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Research

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GRASS ROOTS

70 YEARS OF GRASSLAND RESEARCH

MILK FRACTIONS FOR PIGS

THE FUTURE IS KELP!

BREXIT AND FARM INCOME

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CONTENTS

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70 years of grassland research – Michael Walshe remembered

Grassland research over the last 70 years has underpinned the profitability, competitiveness and sustainability of the ruminant livestock sector. In the early years one of the key leaders in the development of grass-based systems of animal production in Ireland was the late Michael Walshe.

Michael graduated with a first-class honours degree in Agriculture Science from UCD in 1954. He joined An Foras Taluntais (AFT) at Moorepark as the first Officer-in-Charge in 1959. Moorepark was a derelict farm at the time. By the time he left 12 years later, Moorepark was a fully operational research centre with the land, buildings, animal laboratories and staff needed to support a competitive dairy and pig industry. The land area and number of cows devoted to experimentation had increased to approximately 1,200 acres, 1,100 dairy cows and 300 sows and their progeny.

At Moorepark, Michael also gathered and led a world-class team of researchers that supported the fledgling Irish dairy industry during the 1960s. The first of many annual open days was held in 1963 with an estimated 10,000 dairy farmers, and these run to this day. He also instigated the idea of 'demonstration research farms' at Mullinahone, Kilmeaden and Ballyraggett, which replicated the varying soil conditions in Ireland.

In 1961/62, Michael took a study trip to Ruakura, New Zealand, to investigate the application of New Zealand pastoral research to Ireland. Along with Dr C.P. McMeekan, he co-authored one of the most cited scientific publications ever in grassland science: 'The inter-relationships of grazing methods and stocking rate in the efficiency of pasture utilisation by dairy cattle'. Additionally, during his visit, Michael realised that farming skills in relation to fencing and milking were lacking in Ireland, and he was responsible for introducing the first wire strainer to Ireland.

In 1971, Michael joined the World Bank and made a positive impact on international livestock development, bringing with him his expertise in dairy and grassland management and pig production. Over the decades, he participated in numerous missions across the globe.

Michael is recognised by his peers, both past and present, as the dynamic leader who laid the foundations for the world-class research effort into sustainable, grass-based, profitable milk production. This issue of *TResearch* is in honour of the late Michael Walshe and we reflect on past, current and future grassland research programmes.

Pat Dillon
Head of Programme, Animal and
Grassland Research and Innovation

Taighde 70 bliain ar fhéarthalamh – cuimhní ar Michael Walshe

Rud atá mar bhonn agus thaca ag brabúsacht, iomaíochas agus inbhuanaitheacht na hearnála beostoic athchogantaigh is ea an taighde atáthar ag déanamh ar fhéarthalamh le 70 bliain anuas. Duine de na príomhcheannairí i gcórais fhéarbhunaithe an táirgthe ainmhithe in Éirinn a fhorbairt sna luathbhlianta ba ea Michael Walshe nach maireann.

Bhain Michael céim onóracha den chéad ghrád in Eolaíocht Talmhaíochta amach as an gColáiste Ollscoile, Baile Átha Cliath, sa bhliain 1954. Chuaigh sé isteach san Fhoras Talúntais ar an gCloch Liath mar Chéad Oifigeach i gCeannas i mí an Mhárta 1959. Feirm thréigthe ag an am ba ea an Chloch Liath. Faoin uair a d'éirigh sé as 12 bhliain ina dhiaidh sin, bhí an Chloch Liath ina hionad taighde lánoibríochtúil a bhí comhdhéanta de thalamh, d'fhoirgnimh, de shaotharlanna ainmhithe agus de bhaill foirne a bhí ag teastáil chun tacaíocht a thabhairt do thionscal iomaíoch déiríochta agus muc. Méadaíodh an t-achar talún agus an líon bó a bhíothas ag úsáid le haghaidh turgnamh go thart ar 1,200 acra, 1,100 bó dhéiríochta agus 300 ceann de chránacha agus a sleachta.

Ar an gCloch Liath, bhailigh agus threoraigh sé foireann taighdeoirí den chéad scoth a thug tacaíocht do thionscal déiríochta nua na hÉireann le linn na 1960í. Cuireadh an chéad cheann de lear laethanta oscailte bliantúla ar siúl sa bhliain 1963, rud ar fhreastail thart ar 10,000 feirmeoir déiríochta air. Reáchtáiltear na laethanta oscailte sa lá atá inniu ann fós. Chomh maith leis sin, ba eisean an duine a cheap an smaoineamh go gcuirfí 'feirmeacha taighde taispeána' ar bun i Muileann na hUamhan, i gCill Mhíodáin agus i mBéal Átha Ragad, mar a macasamhlófaí na cineálacha agus riochtaí difriúla ithreach atá le fáil in Éirinn.

In 1961/62, chuaigh Michael ar chuairt staidéir ar Ruakura, an Nua-Shéalainn, chun imscrúdú a dhéanamh ar an dóigh a bhféadfaí taighde tréadach na Nua-Shéalainne a chur in oiriúint d'Éirinn. I gcomhar leis an Dr C.P. McMeekan, bhí sé ina chomhúdar ar cheann de na foilseacháin eolaíochta ba mhó lua riamh san eolaíocht féarthalún: 'The inter-relationships of grazing methods and stocking rate in the efficiency of pasture utilisation by dairy cattle'. Le linn a chuairte, thug Michael faoi deara gur in easnamh in Éirinn a bhí scileanna feirmeoireachta a bhaineann le fálú agus bleán, agus ba eisean an duine a thug an chéad stráinín sreinge isteach in Éirinn.

Sa bhliain 1971, chuaigh Michael isteach sa Bhanc Domhanda agus rinne sé difear dearfach don fhorbairt idirnáisiúnta beostoic, agus leas á bhaint aige as a shaineolas ar bhainistíocht déiríochta agus féarthalún agus ar tháirgeadh muc. Thar na blianta, ghlac sé páirt i neart misean de chuid an bhainc.

Aithníonn a bpiaraí san am i láthair agus san am atá thart gurbh é Michael an ceannaire dinimiciúil a leag an bhunsraith le haghaidh na hoibre taighde den chéad scoth atá á déanamh ar tháirgeadh bainne atá inbhuanaithe, féarbhunaithe agus brabúsach. Tá an t-eagrán seo de *TResearch* á thiomnú do Michael Walshe nach maireann agus déanaimis ár machnamh ar chláir thaighde féarthalún an ama atá thart, an ama i láthair agus an ama atá le teacht.

Foresight study on occupational safety and health

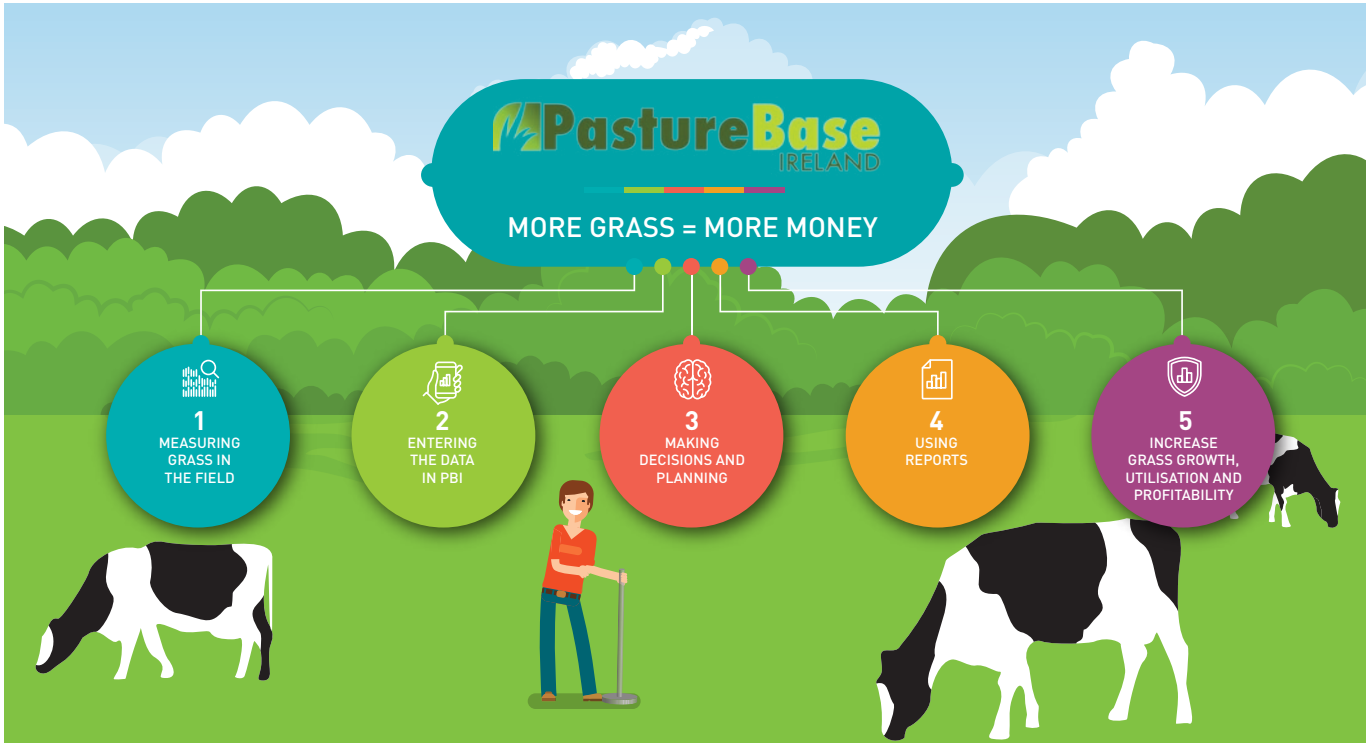
A new foresight report co-authored by Teagasc's Health and Safety Specialist, John McNamara, has been published by the European Union Occupational Safety and Health Agency. The report, 'Future of agriculture and forestry: implications for managing worker safety and health', provides an expert review on the main trends affecting agriculture, the resulting technological and organisational changes, and the consequent implications for the health and safety of workers in the sector. According to John: "The review will support policy makers at European and national levels in their development of strategies, regulation, enforcement, guidance and support measures. It will also indicate knowledge gaps to help identify research priorities". The study is available at: https://osha.europa.eu/en/publications/future-agriculture-and-forestry-implications-managing-worker-safety-and-health/view.

Focus on grassland research

In this issue of *TResearch* we feature a special focus section on grassland in tribute to Michael J. Walshe, who sadly passed away last year. Michael was instrumental in establishing the world-renowned Moorepark research facility and among Michael's legacies was the Moorepark Open Day.

Moorepark 1963

In memory of Michael and his colleagues, pictured are Teagasc Moorepark staff from the first open day in 1963 taken at the 2015 open day, including Michael Walshe (third left, front row). Also pictured are: front row (from left): John O'Brien, Jim O'Grady, Michael Walshe, Dan Browne, Pat Gleeson, Peg Shanahan, Deirdre Drinan and Roz McFeely. Second row (from left): Matty Sweeney, Jack Shanahan, Hannah Shanahan, Kay Gleeson, Mary Nyhan, Sean Hegarty, Peggy McCarthy, Finbarr Drinan and Sean Donnellan. Third row (from left): Jack O'Mahony, Kay Browne, Etty Kearney, Kay Gardiner, Kathleen Anglum, Veronica Whyte, Kay Lillis, Mary McKenna, Gertie O'Donovan, John Shanahan and Pat McFeely. Fourth row (from left): Kathleen Bermingham, Tom Bermingham, Bob Kearney, Jim McDonnell, Arthur Anglum, Pat Walshe, Mary Crowley, Maura Reidy, Siobhan Cahill and Sheila Hegarty. Back row (from left): John O'Donoghue, Mick Reidy, Mick Joe Condon, Liam McGarry, Con Crowley, Aidan Conway, Tom Lillis, Tim Cogan and Maurice O'Donovan.



Nutrition in older life

Teagasc researchers have received funding for research as part of the EAT4AGE project on prevention of under-nutrition in active ageing.

Teagasc Moorepark Food Research Centre's researchers André Brodkorb, Sean Hogan, Laura Mascaraque and Linda Giblin recently received funding of €249,874 for the EAT4AGE project. Recently announced by The Minister of State at the Department of Agriculture, Food and the Marine, Martin Heydon, TD, the award comes under the EU 'Joint Programming Initiative – a Healthy Diet for a Healthy Life' (JPI-HDHL), which in 2020 issued a competitive research call seeking transnational and transdisciplinary research proposals relating to the development of targeted nutrition for the prevention of under-nutrition in older adults. This can often arise as a result of a loss of appetite and/or issues related to food composition and texture.

The EAT4AGE project aims to develop palatable, nutritious and digestible foods for the prevention of under-nutrition in active ageing.

Other collaborating partner countries include Norway, the United Kingdom, France and Israel. The project intends to investigate the formulation of innovative and energy-dense foods that increase appetite and improve bioavailability of proteins in age-tailored food products.

Forest carbon tool

The planting of new forests is a highly significant land-based measure to help address the effects of climate change. Forests play an important role in the capture and removal of carbon dioxide from the atmosphere and subsequent storage in forest biomass and soils, a process called sequestration. The long-term storage of carbon in harvested wood products (HWPs) and the substitution of selected wood products for fossil fuel energy sources, are also important pathways to help meet the climate change challenge.

Teagasc, in conjunction with the Department of Agriculture, Food and the Marine (DAFM) and Forest Environmental Research and Services (FERS) Limited have developed an online forest carbon tool. The tool provides indicative data for potential carbon sequestration associated with new forest enterprises, which include current options under the DAFM Forestry Programme. It also provides indicative sequestration data for specific tree species and species groups.

Access the tool at this link: https://www.teagasc.ie/crops/forestry/advice/environment/forest-carbon-tool/.

Researcher profile — Deirdre Hennessy

Deirdre Hennessy is a Research Officer in Teagasc's Grassland Science Department at the Animal & Grassland Research and Innovation Centre, Moorepark in Co. Cork. She has a degree in agricultural science from UCD (BAgrSc), graduating in 2001, and completed her PhD in Queen's University Belfast in 2005. Her PhD was funded through the Teagasc Walsh Fellowship Programme and her thesis title was 'Manipulation of grass supply to meet feed demand of beef cattle and dairy cows'. Research for the PhD was undertaken at Teagasc Grange and Moorepark.

Deirdre joined Teagasc immediately after completing her PhD as a Postdoctoral Researcher. She organised and managed the establishment of the Dairygold experimental farm in 2006 and became a Research Officer in 2008.

Deirdre's current work involves grass-clover milk production systems and grass growth modelling with an emphasis on herbage production and utilisation, dairy cow performance, dairy cow dry matter intake, nitrogen (N)-use efficiency and N balance, grass growth modelling and sustainability of pasture-based systems.

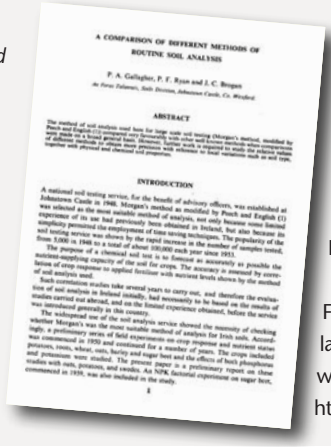
One project she is currently involved in is examining aspects of the management of white clover for production and persistence, the effect of N application rate and strategy on herbage production, and clover content in grass-only and grass-clover swards. She is also involved in a large-scale research project looking into the effect of dairy cow diet on milk production, milk quality and milk processability.

As part of her role, she helps to organise Moorepark open days, farm walks, conferences, and other dissemination events. She is an active member of the Teagasc Science Communication and Outreach Working Group and the SFI VistaMilk Centre's Education and Public Engagement Committee. She is Chairperson of the Moorepark Animal Welfare Body and a past President of the Irish Grassland Association. When the European Grassland Federation General Meeting came to Cork in 2018, she held the role of conference secretary.

Deirdre has been published in over 70 peer-reviewed publications and has been Senior Editor of the *Irish Journal of Agricultural and Food Research* since 2018. She also lectures to the UCD Dairy Business Degree students and the Professional Dairy Farm Manager students.

Teagasc's peer-reviewed journal marks 60th anniversary

This year marks the 60th anniversary of Teagasc's peer-reviewed journal the *Irish Journal of Agricultural and Food Research (IJAFR)*. First published in 1961, the journal is fully online and open access. According to the journal's senior editor, Deirdre Hennessy: "Research published in the *IJAFR* is of interest to both national and international audiences. The journal is an important repository for Irish agricultural and food research". To mark the occasion, a special issue will be published later in the year to highlight the scientific advancements of the last 60 years, and to look to the future by addressing how current research can help us meet future targets.



A COMPARISON OF DIFFERENT METHODS OF ROUTINE SOIL ANALYSIS

P. A. Gallagher, P. F. Ryan and J. C. Brogan

ABSTRACT

INTRODUCTION

Catriona Boyle, *IJAFR* Editorial Consultant, said: "We were very lucky to have been involved in a project to have the *IJAFR* digitised by Queen's University Belfast as part of the JSTOR Ireland collection in 2009, so every issue back to 1961 is available to view on the JSTOR repository. This is such a great resource for anyone who has an interest in agriculture and food research in Ireland".

For more information about submissions or to read the latest research papers, visit the journal's website: www.ijafr.org. See the JSTOR repository: https://www.jstor.org/journal/irisjagrirese).

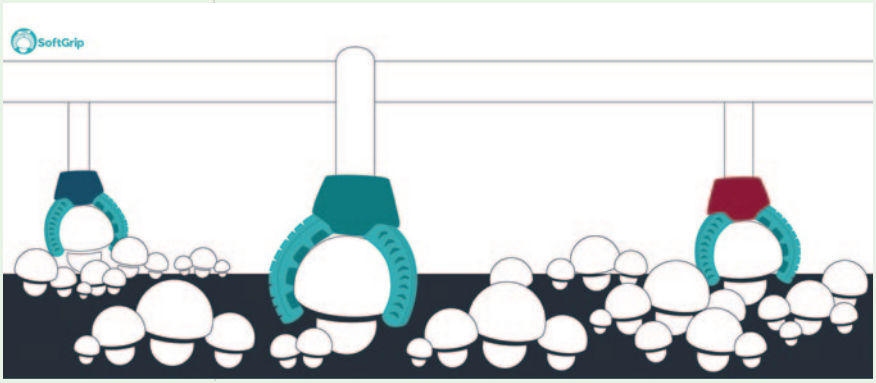
Gentle robots

The Horticulture Development Department recently commenced work on a three-year EU project called 'SoftGrip'. This focuses on using a functionalised soft robotic gripper for harvesting delicate produce, in this case mushrooms, powered by imitation learning-based control.

Teagasc's role in the project is to ensure that the user needs and functional requirements of a robotic gripper are understood and incorporated into the design, manufacture and performance of the gripper. The partners include the Sant'Anna School of Advanced Studies in Italy, the Institute of Communication and Computer Systems in Greece, the University of Essex in the United Kingdom, TWI Hellas in Greece, and Mitsui Chemicals Europe GMBH in Germany. Novel 'intelligent' materials will be used that are food safe, self-repairable and recyclable, so that they are more environmentally sustainable. The gripper will also 'learn' how to harvest mushrooms by 'imitation' of the harvesting process performed by actual harvesters.

Once travel restrictions around Covid-19 are relaxed sufficiently, the SoftGrip team will be on site at the Teagasc Mushroom Unit in Ashtown, where they will develop the soft gripper functionality in conjunction with actual mushroom crops, and eventually demonstrate its performance once it has been refined and perfected.

Teagasc researchers are involved in a three-year project called 'SoftGrip' to develop a soft robotic gripper for harvesting delicate produce.



Pasture-based dairy systems in temperate lowlands

TEAGASC research looked at the challenges inherent in pasture-based dairy systems, and opportunities for the future.

Improved efficiency in dairy systems is a significant challenge for the future, to meet increased food demand while competing for resources, adapting to climate change, and delivering ecosystem services. Future grazing systems can play a major role to supply healthier foods within systems with a reduced reliance on fossil fuels and chemical inputs, while also delivering environmental, biodiversity and animal welfare benefits. We identify three pertinent opportunities for temperate, pasture-based, dairy systems to deliver efficient levels of output based on a lower reliance on imported concentrates and inorganic fertilisers, and an increased reliance on extended grazing seasons and high-quality forage.

Matching the cow to the system

In low-input pasture-based systems, more than others, the dairy cow is a feed-to-food transformer who must possess critical attributes associated with the conversion of grass to milk. The available feed resource is primarily forage characterised by a higher fill value and a low energy density. In addition, achieving high levels of grazing efficiency requires a low post-grazing residual height, which restricts animal intake, and pasture supply is naturally seasonal and varies both in supply and in quality. In consequence, such systems fail to fully meet the nutritional requirements of high genetic merit dairy cattle for milk yield within a predominantly pasture diet. At the same time, and as a consequence of the seasonality of grass growth, dairy farmers are highly motivated to synchronise herd demand with

Future grazing systems can play a major role to supply healthier foods within systems with a reduced reliance on fossil fuels and chemical inputs, while also delivering environmental, biodiversity and animal welfare benefits.

grass availability using compact calving in spring to maximise pasture utilisation. On that basis, the Economic Breeding Index (EBI) in Ireland has successfully produced dairy cows capable of both increased productivity and improved compactness of calving within Irish dairy herds. Building on this success, specifically at grazing, the selection of animals that exhibit greater longevity within such systems, and are resistant to lameness and parasitism to limit the use of antibiotics and anthelmintic products, is an opportunity for the future. At the same time, more erratic grass growth patterns due to climate change will increase pasture supply variability and will require future dairy cattle that can withstand periods of nutritional restriction. The ideal dairy cow in low-input pasture systems should

have the inherent capability to reduce milk yield during periods of restriction and rebound when forage supply recovers. Genetic selection on this capability will be a key attribute for grazing dairy cattle for the future. Finally, a well-adapted dairy cow must achieve greater longevity to produce high fat and protein content milk from pasture with a low replacement rate to reduce environmental impacts such as greenhouse gas (GHG) emissions from the dairy system (Dall-Orsoletta *et al.*, 2019). Ultimately, the dairy cow required for future climate-smart grazing systems will be placed in a less controlled, less artificial environment and, consequently, should be more adaptable, with increased health and robustness to prosper within the changing environment.

Multi-species pastures: benefits of diversity

There is renewed focus on the role of legumes within intensive grassland-livestock systems to increase pasture productivity and reduce inorganic nitrogen (N) requirements and production costs. The inclusion of forbs within grass-legume swards can bring extra yield and more complete feeding value, especially of minerals and bioactive secondary metabolites (Delagarde *et al.*, 2014). On a broader scale, by diversifying plant species, the risk of deficiency in any aspect of an animal's diet is reduced, resulting in positive effects on animal performance (Roca-Fernandez *et al.*, 2016). Compared to monocultures, sward diversity enhances grassland yield stability under drought (Finn *et al.*, 2018), contributes to increased carbon sequestration, and reduces weed invasion and associated reliance on herbicides (Connolly *et al.*, 2018).

Biodiversity and ecosystem service provision

Much of European biodiversity is associated with extensively managed farmland, while agricultural intensification has been a major driver of recent biodiversity loss through conversion to cropland or single-species grasslands. There is a growing expectation from society for agricultural systems to improve their environmental sustainability, and to respond to the climate and biodiversity crises. Lower-input pasture-based dairy systems can support and improve biodiversity by protecting existing natural habitats, enhancing the wildlife quality of degraded farmland habitats through improved management, and creating new wildlife habitats. The benefits of such actions extend beyond the improvement in allocation of space for biodiversity. For example, for hedgerows and wooded areas that are characteristic to Ireland, wider benefits include the provision of shelter and shade for animals, improved carbon sequestration, water infiltration and pollination services, and the control of agricultural pests and diseases, while simultaneously reducing reliance on chemical methods of weed and pest control.

Conclusion

Future pasture-based systems must be realigned to extend beyond food production to deliver additional benefits to farmers, consumers and society at large. Such systems will need to rely less on imported feed and chemical inputs and more on high-quality home-produced forage. Such systems will require:

- more robust animals that are healthier and adapted to the specific requirements of grazing;
- more diverse swards, which support improved animal performance and require fewer fertiliser and chemical inputs; and,
- the further development of systems to support higher biodiversity, reduced nutrient losses and enhanced carbon storage.

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70 years of grassland research in Ireland

TEAGASC grassland research has enabled the transformation of Irish agriculture since the 1950s.

Introduction

The importance of grassland to agriculture in Ireland is indicated by over 70 % of agricultural output (monetary terms) coming from grassland as cattle, milk, and sheep products. This paper gives a summary of the key developments in grassland research over the last 70 years. Initially, grassland research was led by the Department of Agriculture (Johnstown Castle) before the establishment of An Foras Taluntais (AFT) in 1959. Grassland research was transferred to AFT and then to Teagasc. Grassland research was carried out at AFT/Teagasc research centres, including Moorepark (dairy), Grange (beef/sheep), Creagh/Belclare/Athenry (sheep), Oak Park (grass and clover breeding), and Johnstown Castle (soils, agronomy and environment).

Evolution of grassland science

Increased production from grassland has arisen from improved understanding (research and practice) of soil and plant nutrition, plant physiology and cultivar improvement, while improved understanding of feed evaluation, ruminant nutrition, grazing management and silage technology has contributed to increased utilisation of grassland. Annual grass dry matter (DM) production varies from 12.7 to 15 t DM/ha based on Department of Agriculture, Food and the Marine (DAFM) variety trials. More recent data from PastureBase Ireland indicate that average annual grass production on efficient dairy and drystock farms is 13.5 and 10 t DM/ha, respectively.

In the early 1960s, national stocking rates were less than 0.8 LU/ha. The first experiments demonstrated that with some nitrogen (N) for silage, it was possible to stock at 2 LU/ha. Experimental design consisted of self-contained farmlets using rotational grazing. The use of these systems (blueprints) was of great benefit to both advisors and farmers on how best to manage both livestock and grassland at farm level. By the mid 1970s, 2.47 LU/ha or better became the norm on dry soils on commercial grassland farms. Over the next number of years other factors influencing output per hectare were investigated, e.g., soil type/drainage, level of N, genetic merit, concentrate supplementation, and grass species/variety.

Research in the 1990s highlighted the influence of grassland management on animal performance and the importance of grass budgeting using decision support tools to aid grassland management. Additionally, the benefits of extending the grazing season in both spring and autumn, matching feed demand to grass supply and the importance of pasture-based animal genetics were identified.

Forage legumes were highly regarded initially, and then declined (mainly due to the use of high levels of N), but are once again assuming much more importance. Recognition of the environmental implications of grassland management has increased, especially over the last two decades. This includes the need to reduce nutrient emissions from agriculture, improve water quality, and also the role of grassland in biodiversity protection, carbon sequestration and landscape quality.

Key developments from grassland research

The objective of all grassland research is to study the factors that can increase the output of animal production in a sustainable way and integrate this knowledge into a complete, integrated system.

Some key developments over the last 70 years include:

- Research at Johnstown Castle quantified the effect of N, phosphorus (P), potassium (K) and lime on grass production. The first soil survey in the 1970s mapped the soils of approximately half the country. This provided information on productivity of soils and showed that soil drainage was a significant determinant in the level of production achieved. It was estimated that over one million lowland hectares required drainage, which led to the development of both shallow and deep drainage systems. The knowledge gained from soils and environment research over many years is today captured in the 'Teagasc Green Book'.

- Much of the early work carried out at livestock centres (Moorepark, Grange and Creagh) quantified the effect of stocking rate on milk, beef and lamb growth rates. Additionally, the influence of the grassland system (rotational versus set stocking), soil type, drainage and N use were investigated. The application of this knowledge led to the development of blueprints of systems on animal production. In all these systems, the whole management programme for both animal and pasture was specified. These systems are now widely used on farm.

- A key challenge in the early years was the availability and quality of winter feed. There was a great dependence on hay. In 1958, only 160,000 tonnes of grass were conserved as silage, whereas by 1976 this had increased to 10 million tonnes. The reasons for this expansion included the development of simple unroofed silos in conjunction with polythene covering, use of the cold fermentation process, self-feeding systems, and the elimination of the risk in saving hay due to weather conditions. Key innovations (developed mainly at Grange) include knowledge on when and how to conserve grass silage, assessment of its feeding value and how it should be supplemented.

- Systems of grassland management evolved, which placed greater emphasis on grazed grass rather than grass silage or concentrates in animal production. Key livestock production decisions like calving date (dairy, beef) and lambing date for ewes were targeted to maximise use of grazed grass. However, this was only possible where grass-based animal genetics were used. Product quality also improved, and this gave Ireland a unique marketing advantage in the production of 'grass-fed' animal products.

- Grass and clover breeding was initiated at the early stages, so as to breed varieties more suited to the Irish environment. Initially, the focus was placed on yield, but this changed over the years to give greater emphasis on seasonality of yield and quality. Over the period 1973 to 2013, it is estimated that annual DM yield increased by 0.52 % under conservation and 0.35 % under simulated grazing. Over this period, there is no indication of any increase in herbage digestibility.

- Considerable resources were used over the years to strengthen capacity in grassland science. This facilitated a greater understanding of the influence of grazing management on animal performance. The importance of pre- and post-grazing height, as well as pasture allowance, were identified. The use of markers to measure herbage intake helped greatly to understand the interaction between grazing management and animal nutritional requirements. Knowledge gained from this work facilitated extending the grazing season (spring and autumn). These advancements in grassland science have led to the development of decision support tools for farmers (e.g., PastureBase Ireland).

- In the early 1980s, an annual target of 6,820 litres per dairy cow (3.5 % fat and 3.2 % protein) and a liveweight gain in beef production of 1,680 kg/ha, at a stocking rate of 2.47 LU/ha were identified. Using the current Teagasc Road Maps, dairy farming nationally is averaging 6,224 litres/cow at a stocking rate of 2.2 cows/ha (corrected for changes in milk composition), while current research performance is approximately 7,164 litres/cow at a stocking rate of 2.70 cows/ha. The corresponding national performance in suckler beef production is 446 kg/ha, while the current research performance is 983 kg/ha.

Challenges for grassland science in future

Over the past 70 years grassland research has contributed significantly to increasing animal production from grassland. The continued development of grazing technologies will be critical in increasing the future sustainability of grassland farming. Research programmes in the future will place greater emphasis on confronting challenges in relation to climate change, water quality, N-use efficiency, and ammonia emissions.

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Teagasc's current grassland research programme

Researchers across TEAGASC cover a variety of topics from clover and grass breeding to environmental sustainability and more in the grassland research programme.

The competitive advantage of Irish animal production systems is based on the efficient production and utilisation of grazed grass. Irish pasture has the potential to grow between 11 and 15 tonnes of dry matter (DM)/ha/annum, which is approximately 20 % more than that produced in Western Europe. Recent technological advancements have resulted in significant increases in farm profitability through an extended grazing season and higher pasture performance. The development of the PastureBase Ireland decision support tool has allowed the adoption of best grazing management practice at farm level.

The key challenge in the future will be to further increase animal production per hectare by improving pasture growth, grass quality, increasing nitrogen (N)-use efficiency and reducing greenhouse gas (GHG) emissions. The grassland research programme is focused on the following themes.

Grass and clover breeding and evaluation

The research focus is to improve grass production, utilisation and consequently animal performance through the application of plant-breeding technologies. This will be achieved by selecting grass and white clover varieties with improved DM production, canopy structure, quality characteristics, N-use efficiency and persistence.

The continued development of the Pasture Profit Index and a new Clover Profit Index, combined with the continued development of on-farm evaluation of varieties, will ensure that grass breeding and evaluation will be aligned with those traits of most importance at farm level.

The integration of genomic selection into the breeding process has just been initiated into the Teagasc breeding programme.

Grazing management

The focus of this research is to improve the growth and utilisation of grazed grass through improved grazing management practices. Key factors include: pre-grazing herbage mass; post-grazing residual; pasture allowance; and, sward digestibility. Daily grass DM intake will be increased, if not maximised, by adhering to important sward characteristics, such as maintaining a high proportion of green leaf combined with a high clover content within the grazing horizon, while allocating an adequate daily herbage allowance. The extension of the grazing season length is a major objective of all grassland farmers and this will continue to be a focus of the grassland research programme.

Evaluation of grass-clover-based systems

The recognition of the benefits accruing from the high forage quality and N fixation characteristics of grass-white clover pastures has led to a resurgence of interest in white clover. Recent research has shown very promising results in terms of increased animal performance and reduced chemical N requirement, without any reduction in grass DM production from perennial/white clover pastures. This has resulted in

increased N-use efficiency. This will require a strong and focused knowledge transfer (KT) programme in order to get it adopted at farm level. A new aspect of the clover research programme is to incorporate commercial farms with high sward clover content across the country into an outreach project to complement the research.

Rumen digestion and supplementation

There are opportunities to increase the productivity and efficiency of pasture-based systems by strategically modifying the nutrient supply of the cow. Strategies include, but are not limited to, improved pasture management, optimisation of concentrate supplementation, and selection of superior plant genetics. To select the optimal strategy, quantitative knowledge of how the diet interacts with the ruminant, the nutrients it supplies, and the metabolic requirements of the cow, is crucial. Recent results from new feed analysis demonstrate that the neutral detergent fibre fraction (aNDFom) of immature pasture comprises a large, potentially digestible pool that degrades rapidly in the rumen, allowing for high milk production performance to be achieved from pasture-only diets. Autumn pasture was shown to contain a lower proportion of digestible material, which degrades at a slower rate when compared with spring and summer pasture. Incorporating a novel experimental measurement procedure (i.e., the omasal sampling technique) has demonstrated that extensive rumen degradation of pasture amino acids (AA) occurs. It also showed that protozoa supplied a much larger amount of microbial AA and exhibited shorter generation time than previously assumed. This indicates that cows consuming pasture-based diets exhibit a large dependence on microbial AA to support metabolisable AA supply. Overall, these findings highlight new opportunities to increase the productivity and efficiency of pasture-based systems.

Grass growth modelling

Grass growth is highly variable, largely due to the interaction between grazing management, weather and soil components. Additionally, sward growth will be influenced by sward age and composition, and fertilisation management. Increasing the predictability of grass growth and animal requirement increases confidence in feed budgeting. In recent years, there have been major gains in this research area. The Moorepark-St Gilles model is now used to predict grass growth on grassland farms across the country. Information required to complete the predictions includes grassland measurements and fertiliser management recorded in PastureBase Ireland, as well as meteorological data from Met Éireann. It is hoped that this will be rolled out nationally in 2022 for grassland farms on PastureBase Ireland.

Environmental sustainability

Grazing systems need to become more environmentally sustainable, as necessitated by a range of environmental directives including the EU Nitrates Directive, EU Water Framework Directive, the Kyoto Protocol and the EU Farm to Fork strategy. In developing sustainable grass-based systems, research will focus on ways to avoid conflicts in meeting these demands and find win-win situations that boost production and decrease environmental impacts. The research programme is focused on the improvement in use efficiency of phosphorus (P) and N on farm, and defining the net global reduction in GHG per unit of milk production (kg milk solids) that can be achieved with grass-based systems.

Evaluation of grazing systems

The focus of this research is to achieve maximum performance of the whole farm system by optimising the interaction between grass, supplementary feeding and grazing animals. Grazing systems must integrate the main technologies from component research studies within the farm system to achieve a balance between best management practices to maximise grass growth and utilisation, while continuing to achieve relatively high animal performance. The major limiting factor to increased animal production from pasture is acknowledged to be the amount of pasture grown and utilised on the farm. The emphasis in grazing system research is on improving growth of the existing sward on the farm through a combination of improved nutrient-use efficiency and achieving an improved alignment between grass growth and feed requirement during the grazing season, as well as reseeding poor-performing pastures with higher-performing varieties (grass or grass-clover combinations). The evaluation of multispecies swards is now part of this research strategy, with some of these species having potential beneficial effects on reducing urinary N leaching (plantain).

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Grassland research – where to from here?

TEAGASC researchers examine how their work will help to meet some of the major challenges of modern and future food production from grassland.

In the last decade, the requirements on global food systems have shifted dramatically from a focus on quantity and food security, to meeting the growing needs of an increasing population in a manner that safeguards human health, protects the natural environment and provides a profitable livelihood for farmers. The global food system has a substantial environmental impact and is responsible for approximately 25 % of all greenhouse gases (GHGs) released by human activity. To an increasing extent, the diets of urban populations have become less varied, composed of an ever-greater proportion of high-energy, high-protein and processed products, which fail to deliver nutrition security. Today, one in nine people (some 821 million worldwide) have an insufficient calorie intake, and one in five (1.5 billion) suffer from micronutrient deficiencies, while more than 672 million adults are obese. The challenges for food production worldwide are substantial, and there is a pressing need to adapt both within the farm gate and through to the dietary and lifestyle choices of society. As part of the European Union, Ireland must progressively reduce its dependency on imported animal protein feed and fossil energy for mineral nitrogen (N) formulation, to further improve the efficiency of grazing while reducing the climatic and environmental impacts of such systems. The scope of this article is to outline how Irish grassland systems are adapting in parallel with research innovation efforts to contribute to meet these challenges, while continuing to retain the financial, people and animal welfare advantages of grazing systems.

Further developments in grazing management

Although grazing systems have specific challenges, such as unstable feed supply and reduced individual animal intake and performance, the principal benefit of improved grazing management has been to optimise the quantity and nutritive value of the forage consumed by grazing animals. Notwithstanding the substantial benefits of pasture-based systems, engaging more farmers in pasture measurement in support of more rapid and improved pasture management continues to be problematic. The ongoing development of the national PastureBase Ireland (PBI) database and pasture management systems have increased participation in pasture measurement among Irish farmers, resulting in increased intake and animal performance from pasture on farms. Applying technologies such as image analysis, satellite data analysis and radar, combined with machine learning, may offer the potential for real-time remote measurement of grassland, provide farmers with up-to-date information on pasture quantity and quality, and increase confidence and accuracy in terms of grazing management and supplementation decisions. The further development of pasture growth prediction to include more pasture species, real-time nutrient management decision supports, remote measurement and improvements to usability function will assist more farmers in engaging in pasture measurement and improved pasture management on Irish farms.

Forage breeding

The genetic improvement of forages plays a major role in the enhancement of agricultural systems. In the past, forage breeding has mainly focused on improving animal production, but now climate change mitigation and reducing the environmental impacts of farming are equally important. To this end, breeding will continue to focus on the predominant grass and legume species in Ireland – perennial ryegrass and white clover. However, balancing animal

production targets against the need to reduce the environmental and climatic footprint of farming poses further challenges. This may require traits expressed at levels outside the known range of variation in the currently popular species or even completely new traits. Breeders are currently investigating the genetic potential of novel forage species (e.g., bird's foot trefoil, sainfoin, lotus, chicory and plantain). These species are unlikely to completely replace the more productive species of today but in combination, the whole may be significantly greater than the sum of its parts. New research projects are already underway to identify new traits that can differentiate clovers, while the possibility of a bloat safe, high nitrogen (N) fixation persistent grass clover sward is a major goal. Plant breeding has traditionally moved steadily, albeit slowly. Characterising plant phenotypes is costly and time consuming, which represents a major bottleneck in the process. The advent of new technologies, including optical sensors, machine learning, low-cost genotyping, genome sequencing, and genomic selection facilitates high-throughput phenotyping and genotyping. These new technologies are expected to more than double the rate of genetic gain in perennial ryegrass and white clover. In novel forage species that have undergone very little formal breeding, the rate of genetic gain could be multiple times higher in the future. Future breeding may differentiate varieties for intensive and lower-input sustainable systems, and marginal environments. Greater emphasis will be placed on forage quality, disease and pest resistance, N- and phosphorus (P)-use efficiency, N fixation, root design, and anthelmintic and bloat safe properties.

Although grazing systems have specific challenges, the principal benefit of improved grazing management has been to optimise the quantity and nutritive value of the forage consumed by grazing animals.

Legume-based swards

The incorporation of legumes and other plants in grazing swards to enhance atmospheric N fixation, reduce the use of synthetic fertilisers and pesticides, improve soil quality and enhance biodiversity is a significant ambition for Irish pasture-based systems. The impacts of legume incorporation within grazed swards are substantially increasing voluntary intake, organic matter digestibility, and energy and protein supply in grazed swards. The further development of grazing practices to increase legume content and persistence within grazing swards is a significant focus of ongoing research efforts. At a time when white clover inclusion in grassland swards in Ireland is low, despite the known benefits in terms of herbage and animal production and reduced N fertiliser use, the development of a Clover Profit Index, similar to the Pasture Profit Index (PPI), will provide farmers with confidence in selecting the appropriate white clover cultivars for their system. In future years, and depending on requirement, the development of selection indexes for other species may also be important for the industry.

Further characterisation of milk from grazing

In a context of increasing societal demand for more sustainable and ethical production systems, milk produced from grazing has become a key point of differentiation and the segmentation of dairy markets towards grazing systems is ongoing in many countries. While the distinctive nutritional properties of predominantly pasture-derived milk have received significant attention, the effects of plant- and animal-breeding programmes and sward species diversity on milk composition and functionality require further characterisation to quantify the variability of milk fine composition and technological properties in grazing dairy systems. Detailed pasture-based milk evaluation also has potential to identify accurate biomarkers, which can indicate both the nutritional status of the cow and the relative contribution of pasture to her diet.

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Milk fractions to improve pig health

Researchers at TEAGASC and the University of León, Spain, are looking at the potential of milk bioactive fractions for gut health and development in pigs.

To maximise production and economic efficiency, piglets are usually weaned and transited to independence at 21 to 28 days when they should actually be feeding on sow milk for at least 70 days post parturition and have a smooth transition to solid feed. At the same time, efforts to introduce piglets to creep feed during lactation yield low results, as there is variation in feed intake. These stressors – introduction of new feed, change in environment, maternal separation, mixing with other piglets – lead to feed refusal and/or reduced feed intake post weaning. Consequently, gastrointestinal tract inflammation and dysfunction and gut microbiota imbalance occur, usually resulting in diseases causing some mortality or growth reduction in piglets. Specifically, stress from maternal separation of neonates in mammals affects the transfer of passive immunity by antibodies in milk, which provide local immunity in the gut. Apart from this clear effect, *lactobacilli* from milk may disappear or reduce in the gut. Furthermore, the gut microbiota is significantly involved in the modulation of intestinal mucosal immune response, especially at early stages of life; hence, the need to ensure a balanced gut microbiota community if piglets are to maintain a healthy life. Currently, to ensure the health and welfare of piglets in such conditions, farmers use antimicrobials and zinc oxide supplemented in pig feed. However, the use of these substances will be limited across the European Union from 2022 due to antimicrobial resistance risks. On the other hand, there is no concrete agreement on the efficacy of probiotics, prebiotics and plant extracts as alternative approaches to managing the effects of the identified stressors on gut health and microbiota development. There is a need to apply nutritional approaches, and changes in environment, management practices and in human behaviour, to reduce the impacts of stress from early maternal weaning and transition to solid feed on piglets post weaning. A nutritional approach that needs more investigation is the use of milk bioactive fractions (MBFs).

Researchers at Teagasc and the University of León in Spain are collaborating on a project – Milkobiome – to explore how milk and microbiota affect intestinal health in pigs.

Milk bioactive fractions

Introducing MBFs (e.g., lactoferrin, oligosaccharide and milk fat globule membrane) in pigs' diet could potentially reduce gut microbiota imbalance and increase immune development, while effecting improved growth performance as well. They may potentially replace the use of antimicrobials and zinc oxide. Recent studies involving other mammalian species have shown many and diverse bioactivities by MBFs. Generally,

The Milkobiome project will explore how milk and microbiota affect intestinal health in pigs.

piglet diet is similar to infant milk, and in many cases, piglets are used as animal models for human nutrition. Hence, several studies have attempted to validate the efficacies of human or bovine MBFs using a pig model.

Porcine milk lactoferrin

Most studies on MBFs are related to the use of MBFs from other mammalian species, especially human and bovine. With the observed impacts of MBFs from other species, using a pig model, the question is: can porcine MBFs potentiate the same effects on pigs, and hence improve gut microbiota balance, gut health and development? While porcine milk contains MBFs, little is known about their potential to exert positive effects on gut health and microbiota.

Milkobiome project

Researchers at Teagasc and the University of León in Spain are collaborating on a project – Milkobiome – to explore how milk and microbiota affect intestinal health in pigs. The project aims to develop novel feeding and management strategies to improve gut development (microbiota balance and intestinal integrity), immune development and overall growth performance in piglets post weaning using MBFs in comparison to zinc oxide and antimicrobials. Initial studies at the University of León will identify and quantify MBFs in porcine milk; following this, proof of concepts using identified MBFs will be carried out at Teagasc.

Benefits to pig industry

The estimated production of pig meat will increase to 23.34 million tonnes in 2026 in the European Union. It is therefore hoped that this research will contribute to the success of this increase in the pig meat industry. Findings from the research will potentially support pig farmers in transiting from antimicrobials and in dealing with the challenges of post-weaning diarrhoea on farms.

Acknowledgements

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Understanding the genetics behind mushroom production

TEAGASC research has characterised the genetic activity in mushroom mycelium when mushrooms are actively being produced. This has identified clusters of key genes that mirror crop productivity, as well as genes with interesting expression profiles.

The mushroom industry in Ireland is acknowledged to be one of the best in the world, growing high-quality *Agaricus bisporus* mushrooms for export. It is the largest horticultural sector in Ireland, with a farm gate value of €119 million in 2019, with over 80 % exported to the UK. The industry has improved productivity through harvester training, efficiencies in crop management and increases in compost and casing quality, to a point where average yields are in the region of 30 kg of top-class fresh mushroom product/m^2 – some of the best yields in the world. Significant nutrition remains in mushroom compost at the end of the normal three-flush cropping cycle, so there is potential to increase substrate utilisation, especially in the third flush; however, more information is needed on what mushroom genes relate directly to crop productivity (**Figure 1**).

Microarray analysis

Microarray analysis of gene expression in the compost over the course of a crop was done using custom-designed Agilent microarrays that are available for *A. bisporus*, and which cover the whole genome. Compost samples were obtained every 48 hours from day 13 of the crop cycle until the end of the third flush harvesting (day 37) – 13 time points in total – for comparison to samples taken on day 11. Labelled cRNA was extracted from the compost samples, hybridised to the microarrays, and gene transcript levels were calculated using the appropriate software. Putative temporal gene expression profiles were then identified by comparing transcript levels at each time point with the level detected at day 11 – a time point before the production of mushrooms had started. Using statistical and bioinformatic analysis, the profiles were grouped into clusters of genes with similar expression profiles.

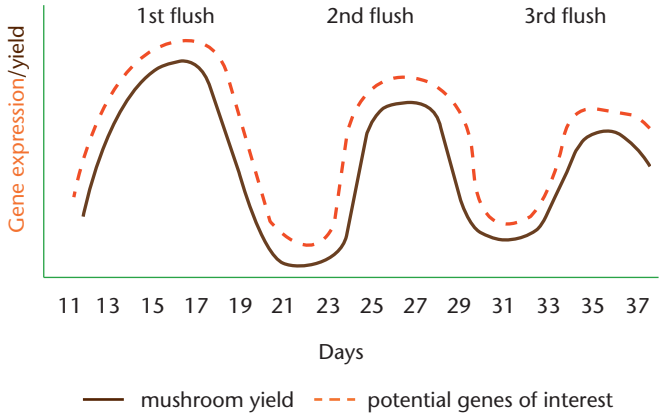

FIGURE 1: Gene expression and yields over the normal three-flush cropping cycle.

Protein expression

Protein expression in compost samples was also measured for seven time points, taken before, during and after the first flush. Proteins were extracted and purified for LC-MS/MS and all of the *A. bisporus* proteins present were identified. Using bioinformatic analysis these proteins were functionally annotated. Fold change calculations were used to identify significantly up- and down-regulated proteins at each time point and compared to the earliest time point to examine differential protein abundances over the first flush cropping period.

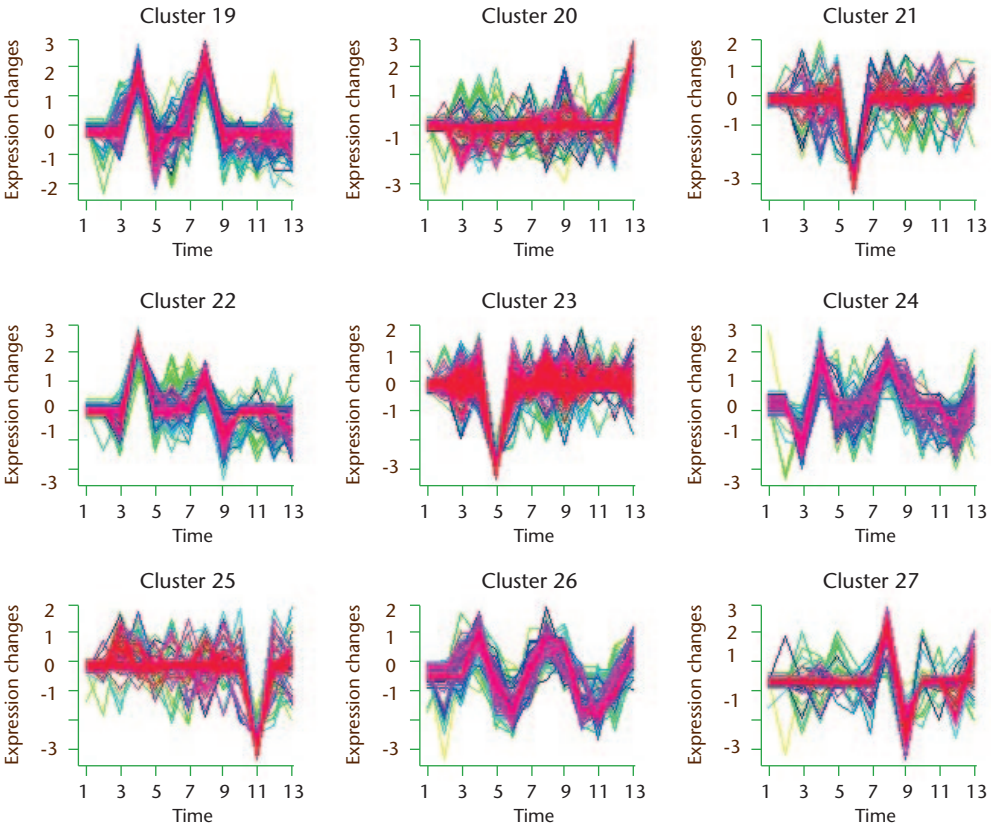

FIGURE 2. Gene expression patterns of A. bisporus *genes.*

Gene clusters and proteins

The gene expression profiles identified by microarray analysis indicated that around 2,000 (20 %) of the *A. bisporus* genes were differentially expressed during the period when mushrooms were being actively produced and these could be aggregated into 40 clusters, each with a distinct expression pattern (see examples in **Figure 2**). Some clusters correlated with the rise and fall of mushroom yield associated with the first, second and third flushes of mushrooms (cluster 26), while some gene clusters were switched on (cluster 20) or off (cluster 19) during the third flush, when mushroom yield was rapidly decreasing. This provides a large bank of data that can be interrogated regarding which genes influence the production of mushrooms. Cluster 26 contained many genes known to be involved in lignocellulose degradation, the main component in mushroom compost. These data have now generated a transcriptomic atlas of *A. bisporus* during mushroom substrate utilisation, which can be referred to with a high degree of confidence. Proteomic analysis identified 558 *A. bisporus* proteins in the period spanning before, during and after the first flush. It was found that the total number of proteins changed similarly to the transcriptome data, but when the gene expression patterns were compared to the proteome data, the proteins took longer to reach their peak.

Opportunity/benefit

This project has increased our understanding of what genes are active or inactive when mushrooms are growing and accessing nutrients from the substrate. This information will enable mushroom breeders and scientists to identify new and interesting genes and pathways that are important for the growth of the mushroom.

Acknowledgements

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Accelerating white clover breeding in Ireland

A TEAGASC project is developing approaches to accelerate delivery of improved white clover varieties that will contribute to the economic and environmental sustainability of grassland agriculture.

White clover in grassland agriculture

White clover can contribute to both the economic and environmental sustainability of pastoral-based production systems. Teagasc research demonstrates that incorporating white clover into grazing swards provides additional nitrogen (N) for herbage production (pastures receiving 150 kg N/ha had similar yields to perennial ryegrass-only pastures receiving 250 kg N/ha) and provides higher-quality forage leading to increased milk yields relative to grass-only swards. Furthermore, the incorporation of white clover into pastures has been identified as a greenhouse gas mitigation measure by Teagasc's Mitigation Abatement Cost Curve (MACC) analysis. Breeding new cultivars of white clover to support pastoral-based production systems is therefore a critically important goal for Ireland.

Breeding new varieties of white clover

Teagasc has been breeding white clover at Oak Park since the 1960s. Five new cultivars have been commercialised in the last 10 years. A typical white clover breeding programme uses genotypic recurrent selection to evaluate the genetic merit of candidates from progeny performance. This is facilitated through evaluating full-sib progeny in field plots in combination with perennial ryegrass over at least three years (following an establishment year) under mechanical cutting and sheep grazing. Evaluation in swards is crucial for improving traits like forage yield and compatibility with perennial ryegrass. Once the best full-sib families are identified, plants are selected within these families as parents to produce an improved synthetic population.
This process represents a single cycle of selection and takes at least seven years to complete from initial pair-crosses to producing a new synthetic population. However, there are opportunities to accelerate genetic gain by using new technologies to reduce the length of the selection cycle and increase selection intensity.

Genomic selection in plant breeding

In recent years there has been an increased interest in the application of genomic selection in plant breeding, an approach to accelerate genetic gain. This has mainly been driven by a reduction in the cost of DNA sequencing and the availability of reference genomes for many plant species (the white clover genome sequence was published in 2019), making it now feasible to characterise genetic variation across large plant genomes. Genomic selection is a form of DNA-assisted selection that uses genome-wide DNA profiles to calculate genomic estimated breeding values (GEBVs). Selection of plants to use as parents for the next generation are subsequently based on GEBVs, thereby avoiding the need to evaluate the progeny of these plants in field trials. Crucially, calculating GEBVs and recombining selected plants can be completed within a single year, which in the case of white clover enables up to seven cycles of selection to be completed in the same time it takes to complete a single cycle with field evaluations. In white clover, genomic selection offers a huge opportunity to accelerate genetic gain for important traits such as yield and persistency.

Developing genomic selection models for forage yield

In order to develop genomic selection, we needed a reference population that had been: (i) genotyped with genome-wide molecular markers; and, (ii) accurately evaluated for the target traits under selection (**Figure 1**). At Teagasc Oak Park, we were able to

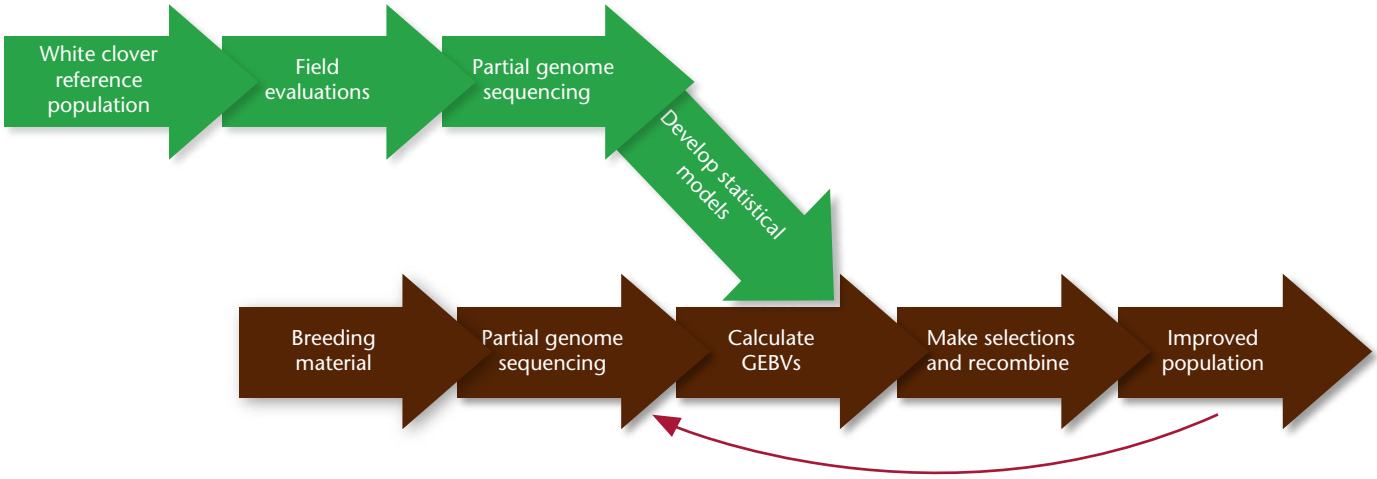

FIGURE 1: Developing genomic selection in white clover. In order to develop genomic selection, a reference population needs to be both genotyped with DNA markers and evaluated for target traits in multi-year field trials. These data are then used to develop statistical models that will enable us to predict a plant's breeding value when only presented with its DNA marker profile. Once prediction models are developed (steps shown in green) they can then be applied to white clover breeding material (steps shown in brown). This involves genotyping selection candidates with molecular markers by partially sequencing their genomes and using the prediction models developed above to calculate genomic estimated breeding values (GEBVs). Selections are then made using these GEBVs and plants are crossed to produce a new and improved population. Another cycle of genomic selection can then be completed using the new population as a starting point. New field evaluations are carried out to update and improve the statistical models.

exploit historical performance data that had been collected on more than 200 full-sib families over a three-year period from 2009-2011. White clover families had been transplanted into plots of perennial ryegrass (common variety across all plots) and total forage yield was measured at up to eight cuts each year.

Seed existed for each family and this was used to characterise DNA sequence variation across the genome of all families. This was achieved by sampling and sequencing a small region of the genome in each family, which enabled us to identify over 100,000 positions that showed variation among the white clover families. Associating genome variation with variation in field performance allowed us to build genomic prediction models for seasonal forage yield. These models can now be used to generate GEBVs for a new line when only provided with its DNA information. The advantage this offers is that DNA information can easily be obtained from three-week-old seedlings, meaning selections can be made without the need to develop full-sib families and carry out field evaluations. This reduces the length of a cycle of selection from seven years to a single year.

What are the next steps?

It is expected that we can more than double the rate of genetic gain for forage yield in white clover using the models developed at Oak Park. The next steps will involve taking these models and applying them to quantify genetic gain over multiple cycles of selection. This will enable us to validate prediction models while simultaneously developing new and improved synthetic populations.

Genomic selection in white clover will accelerate genetic gain for key traits such as forage yield. This will contribute to an increase in on-farm profitability through reduced inputs and increased productivity due to a better nutritional profile.

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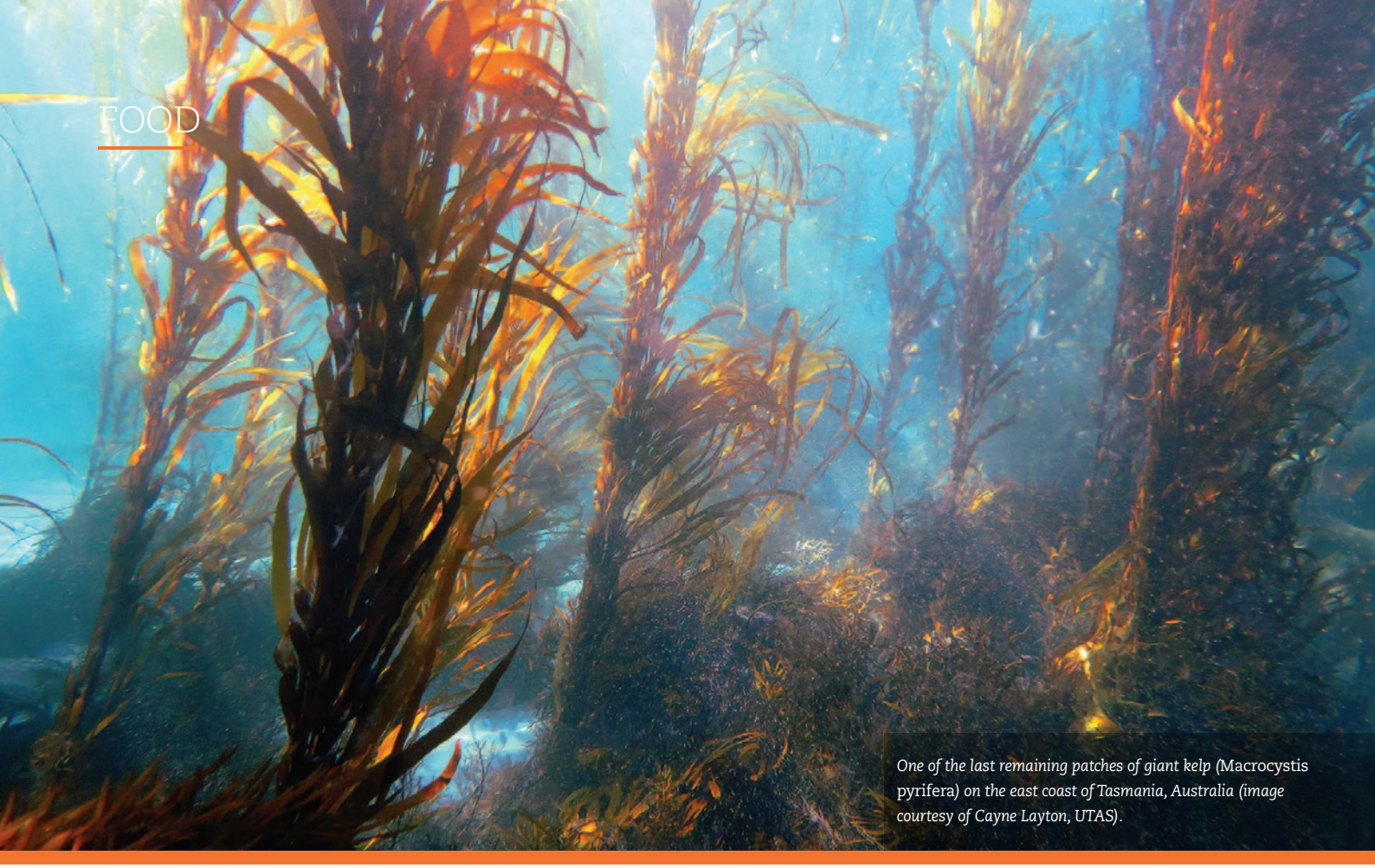

*One of the last remaining patches of giant kelp (*Macrocystis pyrifera*) on the east coast of Tasmania, Australia (image courtesy of Cayne Layton, UTAS).*

The future is kelp!

Researchers at TEAGASC and the Cawthron Institute, New Zealand, are looking at bioproduct isolation from native Irish and New Zealand macroalgal species.

Background

Seaweed has a rich history of use in Asia as food and medicine, and in Ireland it was used as a fertiliser and animal feed (Morrissey *et al.*, 2001). At present, the range of seaweed products spans food, feed, dietary supplements and pharmaceuticals, with bioenergy intermediates and materials. This range of products is attributed to the biological properties of constituents from seaweeds. Kelp is the common name for one order of brown seaweeds, Laminariales, which includes approximately 30 genera. The word 'kelp' originally described the burnt ash of brown seaweed. Kelp species range in size from several centimetres to over 50 metres for the giant kelp found off the coast of Australia, New Zealand, California, and South America. The maximum length for Irish kelp species is four to five metres.

The ALGIPRO research project focuses on two kelp seaweeds: *Laminaria digitata (L. digitata)*, a native Irish species; and, *Macrocystis pyrifera (M. pyrifera)*, a native New Zealand species. *L. digitata* has several common names, including in English oarweed or in Irish leathrach or coirrleach. *L. digitata* is a very common kelp found in low-level waters around the Irish, north European, and eastern North American coast, and can grow up to 2.5 metres long and 60 centimetres wide. Surveys of the Irish coast have found *L. digitata* around the entire Irish coastline, with 56 % of the coast from Donegal to Cork having some level of kelp coverage (Hession *et al.*, 1997). *M. pyrifera* is commonly known as giant kelp and is considered one of the fastest growing kelp species, with one individual growing to more than 45 metres, at a rate of as much as 60 centimetres per day.

Benefits to industry

Within a commercial context, the global seaweed industry is worth just under €5 billion per annum, with 85 % of this used for human consumption, and seaweed-based polysaccharides (carrageenan, agar, and alginates) accounting for almost 40 % of the world's hydrocolloid market. In Europe, brown seaweeds are traditionally used to produce additives (e.g., alginates) or animal feeds in the form of meal.

Almost 300 seaweeds have been investigated for their commercial potential, yet only five genera and 10 species provide 98 % of the seaweed required by the seaweed industry. Interestingly, *L. digitata* and *M. pyrifera* are not included in this list of utilised species.

In 2016, the *L. digitata* global wild harvest yielded ~45,000 tonnes,

and the yield of *M. pyrifera* was 31,835 tonnes, yet *M. pyrifera* only produced ~1 tonne through aquaculture, indicating the potential to increase this volume significantly, which would also protect the native kelp forests from further exploitation.

New knowledge from ALGIPRO

ALGIPRO is focused on these two relatively untapped kelp species for their aquaculture potential to produce kelp bioproducts at a viable commercial scale. This is being pursued through two aspects: firstly, optimised cultivation strategies to improve both the speed of biomass production and also the quality and quantity of bioproduct being produced; and, secondly, optimised extraction through scalable, less environmentally impactful extraction approaches. This will enable improved biomass recovery and conversion to viable products, as well as a reduction in solvent use and extraction costs, which is the area where commercial viability bottlenecks currently occur. Current cultivation trials using *M. pyrifera* are applying factorial analysis of cultivation conditions and concentrating on temperature in the first trial, and then light in the second trial. Recent studies have shown that these conditions significantly impact biomass production and algal health. Initial results from field samples indicate that the protein percentage of dry weight (DW) exceeds 12 %. The aim of this aspect of the study is to mimic optimised field conditions within an aquaculture environment. Regarding optimised extraction at scale, preliminary tests are being carried out at the Cawthron Institute in Nelson, NZ, where the analytical chemistry team is testing extraction protocols on cultivated *M. pyrifera*. The return phase of this Marie Curie co-funded fellowship with Teagasc will focus solely on the optimised, scalable extraction strategies, comparing conventional extraction systems with several new systems including microwave-assisted extraction (MAE), enzyme-assisted extraction (EAE) and pulse electric field (PEF) extraction.

Conclusion

The overall aim of this project is to produce viable bioproducts from these two species sourced for their protein and polysaccharide content. This project is included under the marine farm context and fits appropriately under the European Union's new 'Farm to fork' directive, investigating the marine farm potential of the native Irish kelp, leathrach.

Funding

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Acknowledgements

We acknowledge the assistance of the Analytical Science Team at Cawthron Institute in processing and analysing samples for this project.

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Functional food ingredient development from mesopelagic fish

The MEESO project is investigating the potential for functional food ingredients from mesopelagic fish.

Mesopelagic fish species include *Maurolicus muelleri* (Mueller's bristle-mouth fish), *Micromesistius poutassou* (Blue whiting) and zooplankton such as *Euphausia superba* (krill) (**Figure 1**).

The peculiar environmental conditions that exist in the ecological zone known as the 'twilight zone', including high pressure and darkness, along with the position of mesopelagic fish at the bottom of the food chain, result in a lot of diversity in their bio-composition. Mesopelagic fish are currently an underutilised resource despite the fact that they are rich in proteins, omega-3 oils, and other nutrients and bioactive ingredients (Alvheim *et al.*, 2020). They could afford processors novel opportunities to develop feed, food, and functional food ingredients and products. However, there is also a need to ensure that this resource is not overfished and that processing allows optimum use of the catch in line with UN sustainability goals and the reformed Common Fisheries Policy (CFP). Can organisms living at depths between 200 and 1,000 m in the ocean be harvested in an ecologically and economically sustainable way, or are they too vulnerable? This is the overarching question that the MEESO project, which looks at ecologically and economically sustainable mesopelagic fisheries – and in which Teagasc are research partners – seeks to answer.

Food production from sustainable fisheries is a responsible way to increase food supply without arable land, irrigation or fertilisers. Many forms of aquatic animals have smaller greenhouse gas (GHG) footprints than those that are land based, and are more efficient considering feed inputs and limitations from land or water availability. Consequently, shifting towards more 'blue' food-based diets has major potential to reduce GHG emissions. Furthermore, use of mesopelagic fish species as food ingredients has potential to improve human health. The EAT-Lancet Commission was clear about the health benefits of seafood within planetary boundaries, suggesting a reference diet consisting of 28 g of fish or shellfish per day (range 0-100 g), which is about one or two servings per week

FIGURE 1: Euphausia superba *(krill) and* Maurolicus muelleri *harvested from the twilight zone.*

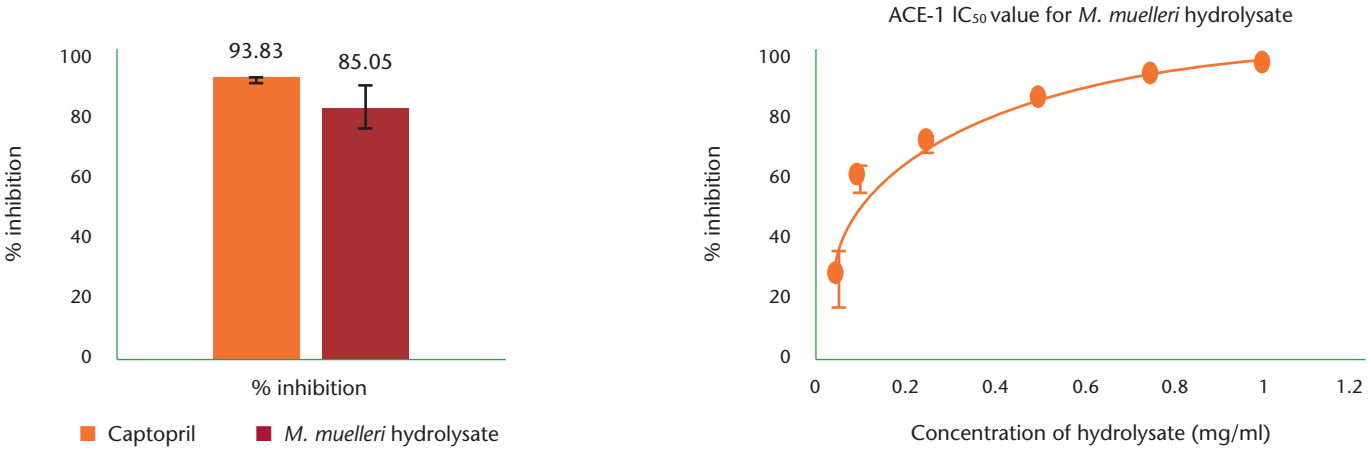

FIGURE 2: Inhibition of angiotensin-1-converting enzyme (ACE-1) by a hydrolysate of Maurolicus muelleri.

(Willett *et al.*, 2019). This recommendation is met by an increased health and environmental consciousness among consumers, which is reflected in an ongoing protein shift, i.e., the replacement of red meat by alternative protein sources.

The research

Work carried out in part by Azza Naik at Teagasc looked at protein extracts generated from mesopelagic fish including *Maurolicus muelleri*, the zooplankton *Euphausia superba* and combinations of these proteins using hydrolysis methods. Protein hydrolysates were generated by partners at Nofima and the University of Bergen using four different enzymes. Hydrolysates were characterised and assessed for their ability to inhibit enzymes important in diseases associated with metabolic syndrome. The ability of generated hydrolysates to inhibit enzymes, including angiotensin-1-converting enzyme (ACE-1; EC. 3.4.15.1) associated with blood pressure regulation, acetylcholinesterase (AChE; EC 3.1.1.7) associated with maintenance of the nervous system, and dipeptidyl peptidase IV (DPP-IV; EC 3.4.14.5) linked with development of type 2 diabetes, was determined. Hydrolysates generated contained greater than 60 % protein when analysed using the DUMAS method. A hydrolysate generated from *M. muelleri* inhibited ACE-1 by greater than 85 % when assayed at a concentration of 1 mg/ml compared to the positive control Captopril, and had an ACE-1 IC50 value of 0.1 mg/ml (**Figure 2**). Peptides were identified using a combination of high-performance liquid chromatography (HPLC) and mass spectrometry.

Conclusion

The abundant availability of fish and zooplankton (1×10^9 tonnes to 7×10^{10} tonnes) in the mesopelagic zone of the oceans is a source of novel raw materials that provides opportunities for sustainable bioprocessing. In this study, a mesopelagic *M. muelleri* hydrolysate was made with the ability to inhibit the enzyme ACE-1 – an enzyme responsible for development of high blood pressure in the renin-angiotensin-aldosterone system (RAAS). This hydrolysate could potentially have antihypertensive benefits to consumers. This work supports sustainable harvesting, while also helping to address EU health issues, including high blood pressure, through the creation of functional food ingredients.

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Alaria esculenta aquaculture in Ireland

TEAGASC researchers are investigating harvest and primary post-harvest methods of seaweed aquaculture for their potential contribution to environmental food production.

Seaweed aquaculture

Seaweed grows in great abundance and diversity in Ireland, where 500 species are found (Morrissey *et al.*, 2001). *Alaria esculenta*, also known as winged kelp, Irish wakame or badderlocks, is a brown seaweed (order Laminariales). It is a nutritious and valuable source of proteins and bioactives. Seaweed aquaculture is a relatively new addition to the aquaculture industry, particularly in the Western world, while commercial seaweed farms have been growing in scale in Asia for some time. The development of a seaweed aquaculture industry in Ireland opens up many novel markets; as an island nation with a strong historical association with macroalgae, Ireland is in a unique position to become an industry leader.

FIGURE 1: Alaria esculenta *aquaculture process. (Photos: Anthony Irwin, Dulra, Co. Mayo.)*

Process

An *A. esculenta* aquaculture process is shown in **Figure 1**. While relatively straightforward, it requires manual labour and time. First, ropes are inoculated with spores, which are carefully embedded in thin fibre resembling twine. These fibres can be produced on site or obtained from a farm with an operating hatchery. As hatchery conditions need close monitoring, it is sometimes more cost-effective to purchase spores from an external source.

The seeded rope is 'planted' at sea, at the designated aquaculture site. A holdfast is established to ensure anchoring of the plant to the line.

Harvest will occur at species-specific seasonal times throughout the year, involving manual cutting of the plant from the rope. Some companies have developed automatic systems for this step. The crop is then brought ashore for post-harvest treatment. Common post-harvest processes include washing, drying, blanching, milling and storing.

A second round of post-harvest processes such as fermentation, cavitation or extrusion can be carried out, usually by an external company.

Table 1: Blanching treatments used on *A. esculenta*.

Treatment	Blanching technique	Description
1	HW	Hot water conventional blanching (70 °C, five minutes)
2	M1000	Microwave, 1,000 W, 120 s
3	M800	Microwave, 800 W, 120 s
4	U100	Ultrasound, 100 %, 300 s
5	U50	Ultrasound, 50 %, 300 s
6	U50M800	Ultrasound, 50 % + microwave, 800 W, 60 s
7	U100M1000	Ultrasound, 100 % + microwave, 1,000 W, 60 s

Post-harvest blanching and drying: examination of impacts on: a) volatile; and, b) mineral content

Seaweed blanching has benefits for extending shelf life through enzyme inactivation, killing pathogens, preserving colour and keeping biochemical compounds intact.

Different blanching methods were tested for their impact on colour, volatiles and mineral composition remaining post treatment. These are important factors to be considered when choosing a method to employ on a commercial seaweed farm. The blanching methods used were: conventional hot water; novel ultrasound; and, microwave. In some treatments, ultrasound and microwave technology were used together, at different power settings (W) for microwave and different amplitude levels (%) for ultrasound (**Table 1**). Following this, the samples were either oven or freeze dried and analysed for outputs.

a. Volatile compounds retention

Over 76 different volatile compounds, from at least nine chemical groups, were detected in blanched and dehydrated *A. esculenta* (solid-phase microextraction (SPME) and gas chromatography–mass spectrometry (GC–MS) analysis). There were significant differences ($P<0.05$) in levels of all pyrazines, furans, amines, acids, alcohols, ketones and aldehydes between drying methods, and in alcohols between blanching treatments.

Overall, freeze-dried samples retained more volatile compounds than oven-dried, in terms of total quantity. However, oven-dried samples had a higher diversity of volatile compounds, with 67 compounds detected compared with 60 compounds detected in freeze-dried samples. Freeze-dried samples that underwent blanching treatments of M1,000 and U50M800 displayed the best retention of volatile compounds.

b. Mineral composition

Overall, blanching treatments had a significant effect ($P<0.05$) on sodium (Na), copper (Cu), iron (Fe) and manganese (Mn). Drying methods significantly affected ($P<0.05$) calcium (Ca), cobalt (Co), Cu and Fe. M1,000 samples had the lowest relative mineral content.

Sustainability

Seaweed aquaculture can play a crucial role in ecosystem stability and recuperation. Macroalgal primary production is part of the global carbon, oxygen and nutrient cycle (Chung *et al.*, 2011), and aquaculture systems should be designed with this advantage in mind. Seaweed aquaculture systems can provide habitats for many animals, namely benthic and mobile invertebrates, as well as fish, to whom seaweed can offer protection during the nursery stage (Skjermo, *et al.*, 2014). A measure of these positive impacts as an ecosystem service could be a key metric to promote for the industry.

Evaluated product

A. esculenta is a well-evaluated product rich in amino acids and polyunsaturated fatty acids like eicosapentaenoic acid (EPA) and stearidonic acid (SDA). It has significant potential for the functional food and nutraceutical markets as products with high added value (Afonso *et al.*, 2020). Its opportunities include as an alternative salt, a flour to enrich traditional flours or make healthy snacks, a powder to enhance beverages, or in capsule form for targeted delivery of benefits.

Summary

Sustainable seaweed production not only provides a valuable protein source to help feed demand for alternative proteins, but also benefits the environment. The automation of harvesting methods, as well as the selection of the most productive post-harvest methods, are important factors determining success of this new industry in Ireland.

Acknowledgement

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Milking DNA

Researchers at TEAGASC have evaluated methods to improve DNA sequencing of the milk microbiome.

Milk is an important source of nutrition for both humans and animals. Human breast milk is highly beneficial to a child's development and milk from animals, particularly cows, is widely consumed across the globe. The study of the microbial communities found in milk is necessary from the perspective of both human and animal maternal health. It is also important to understand the impact of these communities on the safety and quality of milk used for consumption. High-throughput DNA sequencing approaches have been a valuable tool in this regard, providing information on milk microbiomes to reveal beneficial or harmful bacteria. Targeted amplicon sequencing, which mainly uses the 16S rRNA gene (common to all bacteria), has been adopted for the study of many diverse microbiomes, such as the human gut and soil. Shotgun metagenomic sequencing, which analyses the DNA of an entire sample, provides much greater insights regarding the microorganisms present, what they can do, and even allows for the generation of metagenome-assembled genomes (MAGs). These MAGs provide essentially complete genome information for key microorganisms identified in the sample, as well as revealing additional functional and safety properties associated with the microbial community (Bowers *et al.*, 2017). However, as shotgun metagenomic sequencing is an untargeted approach, DNA from the host (human or animal) cells present in the milk is also sequenced, which in the case of milk represents a considerable majority (up to 95 %) of the DNA present. This high proportion of host DNA results in wasted sequencing capacity (lots of host sequence information that is not of microbiological interest) and insufficient sequencing depth of the microbial DNA. To address this challenge, we evaluated different methods to either deplete host DNA or enrich microbial DNA using commercially available kits.

Both bovine and human milk samples were used for the study. Bovine milk samples were collected from farms across Ireland and human milk was collected from mothers in the Microbe Mom study, following ethical approval and with informed consent. Milk samples underwent several washing steps to remove the sample fat before DNA extraction and host depletion/microbial enrichment with three methods. The three methods evaluated are the DNeasy PowerSoil Pro kit (Qiagen), MolYsis complete5 kit (Molzym Gmbh & Co.), and NEBNext Microbiome DNA Enrichment Kit (New England Biolabs). A 10-strain mock community (consisting of 10 known microorganisms) was spiked into a milk sample as a positive control. Shotgun sequencing libraries were prepared from the subsequent DNA samples before sequencing on the Illumina NextSeq 500 platform at the Teagasc Sequencing Facility. Bioinformatic analysis on the shotgun metagenomic reads assigned both taxonomy (names of microorganisms) and genetic functional potential (what these microorganisms can do) of the milk microbiome.

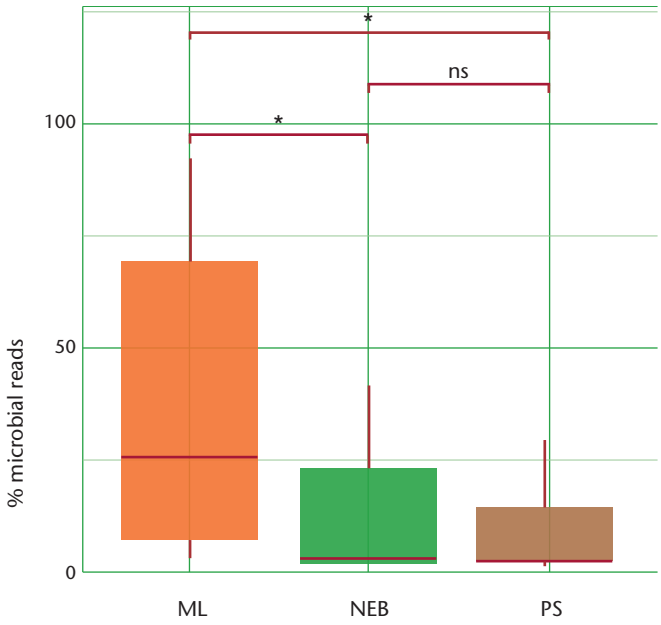

FIGURE 1: Comparison of mean microbial sequencing reads for all samples between the evaluated methods.

Results

We found that the MolYsis complete5 kit (ML kit) was efficient in depleting host DNA, enabling greater sequencing depth of microbial DNA compared to the other two kits evaluated (**Figure 1**). This method improved microbial reads by 20 %. Following bioinformatic analysis, we discovered that the choice of taxonomic classification tool had a

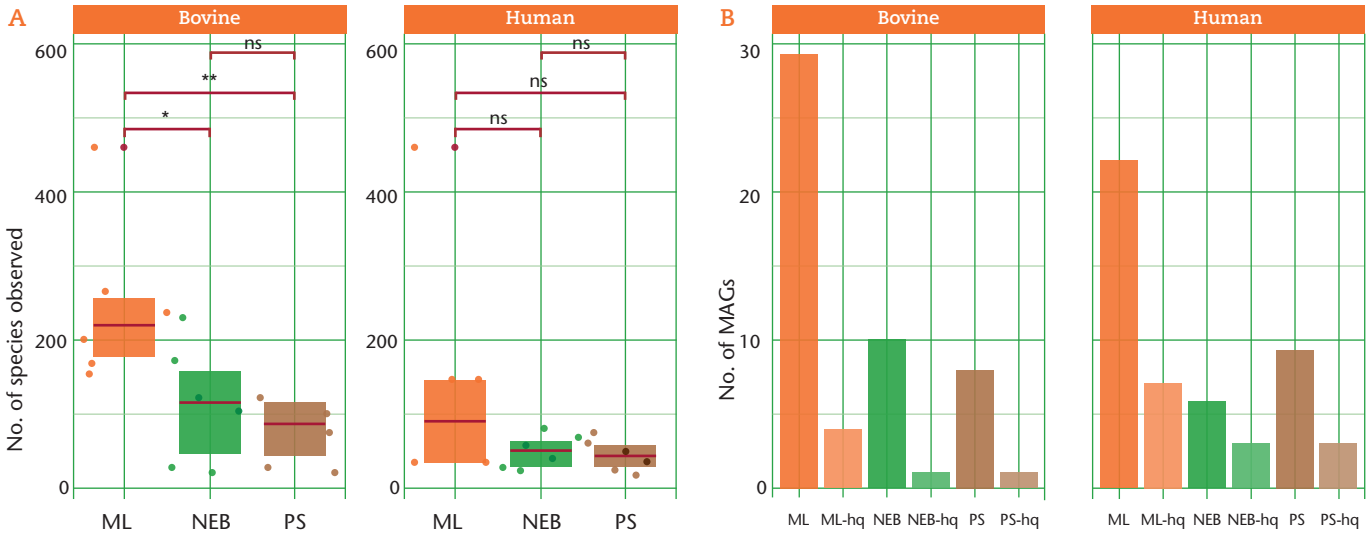

FIGURE 2: Better characterisation of the bovine and human milk microbiome was found for both observable species (a), and number of MAGs and high-quality MAGs (b) when the ML kit was used compared to the other two methods.

greater impact on the reported composition than the method used. The performance of taxonomic classification tools varied when milk samples containing the mock community were compared. Ultimately, one of these tools, Kraken2, was selected for further use as it performed best in terms of overall correct assignment and expected abundances of mock community DNA. The ML kit not only gave a significantly higher percentage of microbial reads, but the greater microbial sequencing depth enabled better characterisation of the milk microbiome after bioinformatics analysis. More unique bacterial species were detected, and more MAGs, and specifically high-quality MAGs, were recovered from the samples that used the ML kit than from the other two methods (**Figure 2**). Importantly, when comparing the community structure between methods, no biases were found.

Conclusion

Overall, this evaluation has addressed two important issues in metagenomic sequencing of the milk microbiome: specifically, poor microbial sequence depth and poor sequencing economics. The results show that the host depletion approach of the ML kit performed better than the enrichment or direct sequencing alternatives by providing the potential for deeper strain-level analysis without an observable bias. The improved sequencing of the milk microbiome that will be provided by this approach will be hugely beneficial in the agricultural, processing and clinical settings, as providing greater characterisation of the microbes present in milk samples can be used to inform food safety/quality practices and treatments.

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Promoting farm health and safety through discussion groups

A research initiative from TEAGASC, supported by the HSA, is looking at how discussion groups can improve farmer health and safety.

Discussion groups use a social learning approach.

Seeking effective knowledge transfer (KT) strategies to assist farmers to strengthen management of occupational health and safety (OHS) is the focus of the Teagasc/Health and Safety Authority (HSA) Joint Prevention Initiative. This Initiative commenced in 2005 following enactment of the Safety, Health and Welfare at Work Act (the Act).

Risk assessment

A cornerstone of the Initiative has been the development and rollout of the Farm Safety and Health Code of Practice and an accompanying Risk Assessment Document (RAD).

The RAD provides farmers, who are mainly self-employed, with a straightforward template to conduct a comprehensive risk assessment as required by the Act.

Research on the RAD has shown that farmers who implemented controls they specified had higher standards of OHS management. Where implementation did not take place, knowledge of hazards alone was not sufficient to gain implementation. This led to consideration of social learning through discussion groups as a stronger approach to promote farm OHS.

Discussion groups

Farmer discussion groups meet regularly (c. monthly) to exchange information and ideas on current farm management issues. They may also conduct other events, such as visits to other farms or away trips, projects or indoor meetings in winter. Discussion groups operate a democratic organisational structure, with a chairperson, and where tasks are delegated to various members. Groups are guided by a facilitator – either an advisor or consultant. Group members can also keep in contact and exchange information between meetings.

Social learning

Discussion groups practise social learning based on farmer-to-farmer interchange in a practical farm setting. Following a discussion group meeting, individual farmers consider farm management issues discussed and then follow up with implementing measures suitable for their individual farms. Discussion groups, as practised in Ireland, have been shown to increase both farm technology and practice adoption for improving farm management.

A theory of planned behaviour study among Irish farmers found that they are strongly influenced by peers in their intentions to adopt OHS (see *TResearch*, 10, 3:2015). Based on this background, it was decided to conduct a research study on the utility of discussion groups in promoting OHS adoption.

Teagasc facilitates about 800 discussion groups across all farm enterprises. It was decided to conduct this research with dairy discussion groups due to their long-established history, wide range of hazards and risks, and the relatively high accident rate among dairy farmers.

Study findings

A key positive finding in phase one of the study shows that 96 % of the 96 discussion groups participating in an initial survey (phase 1) discussed OHS at least once in 2016. Additionally, the majority of discussion groups focused on prevention strategies that are closely aligned with causes of fatal farm injuries. However, a number of important issues, including those related to chronic illness, such as sun and ear protection and timber work, received limited attention (**Figure 1**). In phase two, two discussion approaches were used to address four separate OHS topics: cows at calving; slurry; tractors; and, machinery. In one approach, groups discussed all the topics in a single group meeting, and in a second approach, groups covered one topic per meeting, for about 20 minutes, over four meetings. A control treatment was also implemented where no OHS topics were discussed.

A collaborative design approach was used to design the intervention. Teagasc advisors and specialists from several disciplines were engaged in this process to ensure that the interventions devised would be engaging and feasible, and previously used approaches were considered.

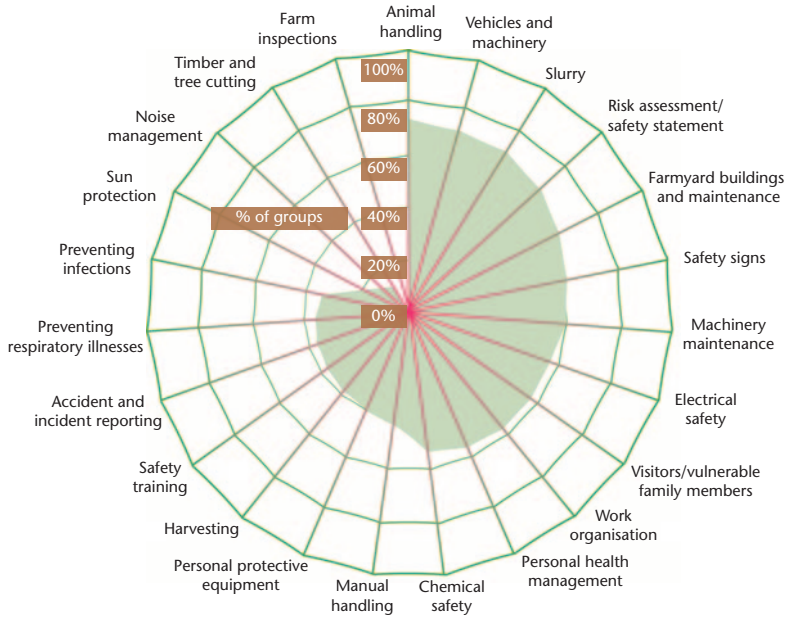

FIGURE 1: Percentage of dairy discussion groups discussing each OHS topic in 2016 (n = 96).

Interpreting a spider diagram

The spider diagram is constructed so that zero is at the centre and 100% is at the outer edge. The % of groups discussing each aspect of farm OHS management is shown in the diagram.

The research findings in phase two indicate that both the single discussion approach and series of short discussions were useful for strengthening both farmers' intentions to work in a safe and healthy way, and to succeed in their efforts to act on those intentions. Comparing the two approaches, the "often, short and focused" shorter discussions approach was most strongly associated with an increase in action taken to increase safety.

Farmers' safety behaviours before and after the intervention pilot were also examined in phase two. Before the intervention, most farmers considered themselves safe (96 %), but 82 % intended to increase their safety practices, indicating self-awareness about safety shortcomings. In the short OHS-focused discussions, a statistically significant increase ($p<0.05$) occurred in the average implementation of two practices, suggesting that OHS engagement frequency influences safe practice implementation.

Discussion enjoyable

A number of advisors reported that groups enjoyed the "often, short and focused" approach in particular and were enthusiastic about the discussions. Furthermore, the discussions were appealing to farmers in different life stages, and with different farming strategies and performance goals. This reflects the universal nature of many farm OHS issues for farmers, as regardless of their number of years of farming experience, farm performance and farm size, many of the risks they face within a particular enterprise are similar.

Study implications

The findings of this study have implications for future OHS promotion research and the design of effective OHS promotion initiatives. While advisors considered the designs feasible during the design phase, advisors and farmers in a number of groups experienced challenges during their implementation. This indicates that the OHS promotion strategies should be optimised to meet the needs of different group contexts, including adaption of the strategies to each individual group by the farmers and advisor.

The critical difference between life and death is how farm risks are managed, and strong support networks that promote effective risk management, such as discussion groups, can help farmers to invest effort and resources in preserving life and health.

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Outlook 2021 – Brexit trade deal avoids large drop in farm income

The latest Outlook 2021 report by TEAGASC economists forecasts that the average family farm income in Ireland will increase by 3 % in 2021. Overall, some price inflation for farm inputs will be more than offset by higher prices for some farm outputs.

Brexit deal – EU-UK Trade and Co-operation Agreement

As 2020 came to a close and in the absence of a Brexit deal, Teagasc economists forecast an 18 % drop in average family farm income (FFI) in 2021. However, this latest revised Outlook Report takes into account the EU-UK Trade and Co-operation Agreement (TCA), which emerged on Christmas Eve of last year, providing for tariff-free access to qualifying goods. At least for the short to medium term, the TCA maintains Ireland's preferential market access to the UK market.

This has ended the prospect of a worst case impact on trade between the EU and UK. High tariffs on trade in agricultural goods would have been triggered on January 1 of this year had a trade deal not been agreed. Ultimately, the deal that has been agreed allows for continued tariff-free trade between the UK and EU, but it does mean that some new impediments to trade have emerged, in the form of customs, product certification checks and rules of origin checks. These checks arise as the UK has now left the EU Single Market and Customs Union, a system which for many years had facilitated trade without the need for such checks. While these new checks have made agri-food trade more cumbersome, they will in large part allow such trade to continue.

General market prospects for 2021 reflect a relatively stable outlook in terms of farm commodity prices. Given the Brexit trade deal now in place, Irish exports to the UK should not change appreciably in 2021.

Farm output and inputs 2021

Irish farm output prices are projected to increase marginally in 2021 for milk, while prices are set to rise about 4 % in the case of cattle and lamb. Pig prices are set to fall by 10 % in 2021, but this relates to reduced demand for EU pig meat exports and is unrelated to Brexit. International prices for cereals at harvest 2021 are expected to be slightly lower than 2020 harvest prices overall, due to projected increases in supply (**Figure 1**). In terms of farm inputs, there are a few cost pressures emerging in 2021, notably for fertiliser and, to a lesser extent, feed and motor fuel. Overall, costs of production are forecast to increase slightly in 2021.

Given the Brexit trade deal now in place, income movements on dairy and cattle farms should be fairly limited in 2021. 'Cattle other' (largely cattle finishing) and cattle-rearing systems should see an increase in income of 3-6 % in 2021, with higher production costs being offset by higher cattle prices.

On dairy farms, a marginal increase in milk prices coupled with an increase in milk output should be sufficient to offset higher production costs in 2021. Therefore, the average dairy farm income in 2021 is likely to be unchanged on the estimated 2020 level.

With Irish lamb prices expected to increase, the average sheep farm income is forecast to increase by 6 % in 2021, with many sheep farms also forecast to benefit from price improvements for their secondary cattle enterprise.

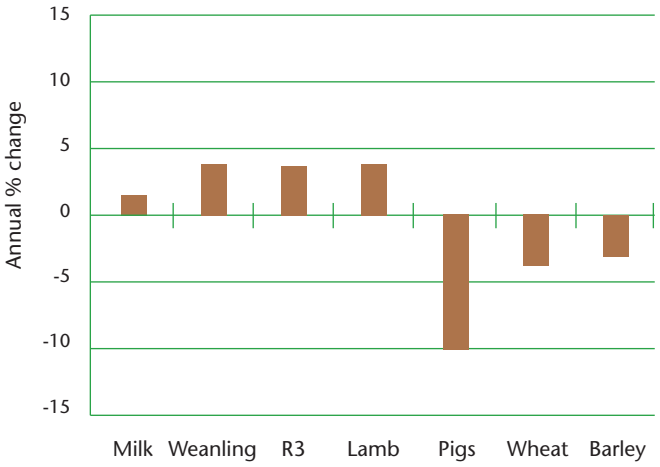

FIGURE 1: Forecast change in output prices 2021 vs 2020.

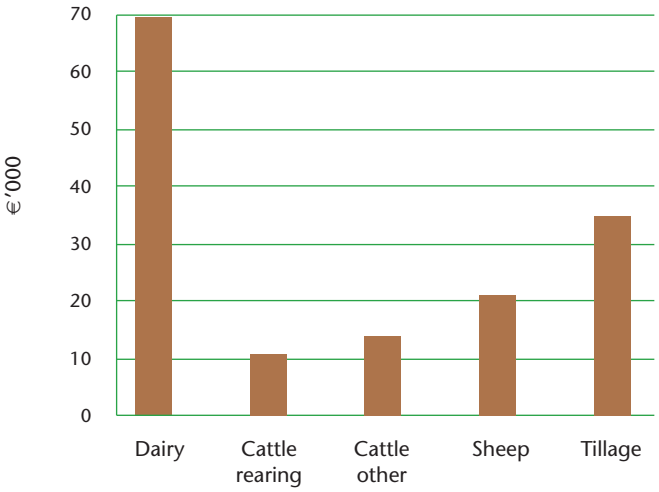

FIGURE 2: Average family farm income forecast 2021.

2021 – Trade post Brexit

- The EU and UK reached a Trade and Cooperation Agreement (TCA) on December 24, 2020.
- The TCA came into provisional effect on January 1, 2021.
- In 2021, qualifying exports from the UK to the EU can claim tariff-free access to the EU.
- In 2021, qualifying exports from the EU to the UK can claim tariff-free access to the UK.
- UK customs checks are only fully applied from January 1, 2022, while EU customs checks have been fully applied since January 1, 2021.

Tillage farms should see a significant improvement in farm income in 2021. The main drivers of this increase will be a higher level of cereal production, additional income from the secondary beef enterprise present on many of these farms, and a pilot straw chopping scheme. Collectively, these factors could be sufficient to increase tillage farm incomes by 17 % in 2021.

Family farm income 2021

Reflecting the agreed Brexit trade deal, the average FFI in 2021 is forecast to increase by a little over 3 % to about €25,600, as detailed in **Figure 2**. This compares to an anticipated reduction in farm income of 18 % in 2021 had no Brexit trade deal been agreed. It is estimated that the Brexit trade deal has avoided an income reduction in excess of €470 million for the Irish agricultural sector in aggregate in 2021.

This income forecast anticipates no dramatic movement in international product prices in 2021, reflecting an assumption that Covid-19 does not lead to any further significant market disruption.

Further detailed information is available in the revised Teagasc Outlook 2021, Economic Prospects for Agriculture, at www.teagasc.ie/media/website/publications/2021/Outlook2021revised.pdf.

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Building gender and diversity into innovation projects

Research and innovation require diverse knowledge and ideas to address complex problems. For this reason, state-of-the-art research and innovation builds gender and diversity into research projects.

Introduction

EU research programme policy and design is recognised as world leading in how it incorporates gender into research and innovation projects. The transition from Horizon 2020 (H2020) to the new Horizon Europe programme has been marked by greater gender equality initiatives, such as mandatory equality plans for applicants. The business case for including gender and diversity in research is simple: research excellence and innovation requires addressing gender and diversity because sex and gender bias produce poor scientific results and impede innovation. Now more than ever, there is a need for research to find innovative solutions to urgent and complex problems. The multi-actor approach has been adopted at an EU level as a means of bringing together diverse actors and stakeholders, to generate new knowledge and better solutions. Diverse groups are recognised as positively contributing to high-performing teams, while involving those directly impacted means solutions are designed that meet their needs and are more likely to be adopted.

> Female farmers frequently have to prove they are 'real farmers', while much human health research is only recently beginning to recognise the importance of gender and sex in designing solutions by, with and for women and men.

What do diversity and gender mean?

Diversity encompasses a range of categorisations, such as gender, race, age and marital status. The sociological concept of

intersectionality originates from the fields of social justice and activism. Intersectionality critically examines intersecting categories of difference along with associated power relations, and how these shape experiences, opportunities and outcomes for individuals and social groups. Put simply, social groups – differentiated according to gender and other features, such as cultural values, economic wealth, and educational attainment – have different types of opportunity and are included to greater and lesser extents in how opportunities are pursued. 'Everyday racism' (Naughton, 2016) or forms of bias, often expressed subtly in how social groups behave towards each other, compromise the rigour of innovation processes. Powerful group norms become the 'status quo' and less powerful groups can regard themselves as not relevant to innovation and/or often must work hard to be at the decision-making table. Female farmers frequently have to prove they are 'real farmers', while much human health research is only recently beginning to recognise the importance of gender and sex in designing solutions by, with and for women and men.

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Research excellence

H2020 and previous EU research programmes have provided practical research guidelines to address gender equity, using these areas to assess research project proposals and performance against three gender criteria. These gender criteria are: fostering gender balance in project teams; ensuring gender balance in decision making; and, integrating the gender dimension into research and innovation content.

What have we learned from other research projects?

LIAISON and FAIRshare are two current H2020 projects involving Teagasc that have utilised H2020 gender criteria within their project work. The LIAISON project consortium elected a gender delegate at an early stage from within their project team, to act as a contact point to address any concerns and to ensure gender was addressed within project work. This delegate is a permanent actor at all project meetings and decision-making processes. All matters are assessed through a lens of gender. This gender delegate role has raised awareness of gender at consortium meetings and dealt with practical gender queries in project work, as they arise. Periodically, the gender delegate assesses how the project is performing against the three H2020 gender criteria, with a comprehensive survey administered at the project midpoint as an awareness-raising exercise. The FAIRshare H2020 project built on this initiative in LIAISON, using a survey for self-assessment to see how the FAIRshare project team has been performing. It adapted the survey tools utilised by LIAISON. The survey has demonstrated that the project team has achieved gender balance at project team level, with gender balance also at decision-making level. The survey has been important as a means to raise awareness of gender, particularly in a project at the nexus of digital technology and agriculture.

Conclusion

Gender and diversity are resources available to researchers, and when integrated appropriately within a research project, they will produce research excellence. H2020 gender criteria provide a framework, a means of achieving research excellence and, together with a focus on intersectionality, will ensure inclusion and state-of-the-art research and innovation. Teagasc social scientists have the knowledge and tools to support meaningful incorporation of gender and diversity considerations in research and innovation projects.

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March

March 31 (9.30am-10.30am)

TEAGASC RESEARCH INSIGHTS WEBINAR: INCREASING THE VALUE OF BEEF FROM THE DAIRY HERD

This webinar is the final of three sessions discussing modern-day strategies to identify genetically elite farm animals. Join Teagasc researchers in this webinar to learn how the co-evolution of breeding and management strategies can deliver on maximising the value of beef from the dairy herd; this can be best achieved by selecting genetically elite beef sires and implementing best management practices in dairy beef systems. Decision support tools such as the dairy-beef index to identify beef bulls suited for mating to dairy females are now being actively used; this index, which is based on the principles of other successful national breeding indexes, attempts to marry the needs of both dairy and beef producers. Harnessing this genetic superiority through associated optimised grass-based management systems will help to ensure a return on investment that is resilient to external factors and also responsible in terms of social acceptability stewardship of the environment.

Contact: donagh.berry@teagasc.ie
https://www.teagasc.ie/about/research--innovation/teagasc-research-insights-webinars/

MAY

May 6 to 7

VIRTUAL INTERNATIONAL CONFERENCE ON FOOD DIGESTION 2021

Due to the Covid-19 pandemic, the physical International Conference on Food Digestion was postponed to May 2022. This virtual event, hosted by the INFOGEST research network, is being held in order to mark the occasion and to give researchers, especially PhD students, an opportunity to present their results on an international stage. The conference will cover six themes relating to food digestion held across two days: May 6 (11.45am to 5.00pm) and May 7 (7.30am to 2.00pm). The seventh session will be a live session from Australia and New Zealand, on the morning of May 7.

Contact: andre.brodkorb@teagasc.ie
linda.giblin@teagasc.ie
https://www.cost-infogest.eu/ACTIVITIES/Virtual-ICFD-2021

JUNE

June 21 to 23

EUROPEAN SEMINAR ON EXTENSION AND EDUCATION CONFERENCE 2021

The European Seminar on Extension and Education (ESEE) conference is a major biennial event that presents new research on agricultural extension and education. ESEE21 will be hosted by Teagasc Ballyhaise College in collaboration with University College Dublin and CAFRE in Northern Ireland. Due to Covid-19 restrictions, the conference will be delivered online. The title of the 2021 conference is 'Learning for Life. Continuous innovation support through extension and education for sustainable farm communities'.

Contact: esee2021@teagasc.ie
https://esee2021.ie/

June 22 to 24

BOVINE PAN-EUROPEAN GENERAL ASSEMBLY

The French Livestock Institute, IDELE, will host the project's fourth pan-European General Assembly meeting from a beef cattle experimental farm named les Etablières in the Pays de Loire region in the west of France. At this event farmers and researchers will hear of the latest research innovations and on-farm good practices from various members of the BovINE team. BovINE is an EU-wide network, led by Teagasc, focused on knowledge exchange through its online platform – the BovINE Knowledge Hub – our Network Managers based in nine EU countries, and our online and face-to-face meetings (when travel returns). Keep up to date with forthcoming events and opportunities that BovINE offers to all involved in cattle farming via our website and social media accounts.

Contact: richard.lynch@teagasc.ie
maeve.henchion@teagasc.ie
www.bovine-eu.net
Twitter @bovine_eu Instagram @bovine_eu Facebook @bovineeu

OCTOBER

October (date tbc)

FOOD INNOVATION GATEWAYS – INNOVATIVE AND SUSTAINABLE DRYING TECHNOLOGIES

Food Innovation Gateways is part of the Teagasc Food Technology and Knowledge Transfer Strategy to support Irish food companies. The Gateways initiative promotes opportunities for the Irish food industry to engage with Teagasc. The subject of the next Gateways event is 'Innovative and Sustainable Drying Technologies' and it will be held as a virtual event. Researchers from Teagasc will present the latest concepts and technologies in dairy processing capabilities at this virtual event, including spray drying, powder analysis and next-generation dehydration technologies. Registration details will be announced closer to the date.

Contact: eoin.murphy@teagasc.ie
https://www.teagasc.ie/food/research-and-innovation/research-areas/food-industry-development/food-gateways/

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For presentations from previous Teagasc events, see www.teagasc.ie/publications