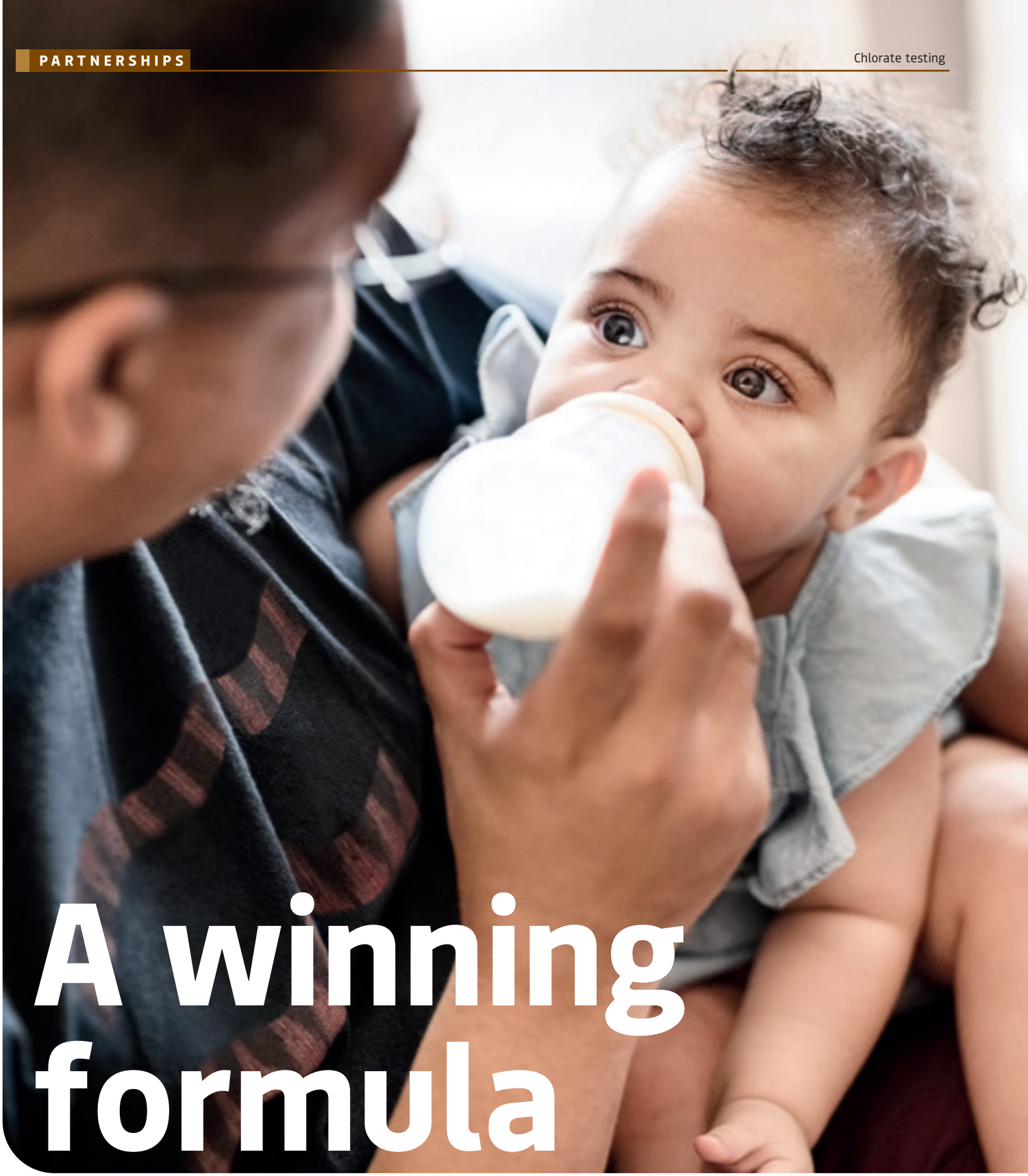
The development of a feed additive or inhibitor that would significantly reduce enteric methane emissions under grazing conditions would be very helpful to agriculture reaching its reduction targets.

As a result of the strategy, what can farmers and the industry expect to see differently from Teagasc in terms of your research and service offering?

Support is at the heart of our new Climate Action Strategy. In fact, Teagasc is proud to offer the best climate advisory service for farmers in the world.

While we mobilise the collective resources of Teagasc, ICBF and Bord Bia to build a unique Sustainability Digital Platform, as well as our Signpost Advisory Programme, the industry can benefit from an accelerated research programme to address emissions reduction.

The new National Centre will help us improve collaboration nationally and internationally, which is key to our mission. T



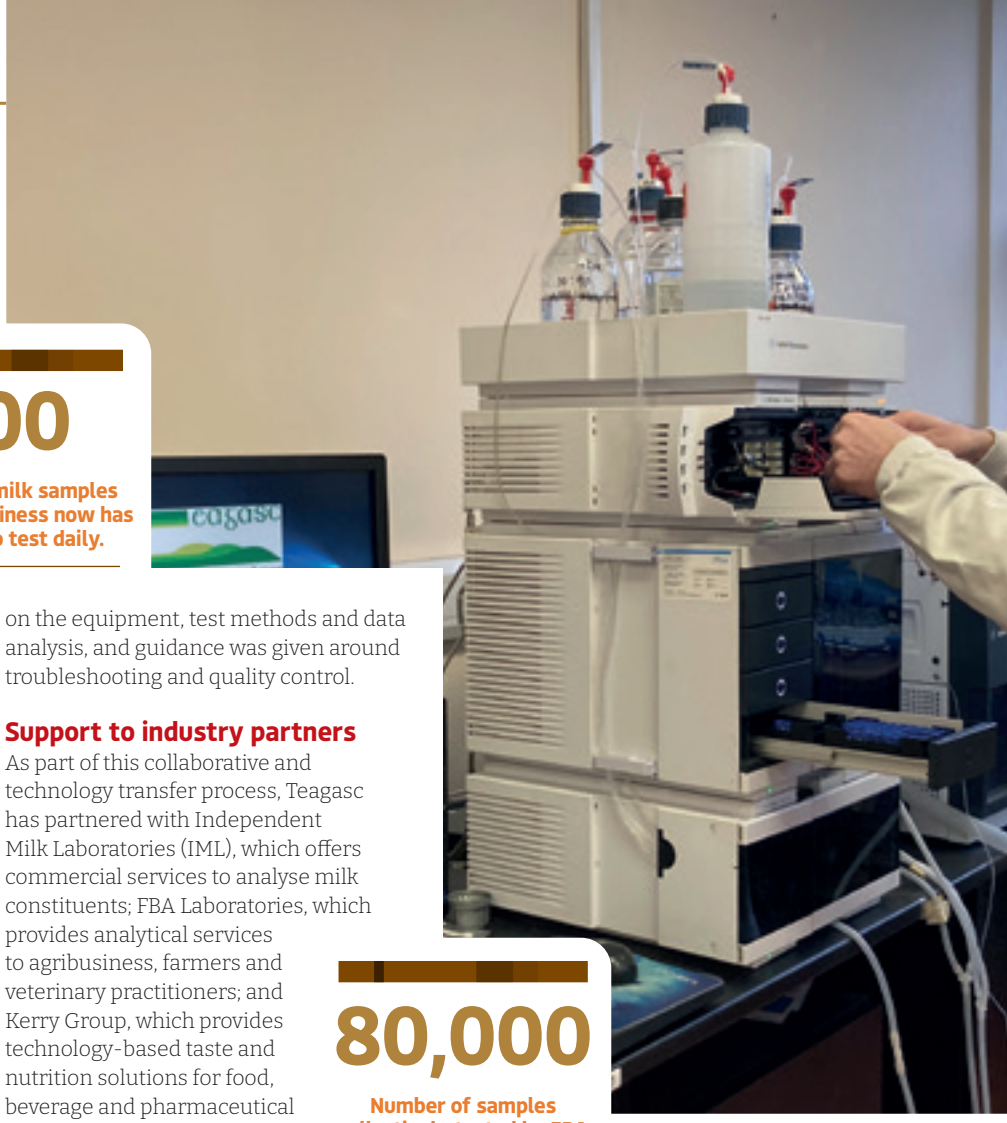
A winning formula

The infant formula market is of huge importance to the Irish dairy industry. Maintaining our excellent reputation is key to the economy, and this includes responding to increased chlorate residue levels in milk, which has health concerns for infants. Teagasc has been key to establishing world-class testing facilities in Ireland.

International markets have set high standards for milk and dairy product quality, including stringent guidelines for residue concentrations. The presence of chlorate and perchlorate residues arising from chlorine-based disinfectants – used to clean milking machines and bulk tanks in processing plants – has attracted increasing attention in recent years.

These residues are competitive inhibitors of iodine uptake in the thyroid, and present a potential health concern for vulnerable groups, particularly infants in their consumption of infant formula. Given how lucrative this market is for Irish milk producers – annual exports are €1 billion from six ▶

NickyLloyd /iStockphoto.com



200

Number of milk samples Kerry Agribusiness now has capacity to test daily.

global infant formula manufacturers based here – any concerns with respect to chlorate residues in milk or dairy ingredients could be detrimental to Ireland's exports and dairy industry reputation.

In 2016, following urgent requests from the Irish dairy industry to develop a rapid, sensitive chlorates test for milk and dairy ingredients, a novel proprietary high-throughput test was validated at Teagasc's Dublin laboratories, receiving ISO17025 certification a year later.

Technology transfer insight

Up to June 2020, Teagasc was the sole Irish provider of accredited chlorate testing for milk samples. Exponential growth in demand provided an opportunity for Teagasc to transfer its technology and related expertise to commercial labs (for service provision to clients) and milk processors (for internal testing).

The reputation of Teagasc's analytical test development, accredited residue testing and personnel expertise, as well as support through its Technology Transfer Office (TTO), was key to ensuring successful industry engagement, allowing companies to promptly establish dedicated laboratories and begin testing with confidence.

Following the licensing of Teagasc proprietary standard operating procedures (SOPs) to the companies, Teagasc supported the establishment of the industry partners' new analytical laboratories – including operation, design, layout, services, equipment and staffing – through consultancy. Bespoke training was provided on the equipment, test methods and data analysis, and guidance was given around troubleshooting and quality control.

Support to industry partners

As part of this collaborative and technology transfer process, Teagasc has partnered with Independent Milk Laboratories (IML), which offers commercial services to analyse milk constituents; FBA Laboratories, which provides analytical services to agribusiness, farmers and veterinary practitioners; and Kerry Group, which provides technology-based taste and nutrition solutions for food, beverage and pharmaceutical markets, including infant formula.

Since 2020, the licensing of know-how and provision of critical consultancy in relation to specialist testing for chlorate residues has had significant impact for all partners and the wider Irish dairy industry.

Teagasc's TTO has supported researchers in the capture of proprietary SOPs as novel IP and in licensing negotiations and subsequent consultancy. It has continued to help the researchers and partner companies to determine outcomes and impacts.

Siobhan Jordan, Head of Technology Transfer and Commercialisation within the TTO, reflects: "The project has enhanced the reputation of Teagasc at home and abroad in being able to support industry and in particular that wider agrifood sector for Ireland.

"Equally, there is further engagement happening between the researchers and industry. We hope that will lead to new research collaborations and other sources of revenue both for Teagasc and the industry partners."

This combined licensing-consultancy route to commercialisation sets an excellent precedent to develop specialised analytical tests for Irish food processors, which once proven can then be successfully commercialised by industry.

80,000

Number of samples collectively tested by FBA and IML – exceeding €1 million revenue to industry.

Significant impact

In addition to job creation and significant increases in revenues and profits, investment into new chromatography infrastructure at the two commercial labs has given FBA Labs and IML scope to expand further through new methods and testing capabilities in this field.

The increased availability of sensitive testing in Ireland has the potential to speed up the response from local dairy processors and their milk suppliers to chlorate residue concerns; this includes prompt identification of chlorate-contaminated milk before further processing, reducing

Teagasc's collaboration with partners to test chlorate residue levels won the Industry Engagement Award at the 2022 Knowledge Transfer Ireland Impact Awards

Teagasc Principal Research Officer Martin Danaher at work in the laboratory

8

Number of jobs created across the three industry partners as a result of additional testing capabilities.

waste and more costly contamination of infant formula. Managing such concerns confidently and quickly is key to maintaining Irish dairy's excellent reputation, especially in the infant formula space, while ensuring safety for consumers – and Teagasc consultancy has been paramount in achieving this.

Such significant impact was celebrated at the 2022 Knowledge Transfer Ireland Impact Awards, where this success story won the Industry Engagement Award. This was a significant achievement given the prestige of these awards and stiff competition from two leading Irish universities also shortlisted.

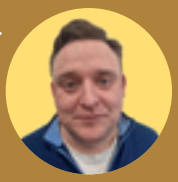
Miriam Walsh, Head of Intellectual Property within the TTO, reflects: "Winning this prestigious award was a huge bonus for all concerned, and all the more valued given its impact was benchmarked against impressive success stories from university peers in Ireland and involving an international judging panel." T

'Teagasc consultancy has exceeded our expectations'

All three industry partners have emphasised the value of Teagasc's expertise and reputation.

Conor Butler, General Manager, FBA Laboratories

Teagasc's consultancy was critical to the establishment of our new laboratory. Martin [Danaher, Teagasc Food Research Centre]'s knowledge, enthusiasm and attention to detail was an enormous help to us in setting up the method – and we greatly value his words of wisdom and advice. Without such support, it would have been much more difficult for us to set up, and any delays during this period would, I believe, have prevented us expanding in the chromatography area. This work has been of real value in allowing us into new areas and to make new contacts that will further develop our laboratory.



Robert Burns, General Manager, Independent Milk Laboratory

The research from Teagasc has exceeded our expectations in terms of what it can deliver for us and the industry. We were able to set up the laboratory and offer a test commercially within a couple of months, which we just wouldn't have been able to do if we'd had to go it alone. Development of the commercial test method took years within Teagasc, so if industry had to start from scratch, we wouldn't have been able to implement that as quickly, and we wouldn't have met the deadline for the legislation.

James O Connell, General Manager, Kerry Agribusiness, a division of Kerry Group

Partnering with Teagasc allowed us to develop the technical capacity of our laboratory in the area of liquid chromatography and mass spectroscopy (LC-MS) in a focused and assured manner. The partnership removed any trial and error phase in the selection of equipment and consumables and, most importantly, the selection and application of test methods. The training and technical support provided by Teagasc, and Martin Danaher in particular, was second to none. Kerry Agribusiness Laboratory management and staff received a rounded education on LC-MS and chlorate analysis and are moving towards further developing our LC-MS analytical capability with Teagasc's guidance.

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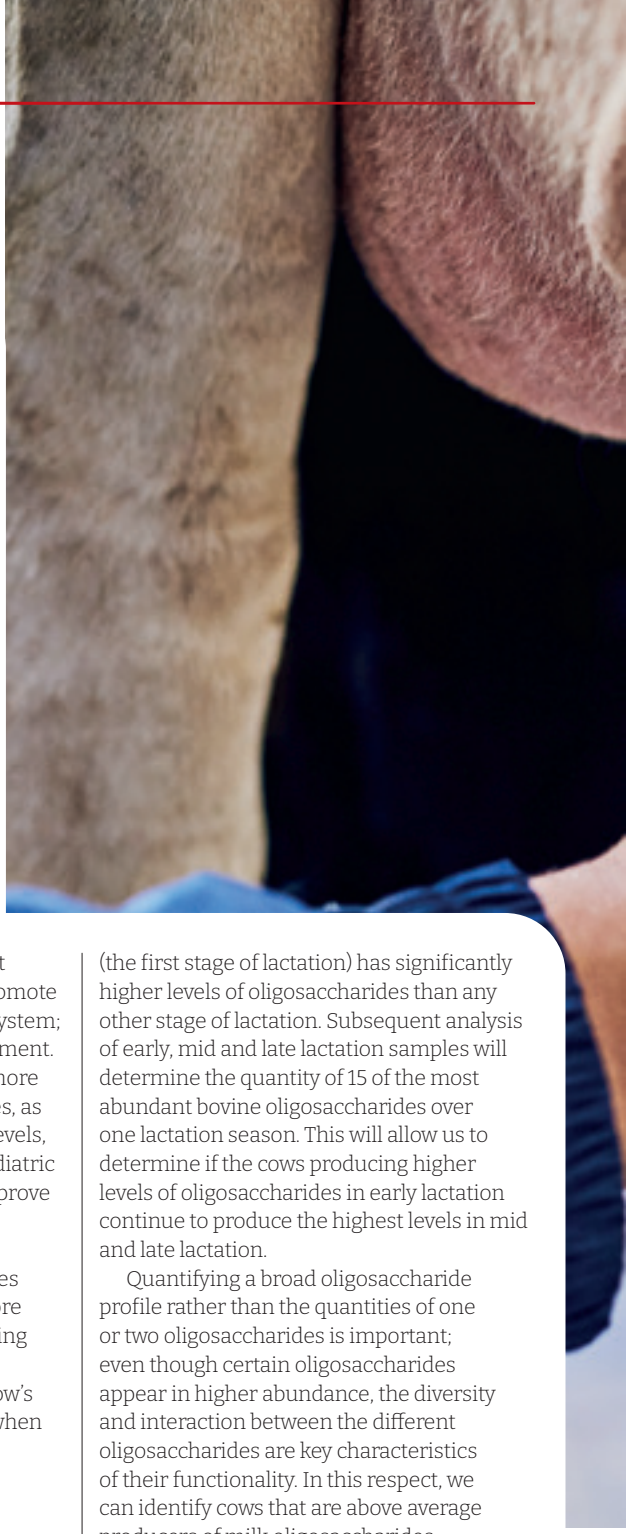


It's all go with OLIGO

Teagasc's understanding of the science behind the presence of oligosaccharides in milk can lead to improved dairy products.

Breast milk is considered the gold standard of infant nutrition because it contains the essential nutrients to support early infant growth, development and immunity. The sugars in human milk, known as oligosaccharides, play a key role in releasing these beneficial functions. A new project is exploring ways to improve the yield and composition of cow's milk oligosaccharides, which will ultimately support the sustainable large-scale extraction of oligosaccharides from bovine milk and its whey derivatives.

This project – known as OPTI-OLIGO – also aims to better characterise the enzymes produced in the mammary gland that lead to the synthesis of oligosaccharides in cow's milk.

By investigating the factors influencing the presence of oligosaccharides in cow's milk, Teagasc hopes to optimise their production in milk. When the study is completed, a plan can be developed for targeted breeding strategies to produce milk with a higher composition of oligosaccharides.

Such knowledge, along with the availability of an oligosaccharide pipeline in the form of "super-producing" cows, will have many applications. These include providing dairy processors with an opportunity for functional product commercialisation and higher value-added dairy products for human consumption.

Why oligosaccharides?

It has been argued that breast milk oligosaccharides selectively stimulate the growth of beneficial microbiota; protect against bacterial and viral infection; promote the maturation of the infant immune system; and improve brain growth and development. It is thought that the incorporation of more and more distinct milk oligosaccharides, as they become available at commercial levels, will revolutionise the landscape of paediatric nutrition and offer opportunities to improve infant health worldwide.

However, currently only a limited number of human milk oligosaccharides are added to infant formula despite more than 200 distinct oligosaccharides having been identified in breast milk. Similar oligosaccharides have been found in cow's milk – albeit at a lower concentration when compared to breast milk.

Assessing factors of influence

Factors that are thought to influence oligosaccharide expression in cows include seasonality, genetics, feeding, age and parity (the number of times an animal has given birth), stage of lactation and disease state.

To assess the effect of these factors on the oligosaccharide milk profile, a large sample set of milk was collected over the course of lactation.

Samples were collected from 199 cows during early, mid and late lactation. The cows included those from the Teagasc Moorepark Next Generation Herd: Holstein-Friesian cows categorised as Elite (top 1% nationally) based on the Irish total merit index, the EBI (n=95); Holstein-Friesian cows representative of the national average, based on EBI (n=60); and high-EBI pedigree Jersey cows (n=44). Samples from all three genotypes were balanced for parity.

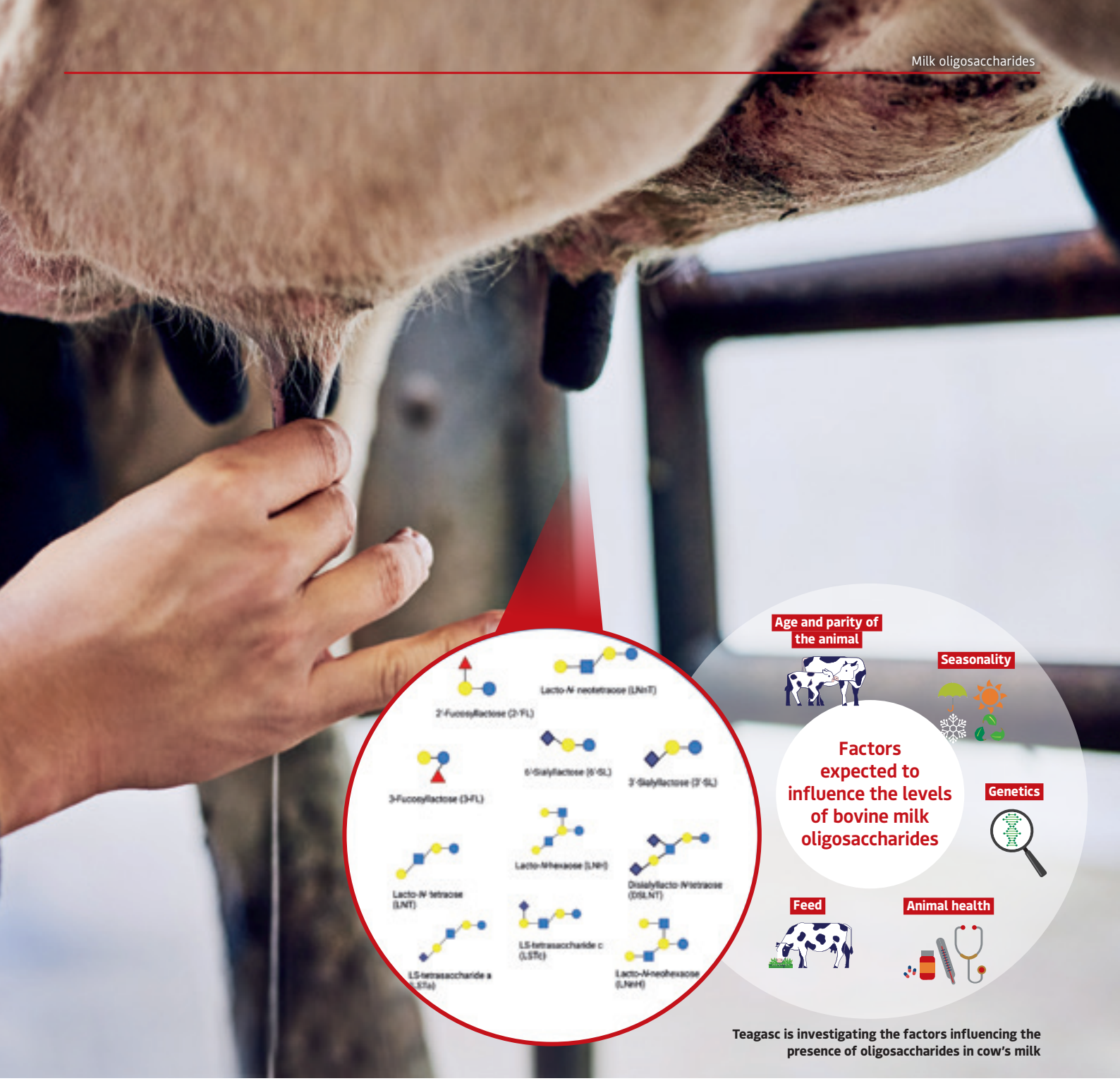
It is already known that bovine colostrum (the first stage of lactation) has significantly higher levels of oligosaccharides than any other stage of lactation. Subsequent analysis of early, mid and late lactation samples will determine the quantity of 15 of the most abundant bovine oligosaccharides over one lactation season. This will allow us to determine if the cows producing higher levels of oligosaccharides in early lactation continue to produce the highest levels in mid and late lactation.

Quantifying a broad oligosaccharide profile rather than the quantities of one or two oligosaccharides is important; even though certain oligosaccharides appear in higher abundance, the diversity and interaction between the different oligosaccharides are key characteristics of their functionality. In this respect, we can identify cows that are above average producers of milk oligosaccharides.

Results that will inform production

To date, oligosaccharide levels in all early lactation samples and many of the mid lactation milk samples have been quantified. In the colostrum samples, Jersey cows were producing the highest levels of the three most abundant oligosaccharides. It was also noted that the elite Holstein Friesians produced more oligosaccharides than the national average Holstein Friesian cows. Interestingly, the majority of the top 10 oligosaccharide-producing cows were in their second parity.

The data generated here will indicate the effect of feed, age and parity on oligosaccharide production. This result will also guide a genome-wide association study (GWAS) investigating the genetic differences in the cows producing high levels of oligosaccharides ('superproducers') when



Teagasc is investigating the factors influencing the presence of oligosaccharides in cow's milk

compared to average and low oligosaccharide producing cows.

The GWAS will identify genetic differences both within and between the breeds. After this, proteomic analysis of the milk samples will profile the level of the various enzymes involved in the biosynthesis of oligosaccharides. This information will relate the genetic differences to enzyme and other protein expression and further expand our knowledge of the pathways leading to milk oligosaccharide production. T

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Shaped by snow and ice

As part of the GenESIS project, Teagasc is using genomic and phenotypic data to understand the nature of adaption and evolution in the North American Sitka spruce tree. This knowledge can then be implemented through the GenESIS research when breeding new and improved trees in Ireland.

It's no easy task for researchers based in Ireland to fully understand the genetics of a tree species that spans 3,000 kilometres of the Pacific North American coast. While *Picea sitchensis* (Sitka spruce) has many uses in Irish and European forestry, this coastal tree's native range spans from Alaska to California.

Luckily, in the 1960s, seed was collected from native North American forests and donated to Ireland as part of an International Union of Forest Research Organizations (IUFRO) project. Today, understanding the evolutionary history of this tree can uncover adaptions that directly lead to better forestry crops in Ireland.

Picea sitchensis occupies a diverse range of ecological niches. Eighty different provenances consisting of populations with about 40 individuals, each forming a mature stand, have grown in JFK Arboretum in New Ross, Co. Wexford, acting as a genetic resource. We extracted DNA from the cambial layer of the tree using a new high throughput DNA extraction system. Genomic libraries of the DNA of these samples were prepared and then sequenced, creating a huge amount of data for the research of conifers.

Tracing the evolutionary history of conifers

Susanne Barth, Teagasc Principal Research Officer for Plant Genetics, explains the findings from the team's data mining: "We discovered Sitka spruce was pushed onto islands and to the fringes of the range during the Pleistocene ice age 18,000 years ago, when glaciers spread throughout North America. These fringe refuges for Sitka allowed the mainland to recolonise once the ice sheets began to retreat.

"We see the earliest stages of recolonisation from the islands in Alaska and from Haida Gwaii in British Columbia, Canada. The latest recolonisation occurred around 15,000 years ago, when the ice sheet retreated from the southern ranges and allowed for the recolonisation of Washington and Oregon. The patterns of recolonisation has given Sitka a diverse mixture of ancestry, with modern Sitka being a combination of Alaskan Sitka, Southern Sitka, Haida Gwaii Sitka and some admixture with white spruce."

Recolonising leading to adaption

The initial collection of seed came from a large range of habitats. Some seed came from areas with an annual precipitation of up to 4,000mm, whereas some only had 620mm. Temperatures of the habitats ranged from –7.3°C to 17.4°C. These habitats had between four-and-a-half and 11 hours of sunlight per day.

Left: Rows of trees native to North America growing as a genetic resource in JFK Arboretum, Co. Wexford; each row represents one provenance

Peter Turner Photography/shutterstock.com

> Sitka spruce was pushed onto islands and to the fringes of the range during the Pleistocene ice age 18,000 years ago, where glaciers spread throughout North America.

This diversity in habitats directly leads to adaption in conifers, explains Susanne.

"Conifers are likely to adapt to their local environment slowly. In Sitka, we see a key divide in northern and southern ranges at the 50th latitude, along the US-Canadian border. The northern ranges have more adaptions that negatively affect height, whereas the southern populations have adaptions that positively affect height.

"However these decreases in height allow for increased tolerance to snowfall, with trees reducing their height to cope with the weight of the snow. Southern populations are more adapted to high solar radiation, reduced rainfall and more temperate climates."

Implications for Irish forestry

We have elucidated the colonisation history of Sitka spruce and discovered ranges where adaptions have occurred. Trees originating from Haida Gwaii have negative adaptions towards height. Trees from Haida Gwaii are commonly used in Ireland and the UK.

To maximise the growth of Sitka, trees from below the 50th latitude should be considered for use in Irish breeding programmes. We have identified adaptions to low water stress in the southern populations, which may unlock resilience to climate change if we incorporate the southern ranges into the breeding program. T

ACKNOWLEDGEMENTS

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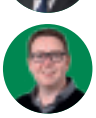


A resurgence of interest in Short Food Supply Chains (SFSCs) comes at a time when Europe is seeking to provide more sustainable and healthier diets for its population.

Short Food Supply Chains:

EU project gathers consumer insight

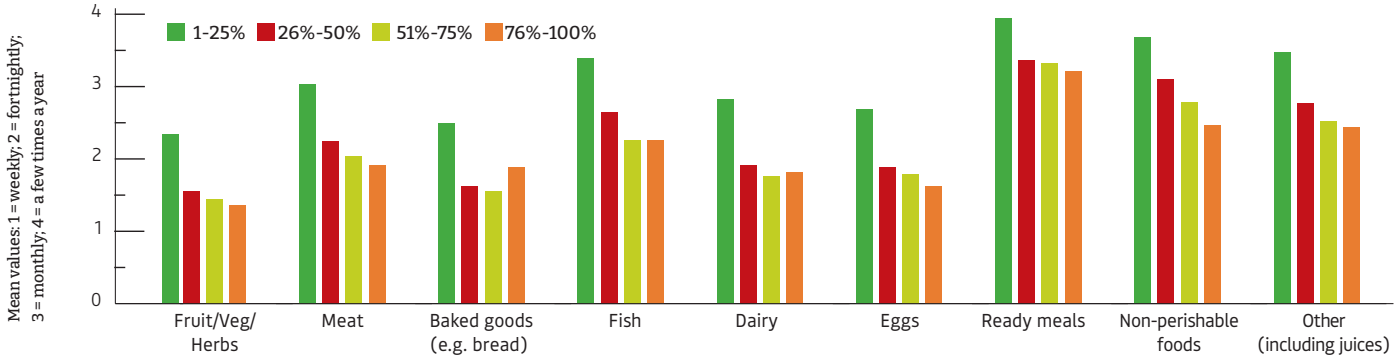
Driven in part by changes in consumer behaviour, Short Food Supply Chains (SFSCs) are going through something of a renaissance. From an EU perspective, SFSCs are an opportunity to reconnect producers and consumers, and to rebalance power in the supply chain.

For that reason, the European Commission funded a project called agroBRIDGES – of which Teagasc is a partner – that aims to empower farmers through new business and marketing models based on SFSCs.

An online consumer survey was conducted across 12 European countries in the summer of 2021. Respondents cited "quality attributes of the SFSC products (in terms of taste, freshness and healthiness)" as the major motivation for purchasing food from SFSCs. Other top motivations included food safety concerns, as well as support of local farmers, producers and the local economy. Access (i.e. a lack of local outlets that sell SFSC products) and affordability, however, remain leading concerns among consumers and hinder their ability to buy food from SFSCs.

More than 2,400 consumers from Denmark, Finland, France, Greece, Ireland,

Figure 1. What percentage of the food you buy in value terms in an average month is from SFSCs?



Hero Images /iStockphoto.com

Good practices that address consumer access

At The Irish Agropreneur Series, discussions focused on improving consumer access to SFSC products in Ireland.

Drawing on insights relating to consumer motivations and barriers, the session moderator, Jennifer Attard from MTU, explained that several good practices have been identified through the agroBRIDGES project, and these could be used to mitigate some of the problems highlighted by consumers, particularly access to SFSC products. Two of these are listed below.

Online ordering platform, Netherlands

Consumers make their orders via the Rechtstreex website and pick up their products in one of 70 pick-up points. Consumers can order two days per week and Rechtstreex runs logistics and distribution of the products. The online ordering platform started in 2013 and currently has 2,500 consumer orders per week.

According to Rechtstreex founder Maarten Bouten, the platform was set up to change the status quo concerning food systems, noting that food is very personal and it seemed strange that the system behind food was very industrial. "It makes sense to see where the food comes from and who makes it, and make that more transparent," he said.

Rechtstreex allows farmers to determine their own prices. Consequently, there are no price negotiations; rather, Rechtstreex simply facilitates the relationship between the farmer and consumer.

Mobile farmers market, Lithuania

Established in 2009, the Lithuanian mobile farmers market features many varieties of foods in terms of taste and quality, according to Mindaugas Maciulevičius, Director of the Agricultural Cooperative, Lietuviško ūkio kokybė.

Mindaugas notes that, depending on the season, up to 500 small and medium farmers and producers sell their produce directly to consumers.

Further information

Further examples of Good Practices collated under the agroBRIDGES project that address consumer barriers are available at *agrobridges.eu/interactive-catalogue-agrobridges*

Italy, Latvia, Lithuania, Netherlands, Poland, Spain and Turkey participated in the survey.

Further findings from the agroBRIDGES study reveal that, on a monthly basis, more than half of the respondents (51.3%) buy between 1% and 25% of their food from SFSCs, while fewer than one in ten (9.3%) buys more than 50% of their foods from SFSCs.

Fruit, veg and herbs top the list

In terms of the frequency of purchase, fruits, vegetables and herbs were bought by the majority of the respondents in the study on a weekly or fortnightly basis (64.1%), followed by baked goods, eggs and dairy.

Interestingly, fruit, vegetables, herbs, baked goods, dairy and eggs tended to be purchased weekly by consumers who bought more than 75% of their food from SFSCs, while those who bought less than 25% of their food from SFSCs tended to buy all products less frequently (see Figure 1).

At the recent Irish Agropreneur Series, hosted by Teagasc and fellow agroBRIDGES partner Munster Technological University, Teagasc Principal Research Officer Maeve Henchion explained the disparity in purchasing patterns, observing that issues relating to communication were also affecting consumers' ability to purchase foods from SFSCs.

"Consequently," Maeve adds, "producers place more emphasis on effectively communicating the benefits of SFSCs to consumers. Along with one-to-one interaction at the point-of-sale, communication initiatives could come in the form of product branding and leveraging of digital technology platforms, such as social media, to create awareness about available products and the benefits SFSCs offer as a whole." T

ACKNOWLEDGEMENTS

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It's in the genes

Teagasc's genetics team plays a crucial role in both the environmental and economic success of dairy, beef and sheep herds.

Photography: Fergal O'Gorman

Genetics is an essential field to the future of the farming industry in Ireland. With new environmental targets being set nationwide, predicting animal characteristics may prove instrumental.

All our research covers different areas of genetics and breeding, but the focus is on creating new tools for farmers to help them make improved breeding and on-farm decisions. It is important that all research carried out can offer a practical use for farmers as well as improve the sustainability of the agriculture industry.

A quantitative genetics research team always existed in Teagasc, staffed by globally renowned geneticists such as Paddy Cunningham and Seamus Hanrahan. The quantitative genetics team in Moorepark was established in 2003, led by one researcher and a small team of PhD students. Since then, the team has grown, providing essential knowledge to both Teagasc and the industry at large.

To find out more about their impressive work in genetics, we spoke to Research Officer Alan Twomey, Post-Doctoral Researcher Maria Frizzarin, and PhD students Cliona Ryan and Elia Dufosse.

Teagasc genetics team members (left to right) Cliona Ryan, Alan Twomey and Maria Frizzarin at Teagasc Moorepark, January 2023

Can you explain the history of the genetics team within Teagasc?

Alan: The team has grown since 2003, and is now staffed by four researchers, three post-doctorates and five PhD students; the team has trained 10 master's students, 33 PhD students and 17 post-doctorates.

Research grants from Department of Agriculture, Food and the Marine and Science Foundation Ireland play a key role in supporting the team's outputs. Teagasc, the Irish Cattle Breeding Federation (ICBF) and Sheep Ireland work in partnership to translate these outputs into outcomes and eventual impact.

What are your core objectives?

Alan: Our team is driven to improve the profitability and sustainability of dairy, beef and sheep herds. Team members regularly speak at events and industry meetings, and also write articles for media outlets to ensure our research has a real impact in the agriculture sector.

Cliona: Data is continually increasing, particularly DNA information, which is available for almost three million Irish cattle. A key objective of ours is to see how we can use the large database of genotype information to generate more tools to improve beef and dairy industries in Ireland.

Elia Dufosse from the genetics team collects a faecal sample to predict the intake of grass consumed by a cow, Teagasc Moorepark

How does your research achieve these objectives?

Cliona: Genomic selection improves cattle and sheep breeding using DNA information to predict an animal's potential performance. This allows for more accurate selection of animals with desirable traits, such as high milk or carcass merit, and can lead to faster genetic progress.

What are the key techniques and tools you use to achieve this work?

Maria: When data is not readily available on important traits, we need to measure these alternatively. In my work, I use a technique called mid-infrared spectroscopy. The spectrometer can analyse many milk samples in a short period of time and produces a spectrum for each milk sample analysed, which can be used as an indicator of the milk characteristics.

We have been working on predicting the change in body condition score, methane emissions and feed efficiency. Hopefully these equations will be available soon to predict these economically important traits.

Alan: We then use these traits, as either actual or predictor measurements to estimate the genetic contribution through ▶

PhD student Cliona Ryan and Research Officer Alan Twomey collect a hair sample from a calf

quantitative genetic approaches. We estimate breeding values for these individual traits using information on their own performance as well as performance of their ancestors.

Cliona: Molecular techniques are another key part of our work. Adding DNA information allows us to improve breeding value estimates. For example, full-sibs have the same pedigree information, but the actual DNA helps us predict the difference between these depending on individual markers.

60%

In Ireland, over 60% of the cows routinely have their milk spectra generated after the milk recording.

What specific projects are you currently working on?

Maria: My work involves predicting new traits of interest and then using the newly developed equations to quantify the traits of interest at a national level. If methane can be accurately predicted using the milk spectrum, it could be used to select more environmentally friendly cows.

Elia: One of our primary goals is to reduce the environmental footprint of the cattle systems. I'm currently using feed intake, milk and meat output data to estimate the nitrogen efficiency of individual cows to potentially breed for nitrogen-efficient cows, which excrete less nitrogen.

Cliona: I'm looking at the effect that myostatin, a gene that controls muscle growth, has on calving difficulty and carcass traits. This is important for improving selection strategies and designing optimal mating plans. Some mutations on the myostatin gene are associated with improved carcass merit, but also increased calving difficulty, while others are only associated with improved carcass merit and have no impact on calving difficulty.

> **Our research will improve the economic and environmental sustainability of Irish farms, but also it provides tools that makes decisions easier for farmers.**

Can you explain why these objectives and your work is important in the context of Irish farming and agriculture?

Maria: This research will improve the economic and environmental sustainability of Irish farms, but also it provides tools that make decisions easier for farmers. All the traits predicted using the mid-infrared spectrum can be used for genetic selection,

Continued contributions: the genetics team share their personal achievements

Maria: I am good at bonding the members of the team together. I like to organise dinners outside working hours, and coordinate team-bonding activities.

Elia: Our team works hard to produce reliable results and make them available to the end user, making the research useful and applicable in the field.

Cliona: The achievement that stands out the most to me is when everyone from the genetics team went to Rotterdam together to present at the World Congress on Genetics Applied to Livestock Production last summer.

Alan: I am proud to be a member of a team that has contributed so much to the industry and I hope that I will continue this great success in the future.

which provides information on the most efficient or most environmentally friendly cows.

Elia: Restrictions on dairy production are put in place to limit nitrogen emissions. Considering the importance of this industry in Ireland, my work could give producers tools to breed environmentally friendly animals, reducing their nitrogen impact.

Have there been any changes made in Irish farming that are a result of your work or recommendations?

Alan: We developed a carbon index for animals, which has been included in our dairy breeding objectives, improving the genetic progress in reducing the carbon footprint of cattle.

Recent research also showed that the genetic trend in carcass traits in animals coming from the dairy herd was declining, so work was done to address this. This was the context to improve the beef sub-index of the dairy breeding objectives, which now includes a trait for age at slaughter which is a world first.

How does Teagasc benefit from your work?

Alan: The team contributes to Teagasc by researching and providing knowledge to the Irish agri-food sector. Also, the team contains key skills, such as being able to handle large datasets, so we can help other departments in Teagasc.

We have also built important relationships with people across Ireland and around the world, which is important for the development of future research projects and to access new data and skill sets.

What trends coming up will affect the team's work?

Alan: Methane and other environmental traits will be the key traits going forward. Our team and others will all need to put our shoulder to the wheel to achieve the national target of a 25% reduction in greenhouse gas emissions by 2030.

Reducing age at slaughter of cattle will be important and the team will be working on developing this further by coming up with tools to predict or identify when animals are suitable for slaughter.

What are the principles you work to that you think make your team successful?

Maria: We all work in the same workspace, so when someone has difficulties, they can easily ask for help. There is open communication, and though we are working on a wide range of areas, the core methodology is similar and everyone in the team is willing to help others. We meet every month to discuss problems within the team and also to talk and to discuss other topics outside our specific work. In the past few months, we have been participating in short teambuilding activities. T

Getting to know

Norina Coppinger

Norina Coppinger graduated with a BA in European Studies, Social Research & Spanish from the University of Limerick in 1993, and is now a Campus Administrator at Teagasc Athenry. Here, Norina talks about her career highlights and her love for travelling.

What is your role at Teagasc?

As Campus Administrator, I lead, manage and co-ordinate an effective administrative, central services and facilities support function across Mellows Campus.

Why have you chosen to build your career at Teagasc?

In 2006 I returned to Galway seeking a job that gave me a work-life balance with little commute, because at that time the drive to the city was over an hour from my house. Today, I enjoy a 15-minute drive to work in Athenry. I am so glad and feel lucky that Teagasc gave me the opportunity to work here.

What is your favourite thing about your job?

Each day I look forward to going to work – what more could one ask for? I absolutely love my job, although it is an extremely busy role. No two days are ever the same, as there is lots of variety.

My favourite aspect is my positive colleagues who smile and make the workplace such a favourable environment.

What is a moment from your career that you have treasured?

The complete success of the Farming and Country Life 1916-2016 event was the main highlight of my career, with 50,000 visiting Athenry over two days – a phenomenal showcase of Mellows Campus.

What are your other interests outside of your job?

Walking and climbing are two of my biggest hobbies. Each year I travel with a local walking group to trek part of the 780-kilometre French Way of the Spanish Camino. We have over 500 kilometres left to complete.

I recently completed the Inca Trail to Machu Picchu in Peru, one of the most amazing and yet challenging trips I have ever completed.

I love travelling, but, in saying that, Ireland is the most beautiful country for exploring. T

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Benefits of once-a-day milking

Work carried out at Teagasc Moorepark suggests that once-a-day milking does not impact Cheddar cheese composition and can improve cheese yield and some sensory and nutritional attributes.

Until recently, limited work had been done to explore how dairy products are affected by milking frequency, but research by Teagasc into once-a-day milking (OAD) has shown no negative impact on cheese quality.

OAD results in lower overall milk volume and milk solids yield than twice-a-day milking (TAD), yet interest in OAD systems is still growing. Approximately 200 dairy farms are operating OAD milking on a full-time basis in Ireland, and this number is expected to increase.

The main reasons for choosing OAD milking include farm layout, reduced milking time, improved farmer wellbeing, opportunities for other business activities and a reduction in labour costs. However, not all milk is equal and it is crucial to consider how changes in milking frequency might affect the nutritional and technical properties of milk as well as the quality of subsequent dairy products.

Researchers at Teagasc Moorepark investigated the effects of OAD milk on some of the major compositional, functional and sensory attributes of full-fat Cheddar cheese. Cheese is an economically important dairy product, with around one-third of all milk in Ireland segregated for cheese production. Any significant changes in cheese-associated altered milk composition linked to reduced milking frequency could have far-reaching implications for the dairy industry.

Methodology for ongoing study

The Animal and Grassland Research and Innovation Centre at Moorepark provided milk from OAD and TAD dairy herds. Raw bulk OAD milk had an average fat, protein and lactose content of 5.4%, 4.46% and 4.41%, whereas raw bulk TAD milk had 5.26%, 4.17% and 4.49% respectively.

OAD and TAD milks were converted to Cheddar cheese at Teagasc Food Research Centre in Moorepark. The milk was

Richard Page (left) and Prabin Lamichhane cut milk gel as part of the process of making Cheddar cheese at Teagasc Food Research Centre, Moorepark

standardised to a protein-to-fat ratio of 0.95, and pasteurised at 72°C for 15 seconds prior to cheese making.

Cheddar cheese from OAD and TAD milks were matured over 180 days, with compositional and functional analysis performed throughout the ripening period. While the analysis of these cheeses is ongoing, interesting insights into the effect of reduced milking frequency are already emerging.

Using OAD milk for cheese-making did not affect overall cheese composition. This is reassurance for cheese producers, should the practice of OAD milking garner wider uptake by farmers. Furthermore, cheese yield was higher from OAD milk than TAD per unit volume of standardised milk, linked to higher innate milk solids. From an efficiency perspective, this provides the added benefit of maximising cheese manufacturing capacity, using existing processing infrastructure.

Sensory characteristics: texture and colour

It is possible to mimic consumer sensory and mouthfeel expectations through laboratory experiments based on texture profile analysis. The texture properties (hardness, cohesiveness, springiness, resilience) of OAD and TAD cheeses were not statistically different in this study. Based on these results, consumers should not detect significant differences in the mouthfeel of cheese made with OAD milk.

Colour is an important quality characteristic of food products, influencing consumer preference, taste perception and purchasing choice. Typically more highly coloured cheese is preferred by consumers, with OAD cheese more visually yellow, or richer in colour compared to TAD cheese.

Nutrition: β-carotene

β-carotene is an important provitamin – a plant pigment that the body converts to Vitamin A. In testing, it was found that β-carotene content in OAD cheese samples was significantly higher than TAD cheese. On average, OAD cheese contained 31% more β-carotene than TAD cheese.

Vitamin A (including β-carotene) is recognised for its numerous health benefits, which include supporting iron metabolism; maintaining of normal skin and mucous membranes; maintaining normal vision; and maintaining of the normal function of the immune system. This indicates that OAD milking could potentially offer additional nutritional benefits to cheese consumers, and this could be a unique opportunity for Irish cheese producers to differentiate their cheese internationally. However, more research is required to confirm this possibility. T

True colours

The colour differences of cheese samples can be quantified objectively by colorimetric analysis.

The L* a* b* colour space is commonly used to identify colour differences in food samples:

- **L* indicates lightness**
- **a* represents green to red**
- **b* represents blue to yellow.**

Colorimetric analysis showed that OAD cheese samples were significantly yellower (higher b* value) than TAD cheese samples, linked to higher beta-carotene levels. Among the factors influencing consumer purchasing decisions, colour intensity of cheese remains a key attribute as it is linked to a perception of higher fat content and a richer product with improved sensory quality. More recently, the yellow colour of Irish dairy products has also been associated by consumers with grass-fed milk, and the associated benefits of that system from animal, nutritional and environmental perspective.

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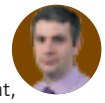

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Reduce Nitrogen Emissions

Reduce Methane Emissions

Experts at Teagasc have been using life cycle assessment, an internationally recognised methodology, to calculate the environmental performance of average sheep systems in Ireland and to determine the effect of recommended practices.

Counting sheep emissions

Ireland is the largest net exporter of sheep meat within the European Union, with the sheep sector generating approximately €300 million every year. However, as with all food production systems, sheep systems can have negative environmental effects. The most pressing in the current climate is greenhouse gas (GHG) emissions, for which the EU and Ireland have set ambitious reduction targets.

Consumers are also becoming increasingly concerned and conscious of how the food they eat – particularly livestock products – is produced. Their purchasing decisions are influenced by environmental concerns, animal welfare and human health.

To reduce the negative environmental impact of livestock production systems while meeting global demand and consumer expectations, the sheep sector must identify and adopt practices that are environmentally sustainable, economically viable and socially acceptable.

Emissions from the sheep sector

In the most recently reported year, 2020, Ireland emitted 58,766 kilotonnes (kt) CO_2 equivalent, of which more than one-third came from the agricultural sector. The digestion of feed and the release of methane (enteric fermentation) dominates agricultural emissions, contributing 61.4%.

The remaining GHG emissions are predominantly associated with manure and synthetic fertiliser application. Sheep directly emitted 1,065kt CO_2 equivalent through the digestion of feed and manure management. The sheep sector is also indirectly responsible for GHG emissions from the use of synthetic fertilisers, fuel and electricity, which are recorded separately.

To avoid the negative impacts of climate change, the European Union has committed to reduce GHG emissions to at least 55% below 1990 levels by 2030. To achieve this target, the Irish agricultural sector has been given a 2030 GHG reduction target of 25% compared with 2018 levels. For the agricultural sector to achieve this, adoption of recommended practices and the identification of new technologies are required at farm level.

Life cycle assessment modelling

Life cycle assessment (LCA) is an internationally recognised methodology that has been widely adopted in agriculture to calculate the environmental impact of a farming system and its products. Researchers in Teagasc have developed LCA models for sheep systems in Ireland. These models adopt a cradle-to-farm-gate boundary, meaning all GHG emissions up to

In 2020, sheep directly emitted more than 1,000kt CO_2 equivalent through the digestion of feed and manure management

the point at which the product (lambs, ewes or wool) leaves the farm are accounted for. On-farm emissions counted and emissions released during the production of farm inputs (i.e. fertilisers, electricity, concentrate feed) are recorded.

By applying this boundary, an LCA can identify the key GHG sources and management practices that have potential to reduce GHG emissions. To determine the GHG reduction potential of proposed management practices and emerging technologies, it is vital to first determine the performance of an average production system. This sets a baseline or starting point to which practices and technologies can be compared.

An LCA of a lowland production system was conducted. Data for flock performance and management practices were obtained from the Teagasc National Farm Survey (Table 1).

Measuring GHG reduction methods

GHG reduction practices and technologies are typically broken into two categories: improve efficiency; and adoption of low-emission technologies. The following GHG reduction practices were investigated:

1. Substituting nitrate fertiliser with protected urea (from 90% nitrate-based to 100% protected urea)
2. Incorporation of white clover into swards (reducing synthetic fertiliser requirement by 20%)
3. Reducing concentrate feeding (103kg per ewe to 50kg per ewe)
4. Increasing weaning rate (1.39 to 1.5)
5. Reducing lamb mortality rate (7.9% to 5%).

38%

Percentage of Ireland's CO_2 equivalent emissions in 2020 that came from the agricultural sector – most of which came from the digestion of feed and release of methane.

The GHG intensity of a typical lowland system was calculated as 10.8kg CO_2 equivalent/kg live weight, which is lower than the global average of 11.3.

Methane contributed two-thirds (66%) of total GHG emissions, predominantly sourced from the digestion of feed (enteric fermentation). Nitrous oxide from fertiliser application, managed manure and manure excreted during grazing contributed a further 19% of total GHG emissions. The remaining 15% of total GHG emissions were sourced from the production of concentrate feed, fertiliser and the consumption of fossil fuels (diesel).

Improving the efficiency of a system typically reduces GHG emissions per unit output. However, there are mixed effects when assessing total emissions. This is the case for improving mortality and weaning rate. Both measures reduced the GHG intensity – by 2.2% and 4.9% respectively – but total emissions remained unchanged. This was due to the greater number of animals in the system because more live lambs were weaned per ewe. As a result, reducing mortality and increasing weaning rate increased live weight sold by 3.0% and 7.4%, respectively. ▶

Table 1. Description and performance of an average lowland sheep system

	Lowland system
Ewes	**140**
Stocking rate (ewes/ha)	**7.8**
N fertiliser (kg N/ha)	**73**
Lambing period	**March**
Replacement rate (%)	**25**
Weaning rate (lambs/ewes)	**1.39**
Concentrate (kg/ewes)	**103**
Carcass output (kg/ha)	**237**

Conversely, when you look at fertiliser-related strategies, improving soil fertility and incorporating clover into swards reduced the quantity of N fertiliser needed to grow the same quantity of forage. As a result, both total GHG emissions and GHG emission intensity reduced by 2.0% and 2.4% while maintaining output.

Similarly, the adoption of low-emission technologies such as protected urea reduced total GHG emissions and GHG intensity by 5.0% and 2.4% respectively. Protected urea has significantly lower GHG emissions per kg N applied in comparison with nitrate-based fertilisers and also significantly lower ammonia emissions than straight urea.

Research Officer Jonathan Herron says: "The production and distribution of concentrate feed typically results in greater GHG emissions per kg than the same quantity of well-managed fresh grass. To meet energy requirements, livestock forage intake increases when concentrate feeding rate is reduced."

> **The Irish sheep sector is starting from a good position... we must be proactive in adopting GHG mitigation strategies.**

Consequently, when land area and yield is fixed, stocking rate and output is reduced. This resulted in the reduction of concentrate fed per ewe from 103kg to 50kg to reduce total GHG emissions and GHG intensity by 4.3% and 1.7% respectively.

Evidence of emissions reduction

The combination of reducing reliance on concentrate feed, the adoption of protected urea, the reduction in N fertiliser through the incorporation of white clover into swards, and the improvement in mortality and weaning rate reduced total farm GHG emissions by 9.7%. This reduced the GHG intensity of a lowland sheep system from a base of 10.8kg CO_2 equivalent/kg live weight to combined 9.6kg CO_2 equivalent/kg live weight while increasing carcass output from 237kg/ha to 255kg/ha. Further development and implementation of low-emission technologies is required to reduce the GHG intensity and total GHG emissions of sheep systems and contribute to the GHG reduction target.

"The Irish sheep sector is starting from a good position," concludes Jonathan, "where a typical lowland system has lower GHG intensity per kg live weight than the global average. For the Irish agricultural sector to achieve the 25% GHG reduction target set by the national climate action plan, the sheep sector must be proactive in adopting available GHG mitigation strategies."

Emissions reduction

A number of practices and technologies can reduce total farm emissions.

5% Reduction of total greenhouse gas emissions when protected urea technology is adopted.

2% Reduction of total greenhouse gas emissions through improved soil fertility and by incorporating clover into swards to reduce the quantity of N fertiliser needed.

4.3% Reduction of total greenhouse gas emissions when land area and yield is fixed and stocking rate and output is reduced, resulting in the reduction of concentrate fed per ewe from 103kg to 50kg.

9.7% Reduction of total farm greenhouse gas emissions through a combination of reducing reliance on concentrate feed, the adoption of protected urea, the reduction in N fertiliser through the incorporation of white clover into swards, and the improvement in mortality and weaning rate.

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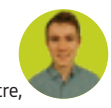

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Genetics: a move in the right direction

Recent studies have proven that 5 star animals deliver more money to the bottom line

The sheep industry is facing challenging times, with increased input costs, resistance to parasitic infection treatments and pressures to meet greenhouse gas targets. While genetics are not the silver bullet, they are a proven solution.

Words by: Kevin McDermott, Programme Manager for Sheep Ireland

The Irish sheep breed improvement programme, while relatively young compared to our international counterparts, can help tackle some of the biggest issues facing our farmers and wider industry today and in the future.

The programme is run by Sheep Ireland, which was established in 2009. Because the foundation of any breed improvement programme is data, a substantial database has been compiled over the past 14 years. It now has more than one million weight records, which are used in the weekly genomic evaluation. Ireland was also the first country in the world to include lameness, lamb vigour, barrenness and ewe mothering ability in the national breeding programme.

A recent study investigated how well the breed improvement programme was identifying the top and bottom performing animals. The study compared the physical, financial and greenhouse gas (GHG) performance of the top 20% (5 star) and the bottom 20% (1 star) genetic merit commercial ewes with full parentage recorded on the national database between 2018 and 2020, with over 380,000 production records included.

Physical and financial performance

The first study analysed the difference in physical performance between the two groups. The main differences were that the top group had an 8% greater lambing percentage (1.70 vs 1.84), 9.4% lower mortality from birth to 48 hours (6.5% vs 7.1%), and 6.5% reduced age at slaughter (203 vs 190 days).

The second study analysed the financial performance of the two groups. Taking all the physical performance differences from the first study and inserting them into the Teagasc Bio-Economic Model, the difference in net profit per ewe was 57% higher for the ewes ranked in the top 20% (€28 vs €44).

The final study investigated the GHG performance of the animals, based on the physical differences found in the first study. These differences were inputted into the Teagasc Life Cycle Analysis (LCA). The results showed that the high genetic merit flock had 6.9% lower GHG intensity than the low genetic merit flock per kilo of carcass produced.

Measuring success

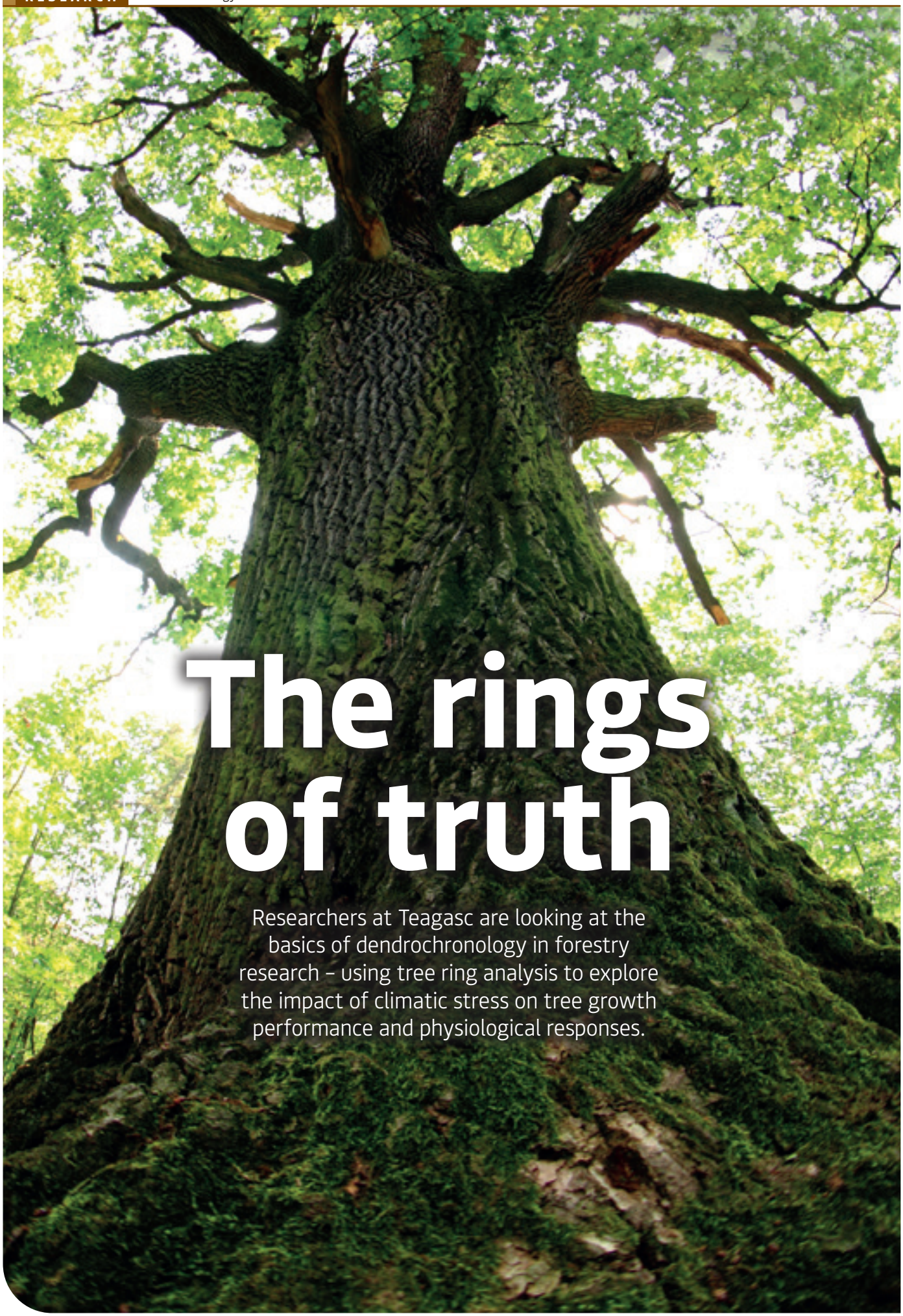
The breed improvement scheme is measured by how much it delivers on industry targets. Our aim is to increase the profitability of the national flock, reduce welfare issues and help meet our national GHG targets.

There are a couple of key elements in achieving these goals: the Replacement and Terminal Indexes, designed and weighted using a bio-economic model to aid the selection of animals that will produce the best genetics; and genomic evaluations, introduced in 2020, which involve the use of DNA to predict how an animal and their progeny will perform.

30%

LambPlus, the performance recording service offered by Sheep Ireland, has grown by 30% in the last two years, resulting in greater data collection and availability of performance-recorded rams.

It has never been easier for farmers to identify and source the right genetics for their flock. All the lowland breeds in Ireland now host their flockbooks on the national database. In turn, the star ratings are clearly visible at society sale catalogues for the performance-recorded animals. For farmers that prefer to buy direct from the breeder, ramsearch.ie is an amazing resource. This allows farmers to search for rams in their area that meet their requirements and look for local performance-recording breeders. T



The rings of truth

Researchers at Teagasc are looking at the basics of dendrochronology in forestry research – using tree ring analysis to explore the impact of climatic stress on tree growth performance and physiological responses.

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Projections of increased temperature coupled with decreasing precipitation during the growing season have the potential to cause reductions in the growth of certain tree species if water becomes a limiting factor.

The DAFM-funded Fit Forests project aims to assess the response of key species in Ireland to the uncertainties of climate change. Researchers at Teagasc and University College Dublin are using dendrochronology – a tree-dating technique – to understand past responses to drought events to predict future responses of trees to climate change.

These quantifications of past performance data can be modelled within future climate change scenarios under different warming levels and rainfall patterns. Therefore, we can forecast the growth trend of forest tree species based on future climate change predictions and assess their climate resilience, and then use this information for better management of species and more sustainable timber production.

The formation of tree rings

Tree rings are well-defined increments encircling the entire stem, resulting from wood formation with seasonal dynamics driven by genetic and environmental factors.

PhD Walsh Scholar Hui Xing says: "The annual rhythm of growing and dormant seasons drives the formation of annual tree rings. But external environmental forces, particularly climatic variations at both inter-annual and intra-annual levels, give us different ring characteristics and chemical properties. It is these annual growth increments and the science of identifying them – assigning them to an exact year – that form the basis for dendrochronology."

The yearly resolution of tree-ring data makes it possible to detect the impact of climatic extremes on growth performance and the underlying physiological process of trees' responses to inter-annual climate variation.

"This characteristic comes from two peculiarities of trees that are rare in the living world," explains Hui. "They are both sessile (fixed in one place) and long living. Being sessile and rooted in the ground is an advantage for researchers, providing an absolute stability in the recording location, in addition to the wealth of environmental signals that trees record along their life span.

"Whenever there is a climatic extreme, such as a drought event, the physiological response of trees is ingrained directly in tree ring structures as a functional trade-off between carbon gain and water loss during photosynthesis. Therefore, tree rings are libraries, keeping a precise record of regional climatic information and environmental cues in long tree ring chronologies.

"In turn, the retrospective analysis of tree ring series, such as ring width, wood density and isotopic compositions in wood cellulose, offer us an insight of past climatic extremes, such as drought, and their impact on tree growth performance and physiological responses."

> **Tree rings are libraries, keeping a precise record of regional climatic information and environmental cues.**

The growth performance can be quantified through indicators of the resistance, recovery and resilience of trees before, during and after drought events.

Dendrochronology in forestry research

Climate variability causes variability in tree ring width and density at inter-annual and intra-annual scales.

Variations may occur within a single tree ring, such as density fluctuations (or 'false rings'), and the transition from earlywood to latewood in conifers and ring-porous broad-leaved species (such as ash or oak). Variations in ring width may also occur between tree rings formed in different years. For example, the sequence of wider and narrower tree rings in a series reflect changes in climatic conditions, notably for trees growing in their natural ecological settings. Favourable conditions such as ample water supply and ambient temperature typically result in wider rings, whereas climatic stress such as drought and heat may result in narrower rings.

These anatomical variations in tree rings serve as temporal markers for researchers to assess inter-annual, intra-annual and intra-seasonal variations in tree-climate interactions.

Radial growth is a good indicator of regional climatic conditions if trees grow close to the limits of their natural geographical distribution and are not affected by competition. In forestry, however, trees are planted in close stands in moderate favourable environments. Under these conditions, radial growth is found to respond less strongly to changes in rainfall and temperature due to complex integrating factors.

Complementary measures, such as the oxygen and carbon isotopic signatures of wood cellulose, can provide an additional, nuanced environmental fingerprint that records subtle shifts in temperature, precipitation and drought conditions. As the isotopic ratio in tree rings acts as a passive monitor of environmental change and is not dependent on net growth, it can potentially provide past climate information for regions that are not close to an ecological limit, such as in a forestry plantation setting. T

Tree terms

Dendrochronology – a tree-dating technique pioneered by Andrew E. Douglass in the early 20th century. It evaluates the annual growth increments of trees by identifying the exact year a tree ring was formed and examining how its formation was affected by historical climatic events.

Wood formation – a complex process of cambium activity and differentiation of secondary xylem, which is a process of xylem cell formation called xylogenesis. Annual growth rings are the result of cambial activity following periodical changes during xylogenesis.

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Diversification

Anaerobic digestion will sanitise organic waste while providing cheap, sustainable energy and fertiliser

Overcoming the pathogen hurdle

Climate change, the energy crisis and the drive for agricultural sustainability have moved anaerobic digestion centre stage. Teagasc researchers are investigating and eliminating bacterial, viral and parasitic pathogens in feed stock and digestate.

Wastewater treatment sludge (WWTS) is the solid, semi-solid or slurry by-product of treatment processes in sewage plants. European legislation prohibiting disposal at sea or in landfill is encouraging the use of WWTS in agriculture, where other organic wastes, such as animal manure and slurries, are already used as natural fertilisers. However, the full potential of these waste materials – an essential part of the future circular economies mandated in the EC Green Deal – can only be realised if their use does not present a public or veterinary health risk.

Anaerobic digestion (AD), followed by pasteurisation, offers a means of 'sanitising' animal wastes and WWTS, while generating biogas and digestate, a nutrient-rich organic fertiliser. AD therefore offers future farmers and society clean and cheap fertiliser and energy, while solving the issue of WWTS disposal without compromising the health of the environment, animals or humans.

Optimising pathogen destruction

Unlocking the potential of this technology relies on pathogen destruction in the bioreactor and during subsequent processes. Teagasc research, in collaboration with University College Dublin, the University of Galway and the Technological University of Dublin, will investigate the fate of bacteria, viruses and parasites under different bioreactor conditions to inform the design of AD processes that optimise both pathogen destruction and biogas production.

This is not as simple as it might first appear, as biogas production is reliant on maintaining a healthy population of methanogenic bacteria in the bioreactor. The challenge is to selectively target one group of bacteria to be reduced or eliminated without adversely affecting another. Potential strategies include manipulating bioreactor conditions to maximise ammonia and volatile fatty acid concentrations, but research is required to ensure biogas production is not reduced. Increasing solid retention time would also enhance pathogen destruction, but the times required to completely sanitise the waste are currently too long.

Research findings

Our research has already shown that under the right conditions, mesophilic (approximately 30-40°C) digestion will reduce bacteria such as *Escherichia coli*, *Salmonella spp.*, *Yersinia spp.* and *Enterococcus spp.*, but other pathogens will survive. Some will even survive thermophilic (approximately 50-60°C) digestion, especially spore-formers. Post bioreactor stages in the AD process are therefore critical for pathogen control.

Current EU legislation requires a pasteurisation step (70°C for one hour or equivalent) to eliminate any *E. coli* to below the limit of detection and *Enterococci* numbers to below 1,000 colony-forming units per gram. Our data suggests dangerous bacteria such as *Salmonella spp.* and *L. monocytogenes* may be reduced by pasteurisation, but research on time-temperature combinations is required to optimise pathogen destruction.

Drying is another thermal process, undertaken to reduce the weight and volume of digestate during transport and storage. It also offers an opportunity to sanitise the digestate, but is not commonly practised in Ireland as it requires energy input and produces greenhouse gas emissions. Moreover, the digestate has a lower fertilising value, because nitrogen is lost through ammonia volatilisation.

The final stage in the process is storage; digestate is only applied to land at specific times throughout the year. It may be possible to manipulate the storage conditions and/or apply disinfectants, such as calcium oxide, to ensure the digestate is pathogen-free before land spreading.

To date, our collaborative studies have established the potential for pathogen destruction during AD and subsequent processes. The planned research for 2023–24 will quantify the pathogen load in animal wastes and WWTS and establish the bioreactor conditions for optimal pathogen destruction. T

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Estuary Pig/Shutterstock.com

Events: my take-home message

Teagasc's researchers attend many events throughout the year, sharing the findings from their research with national and international audiences. Here, we capture the take-home messages – key pieces of information that our researchers want people to remember – from recent events.

Benefit of soils

Event: BT Young Scientist & Technology Exhibition 2023, Dublin
Date: 12 to 14 January

This event has been celebrated for more than 50 years, and attracts over 40,000 visitors (between students and general public), making it one of the largest events of its kind in Europe! Teagasc showcased a variety of the latest scientific projects and findings from our organisation.

Using interactive experiments and eye-catching displays, a team of Teagasc researchers, students and technical staff members engaged with an enthusiastic public during the exhibition.

Luis Lopez-Sangil, Soil Health Technologist in Teagasc's Environment, Soils and Land Use Department, Johnstown Castle, noted: "Our soils display is colourful and full of different textures, which works well in catching the attention of the public passing by the stand. Each soil has a different story, with different formation factors, capacities and vulnerabilities. I use these stories to introduce the concepts of soil functions and soil diversity, and link those with the importance of protecting soil's health to support food production human health and the environment. Soils are valuable resources!

Teagasc's Luis Lopez-Sangil (right) chats to visitors at the BT Young Scientist & Technology Exhibition 2023

"Using a soil quiz, I can easily engage with the public – both adults and students – as I think it's important to have fun with soils, so we value them more."

Representatives from the 15 project partners, across 10 EU countries at the kick-off meeting

Women leading the way in innovation

Event: FLIARA project kick-off meeting, Brussels, Belgium
Date: 26 & 27 January 2023

FLIARA (Female Led Innovation in Agriculture and Rural Areas) is a three-year project with a €3m budget, led by the University of Galway. It aims to enhance the role of women in rural life, agriculture and rural affairs and identify visions for sustainable farm and rural futures.

Anne Kinsella, a Senior Research Officer in Teagasc's Agricultural Economics and Farm Survey Department and Teagasc co-ordinator on the project, attended the project launch.

"From the outset, the topic of discussion has been the absence of gender diversity in rural research and how the FLIARA project will not only highlight these gaps, but focus on supporting and promoting female-led innovations. FLIARA will actively involve female farmers and female rural entrepreneurs," says Anne.

"Building on the research capacity from the EU Horizon Ruralization project," continues Anne, "project partnerships are sustained and strengthened with innovation-focused partners, rekindling former research bonds and beginning new research connections."

Maura Farrell, FLIARA Project Co-ordinator, University of Galway, adds: "The project aims to create an awareness around the value of women-led innovations to the development and sustainability of rural areas. Traditionally, rural women's employment opportunities and contribution to innovation has been overshadowed, and often suppressed, by a patriarchal ethos."

The project aims to combine futures and case study methods, alongside network building and policy benchmarking.

Save the date

Listeria monocytogenes in Foods: Recent Advances and Outstanding Questions

Date: 24–25 May 2023
Location: Teagasc Food Research Centre, Ashtown, Dublin

***Listeria monocytogenes* is the species of pathogenic bacteria that causes the infection listeriosis. Teagasc is hosting this international symposium, bringing together researchers interested in all aspects of the organism in foods to share their findings, develop new collaborations and reinvigorate networks.**

Research partners for this event include Irish universities (UCD, UCC, UG and UL) and the European Food Safety Authority-funded ListeriaPredict project. Themes include stress response and virulence, persistence in the food processing environment, and predictive modelling in food systems, as well as updates from regulatory agencies and other stakeholders.

Don't miss out on Teagasc's upcoming events! Visit our website to see what we have planned: www.teagasc.ie

Web designer

This image was taken in a field of rye grown in the crops research centre, Oak Park, Carlow. Green orb-weavers are a common native species in Ireland and the UK. Their webs snare insect prey and can trap pollen and fungal spores. Despite their almost fluorescent colour, they can remain camouflaged among vegetation.

When recycling their orb webs, the spiders also feed on adhering pollen grains or fungal spores via extra oral digestion. They are extremely beneficial as a natural bio-control in crops.

This photo was the overall winner of Teagasc's 2022 "Vision of Research and Innovation" photo competition, for which staff and students submit images created in the course of their work.

Photo and description by:
Fiona Hutton

Teagasc project:
BioCrop