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Research

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Searching for a cure

PIECE OF CAKE

WHITE CLOVER AND DAIRY

GENETICS AND SITKA SPRUCE

teagasc
Agriculture and Food Development Authority

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

ADMINISTRATOR *Ann Kane* ann.kane@teagasc.ie

EDITORIAL STEERING GROUP

Catriona Boyle, Eric Donald, Tim Guinee, Anne Kinsella, Paul O'Grady, Declan Troy, Stephen Butler, Niall Farrelly, Richard Hackett, Gary Lanigan, Edward O'Riordan, Miriam Walsh, Michael Diskin, Helen Grogan, Ann-Marie Hardiman, Sinéad McCarthy, Brijesh Tiwari

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TResearch Teagasc, Oak Park, Carlow, **R93 XE12**

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T: 01 856 1166 E: ann-marie@thinkmedia.ie www.thinkmedia.ie

Design: Tony Byrne, Tom Cullen and Niamh Short

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

Covid-19, Teagasc and the agri-food sector

Coronavirus (Covid-19) is a major pandemic, which requires a massive public health response. The main impact will obviously be on human health and lives. We are still at an early stage of the pandemic, both in an Irish and a global context, so it is impossible to predict the ultimate effects, but it is very worrying. It has also changed people's lives in ways that only a few weeks ago were unimaginable: hundreds of thousands of Irish workers are expected to lose their jobs; all sporting events have been cancelled; bars, restaurants, theatres, cinemas and most retail outlets are closed; and, weddings and baptisms have stopped. A new phrase – social distancing – has become a way of life. The pandemic is also having a major impact on the agri-food industry, with disruption to our markets and supply chains, livestock marts closed, and concerns about the ability of the processing sector to continue operations in the face of the disease. This is particularly pertinent for dairy processing, as it nears the period of peak milk supply.

Teagasc's activities are also impacted by the requirement for social distancing. Some staff can work from home, which is encouraged, but many continue to work in our research centres to keep farm operations and other critical services going, and to carry out essential and time-critical measurements and laboratory work. Some experimentation has had to be delayed or curtailed, such as on-farm work where close contact with the farmer or others is required, meat sampling in abattoirs, and visits by National Farm Survey recorders to farms but, by and large, the research programme is continuing. Much greater use is being made of digital communication methods in our advisory and education services. We are all conducting much more business by phone and video link, and less face to face. These alterations to our work methods and our programme pale into insignificance beside the public health crisis. It is important that Teagasc continues its mission to support the agri-food sector, given the industry's essential nature, and the additional challenges it faces as a result of the Covid-19 crisis.

Frank O'Mara
Director of Research
Teagasc

Covid-19 agus an tionchar ar Teagasc agus ar an earnáil agraibhia

Is paindéim mhór é galar coróinvíris (Covid-19) lena n-éilítear freagairt ollmhór do shláinte an phobail. Is léir go mbeidh an tionchar is mó leis ar shláinte agus ar shaol an duine. Táimid fós ag céim luath den phaindéim, i gcomhthéacs Éireannach agus i gcomhthéacs domhanda araon, agus mar sin ní féidir na héifeachtaí deiridh a thuar, ach is cúis mhór imní dúinn é. Tá saol dhaoine athraithe freisin ar bhealaí a bhí deacair a shamhlú roinnt seachtainí ó shin: is dócha go gcaillfidh na céadta míle oibrithe Éireannacha a bpoist; tá gach imeacht spóirt curtha ar ceal; tá beáir, bialanna, amharclanna, pictiúrlanna agus an chuid is mó d'asraonta miondíola dúnta, tá bainiseacha agus baistí curtha ar ceal agus tá frása nua – fadú sóisialta – ina shlí mhaireachtála anois. Tá tionchar mór ag an bpaindéim ar an tionscal agraibhia, agus an cur isteach leis ar ár margaí agus slabhraí soláthair, tá margaí beostoic dúnta, agus tá imní ann faoi chumas na hearnála próiseála leanúint d'oibríochtaí i bhfianaise an ghalair. Tá sé seo ábhartha go háirithe i dtaca le próiseáil déiríochta, toisc go bhfuilimid ag druidim le tréimhse an bhuaicsholáthair bainne. Mar gheall ar an gceanglas maidir le fadú sóisialta tá tionchar ar ghníomhaíochtaí Teagasc freisin. Is féidir le roinnt ball foirne oibriú ón mbaile, rud a spreagtar, ach leanann go leor ball foirne leis an obair inár n-ionaid taighde chun oibríochtaí feirme agus seirbhísí criticiúla eile a choinneáil ag dul agus chun tomhais agus obair shaotharlainne atá riachtanach agus criticiúil a dhéanamh. Bhí sé riachtanach moill nó srian a chur le roinnt turgnamhaíochta, amhail obair ar an bhfeirm nuair a bhíonn dlúth-theagmháil leis an bhfeirmeoir nó le daoine eile ag teastáil, sampláil feola i seamlais, cuairteanna ag cláraitheoirí an tSuirbhé Náisiúnta Feirme ar fheirmeacha; ach tríd is tríd, leantar ar aghaidh leis an gclár taighde. Tá i bhfad níos mó úsáide á baint as modhanna cumarsáide digití inár seirbhísí comhairleacha agus oideachais. Táimid go léir i mbun gnó i bhfad níos mó trí nasc teileafóin agus físe, agus ní tharlaíonn cruinnithe duine le duine go minic. Ní bhaineann an-tábhacht leis na hathruithe seo ar ár modhanna oibre agus ar ár ngnáthchúrsaí i gcomparáid leis an ngéarchéim sláinte poiblí. Tá sé tábhachtach go leanfaidh Teagasc lena mhisean chun tacú leis an earnáil agraibhia, i bhfianaise nádúr riachtanach na hearnála sin, agus na dúshláin bhreise atá roimpi mar thoradh ar ghéarchéim Covid-19.

Frank O'Mara
Stiúrthóir Taighde
Teagasc

Keep up to date with Teagasc podcasts

Podcasts are like on-demand radio and are a great way to keep up to date with topics of interest to you while multitasking or on the move. Teagasc has a number of free podcasts available on its website. You can subscribe on your smartphone or tablet to be alerted when a new episode is released. You can also download episodes for listening to later. *The Research Field* podcast is an accompaniment to *TResearch* magazine. Presented by science journalist Sean Duke, with regular contributions from Catriona Boyle, Science Communications and Outreach Officer with Teagasc, the podcast gets out and about and talks to Teagasc researchers.

The Dairy Edge is Teagasc's weekly dairy podcast for farmers. Presented by Emma-Louise Coffey, the podcast covers the latest information, insights and opinion to improve dairy farm performance.

The Beef Edge is Teagasc's fortnightly beef podcast for farmers. Presented by Catherine Egan, it covers the latest news, information and advice to improve beef farm performance.

OviCast is the Teagasc sheep podcast, which is presented by Ciaran Lynch and features the latest advice, insights and technical updates for the sheep industry.

You can access the podcasts on your iPhone or Android podcast app, or on many other services such as Spotify, SoundCloud, Stitcher, TuneIn radio, or wherever you listen to podcasts.

Royal visit to Grange

Paul Crosson (second left) and Edward O' Riordan, beef researchers at Teagasc Grange, talking to TRHs The Duke and Duchess of Cambridge.

Teagasc's Director, Gerry Boyle, and Chairperson, Liam Herlihy, greet the royal couple.

The British royals, the Duke and Duchess of Cambridge, visited Teagasc Grange on a recent visit to Ireland. The couple were met and welcomed to Teagasc by Michael Creed TD, Minister for Agriculture, Food and the Marine, and Liam Herlihy, Chairman of Teagasc. They were introduced to Gerry Boyle, Director of Teagasc, Councillor Wayne Harding, Cathaoirleach of Meath County Council, and Jackie Maguire, Chief Executive of Meath County Council. Members of the Teagasc Authority were also present.

Paul Crosson and Edward O'Riordan, beef researchers at Teagasc Grange, showed the royal couple, Prince William and Catherine, three cows, each with twin calves, which are part of the Derrypatrick demonstration suckler herd at the Teagasc Animal & Grassland Research and Innovation Centre (AGRIC) in Grange, Co. Meath. Paul and Edward outlined the steps taken on Irish cattle farms to ensure that beef is produced in an environmentally sustainable way, and also spoke about the technologies that have been developed and adopted to reduce greenhouse gas emissions from the herd.

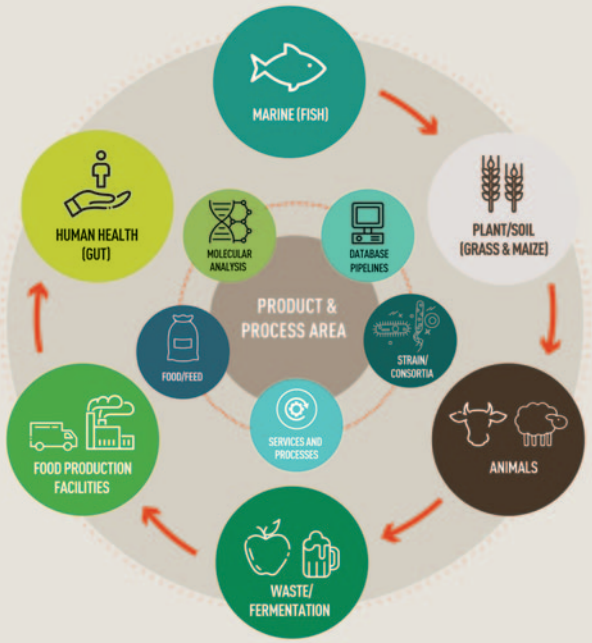
The royal couple were introduced to Catherine Keena, Teagasc Countryside Management Specialist, who spoke about the initiatives at Grange and on other farms around the country to promote biodiversity and develop hedgerows so they are fit for both 'birds and bees', providing suitable nesting sites and berries for the birds, and plenty of flowers for pollinators.

The couple then met Teagasc advisors Eilish Burke and William Byrne, who introduced them to farmers Ronan Hughes, Justin Walsh, Teleri Thomas, David Hannon, and Donal Keane, who spoke about what they are doing to farm with nature. They told stories of how they are using the best animal genetics, grass-based production systems focused on reseeding and good paddock organisation, and in the case of Donal Keane, how he is an organic demonstration farmer.

Eileen O'Reilly, Principal of Kiltale National School, Dunsany, Co. Meath, with 10 sixth-class students, were also in Grange to meet the royal couple. The pupils had completed projects on farm to fork, food production and sustainability.

MASTERing microbiomes

Scientists within the Teagasc project, Microbiome Applications for Sustainable food systems through Technologies and EnteRprise (MASTER), are using high-throughput sequencing technologies to map microbial communities (microbiomes) across a range of food and non-food environments. The project will improve the quantity, quality and safety of food, by developing microbiome products, services and processes. Knowledge generated within MASTER will reduce the demand for traditional insecticides, fertilisers and antibiotics.



MASTER has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 818368.

Irish Laboratory Awards

Teagasc enjoyed a number of successes at the recent Irish Laboratory Awards. The Best Chemical Laboratory award was presented to (from left): Elena Garicano; Maria Kyraleou; and, Iwona Skibinska. They collected the award on behalf of Kieran Kilcawley's Flavour Chemistry Facility in Moorepark. The award was presented by Kevin O'Driscoll, Director of Partner Programmes, BusinessRiver.

The Agricultural Laboratory of the Year was presented to (from left): Katie Fala; Laura Wosinska; and, Amy Fitzpatrick. The researchers collected the award on behalf of Paul Cotter's Vision 1 Laboratory in Moorepark. The award was presented by Shane Flynn, Business Development Manager, CBRE Global Workplace Solutions.

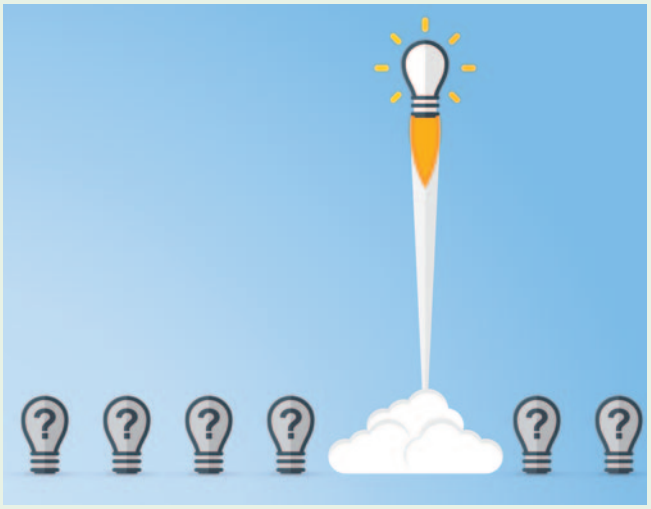
IJAFR papers

Teagasc's peer-reviewed open-access journal, the *Irish Journal of Agricultural and Food Research* (*IJAFR*), recently published a number of papers: 'Production of probiotic Bulgarian yoghurts obtained from an ultrafiltered cow's milk' by Bulgarian authors Kodinova *et al.*; 'Meat quality characteristics of high dairy genetic-merit Holstein, standard dairy genetic-merit Friesian and Charolais x Holstein-Friesian steers' by McGee *et al.* (Teagasc Grange and UCD); and, 'Yield of binary- and multi-species swards relative to single-species swards in intensive silage systems' by Moloney *et al.* (Teagasc Grange and Ashtown and UCD). To read these papers and find out how to submit to the *IJAFR*, see: https://bit.ly/IJAFR2020.

Revised Teagasc IP policy

In 2019, the Government, through the Department of Business, Enterprise and Innovation (DBEI), launched the third iteration of the National Intellectual Property (IP) Protocol, 'A Framework for Successful Research Commercialisation'. The Protocol has been updated to include recommendations on spin-out company formation, in addition to IP management, licencing, and research collaborations between research-performing organisations (RPOs) and industry. Its ultimate aim is to help industry (start-ups, small and medium enterprises, multinational corporations, entrepreneurs and investors) to access the research and development outputs from Ireland's RPOs, by setting out the Government's policy for research commercialisation, and outlining practical arrangements for this to happen.

The Government's seventh 'Action Plan for Jobs', published in 2018, recognises the importance of entrepreneurship, retaining high-quality talent, and global leadership in innovation in driving Ireland's continuing economic growth. In view of this, Teagasc has recognised the importance of upskilling its staff in entrepreneurship and supporting involvement in creating innovative companies, as well as supporting existing Irish industry. With this in mind, Teagasc revised its IP policy in 2019 in accordance with the minimum requirements for an RPO IP commercialisation policy, as set out in the National IP Protocol, to promote a culture of entrepreneurship, and enablement of Teagasc researcher involvement with spin-out companies (start-up companies established to exploit IP generated within Teagasc). The main revisions are centred around encouraging the involvement of Teagasc research staff in the formation of spin-out companies, and



ensuring that any potential conflicts of interest or commitment in forming such spin-outs are managed properly. This represents a significant development and culture change at Teagasc, and it is hoped, through the revised policy and associated supports to be provided, that Teagasc can contribute to the formation of new companies and job growth, and nurture entrepreneurs for the benefit of the economy. Teagasc's Technology Transfer Office plans to promote this policy and the implications to its research staff through its education programme in 2020, and the policy will be made publicly available through its website.

Researcher profile — Philip Creighton

Philip graduated from UCD with an animal and crop production degree in 2008 and completed a PhD with Teagasc Moorepark and UCD in 2012 investigating the impact of varying levels of perennial ryegrass content on sward production potential. He also completed work looking at the effect of alternative reseeding methods.

Philip commenced his current role as Research Officer in Teagasc Athenry in 2011, focusing on sheep grassland systems. He established the Sheep Research Demonstration Unit at Athenry, where he developed and leads, in collaboration with colleagues, a grassland research programme focused on sheep systems, a programme that is widely recognised nationally and internationally through numerous peer-reviewed publications and conference presentations.

Philip's work has had significant industry impact, providing clear messages regarding the role of stocking rate and ewe prolificacy level on sheep farm profitability. It has also played a significant role in developing improved grassland management strategies for grass-based lamb production. This work has quantified the feed budget requirements for ewes and lambs within grass-based systems of lamb production in terms of grazed grass, silage and concentrate requirements. Grazing management and budgeting targets specific to sheep systems have also been developed, which will hopefully increase the use of grass measuring and budgeting technologies that have been successfully integrated into other ruminant production systems.

Philip also works closely with the Teagasc Sheep Knowledge Transfer team to improve knowledge transfer from research to industry through regular contributions to advisor in-service training and on-farm events. Current research projects are focusing on the impact of incorporating white clover and other alternative forages into sheep-grazed swards on the productivity of pasture-based lamb production systems with special focus on the animal, environmental and economic impacts.

Cricket team not immune to Delhi belly

A new study, which followed Irish cricket players as they prepared for the 2016 ICC T20 World Cup, found that the travel took a toll on their gut.

For athletes who travel internationally to compete, avoiding gut distress symptoms (aka 'Delhi belly') is crucial to ensure top performance. This study provides insight to identify approaches for athletes preparing for international sporting tournaments.

Researchers at the APC Microbiome Ireland Science Foundation Ireland (SFI) Research Centre partnered with the Sport Ireland Institute and Cricket Ireland to study the gut microbiome of Irish male and female cricket players. The research team, which is based at University College Cork and Teagasc Food Research Centre, Moorepark, tracked changes in the cricket players' gut microbiomes as they travelled to Zimbabwe, Namibia, Australia, the United Arab Emirates, and India in the run-up to the 2016 ICC T20 World Cup.

Lead author Ciara O'Donovan notes that: "Generally, the gut microbiome of healthy adults is expected to remain stable over time. However, our study found that the stability of cricket players' gut-microbiome fluctuated during travel. We found that the type of gut microbes present in cricket players while at home differed from those present during travel periods, in particular after travel to India. Importantly, those microbes that were different have previously been associated with symptoms of gut distress and, notably, several of the athletes we studied did encounter such symptoms".

The study observed another undesirable phenomenon – there was an increase in the number of antibiotic resistance genes present in the guts of travelling athletes, a phenomenon that was most apparent in those who experienced gut distress. However, other research has shown that these genes do not persist.

This research gives a better understanding of the potential impact of travel on the gut microbiome of individuals. For now, practical advice includes avoiding those foods known to be associated with gastrointestinal distress during travel, especially uncooked or unpasteurised products. Going forward, researchers at APC Microbiome Ireland are working towards identifying approaches to protect the gut microbiome during travel.

Infant health collaboration

Rebalancing babies' gut bacteria, whether after antibiotic exposure or caesarean section birth, is the topic of a new collaborative research project between the APC Microbiome Ireland Science Foundation Ireland (SFI) Research Centre and DuPont Nutrition & Biosciences (DuPont). Representatives from both organisations attended an event in Washington DC to celebrate US-Ireland research and development collaborations, and to announce the Missing Microbes in Infants born by C-section (MiMIC) project, and its potential to improve infant health.

Based at University College Cork and Teagasc Moorepark, APC Microbiome Ireland is a pioneer in the field of microbiome science, which focuses on microbes that live in and on the body and play a significant role in human health. The €6.3m, four-year MiMIC project will be funded jointly by SFI's Spokes Programme and DuPont. It aims to develop microbiome-based solutions to help establish a healthy microbiome in early life to facilitate the long-term health of individuals.

APC Director Paul Ross said: "We are delighted to further develop our relationship with DuPont for the benefit of human health. APC Microbiome Ireland is a global leader, particularly in mother-infant and gut-brain areas of microbiome science, and this collaboration further strengthens our capabilities for advancing infant health and development".

The population of bacteria in the gut develops over the first four years of life and plays a key role in human health. Establishment of a healthy gut microbiome in early life is influenced by birth mode, antibiotic use and nutrition, including breastmilk components. Infant gut microbiota can be severely depleted in infants born by C-section or exposed to antibiotics. Breastfeeding can help to improve microbiota composition.

From left: Paul Ross, Director, APC Microbiome Ireland; Lori Lathrop Stern, Science Liaison, DuPont Nutrition & Biosciences; Martin Kullen, Global Research & Development Lead, DuPont Nutrition & Biosciences; and, Catherine Stanton, Principal Investigator, APC Microbiome Ireland.

APC Microbiome Ireland SFI Research Centre is ranked number one globally for research in antimicrobial and therapeutic microbes and is in the top five institutions in the world for microbiome research.

Teagasc's Catherine Stanton, Project Leader at APC Microbiome Ireland, added: "APC Microbiome Ireland has expanded the research and development capabilities of Ireland in an area of immediate relevance to the food and pharmaceutical sectors of industry. This project will allow us to identify the gut microbes in early life that play an important role in the short- and long-term health of individuals, and will help to develop strategies to balance the microbiota following antibiotic exposure or C-section birth mode".

The challenges of rearing large litters

TEAGASC researchers have been looking at the use of maternal feeding strategies during gestation and lactation to ameliorate some of the challenges associated with large litter sizes.

Background

Genetic selection for increased sow prolificacy has resulted in a significant increase in litter size at birth, with the number of pigs born alive per litter increasing from 10.6 in 2000 to 13.7 in 2018 in Ireland (Teagasc National Pig Herd Performance Report). Larger litters are associated with a higher proportion of light piglets at birth (Beaulieu *et al.*, 2010). Compared to their heavier litter-mates, low-birthweight piglets are less likely to survive and experience impaired lifetime growth. Therefore, nutritional strategies to increase piglet birthweight and postnatal growth are increasingly important.

L-carnitine (CAR) is a quaternary compound composed of the amino acids lysine and methionine. CAR plays a vital role in transporting fatty acids across the mitochondrial membrane, where energy is generated through fatty acid oxidation. When supplemented to gestating and lactating sows, it has been shown to increase litter size, piglet birthweight and the concentration of nutrients in milk, as well as improving foetal muscle fibre development. However, there is little information available regarding the efficacy of CAR when supplemented to gilts. Gilts give birth to lighter piglets with lower growth rates than those from sows (Calderón Díaz *et al.*, 2017). Therefore, CAR supplementation could be particularly beneficial for gilt litters. Additionally, most research on CAR supplementation to sows was published over a decade ago and significant increases in litter size since then may invalidate previous findings. It is therefore important to determine if CAR can provide a beneficial effect when supplemented to high genetic merit sows.

WALSH SCHOLARS

Hazel Rooney was the 2019 winner of the Teagasc Gold Medal at the annual Teagasc Walsh Scholarships seminar for her presentation on 'Nutritional management strategies to optimise annual sow output and to promote the growth and development of progeny from large litters'.

Experimental set-up

We investigated the effect of dietary CAR supplementation, to gilts during gestation (Experiment 1), and to high genetic merit multiparous sows during gestation and/or lactation (Experiment 2), on sow productivity and milk composition. Semitendinosus muscle (STM) development and lifetime growth in progeny was also examined. In Experiment 1, gestating gilts (n=84) were assigned to a CAR treatment (0 mg or 125 mg/day) from day 38 of gestation until farrowing. In Experiment 2, multiparous sows (n=64) were assigned to a CAR treatment during gestation (0 mg or 125 mg/day) and/or lactation (0 mg or 250 mg/day). Sow and gilt measures were recorded during gestation and lactation, and progeny were monitored from birth until slaughter (~ 142 days old).

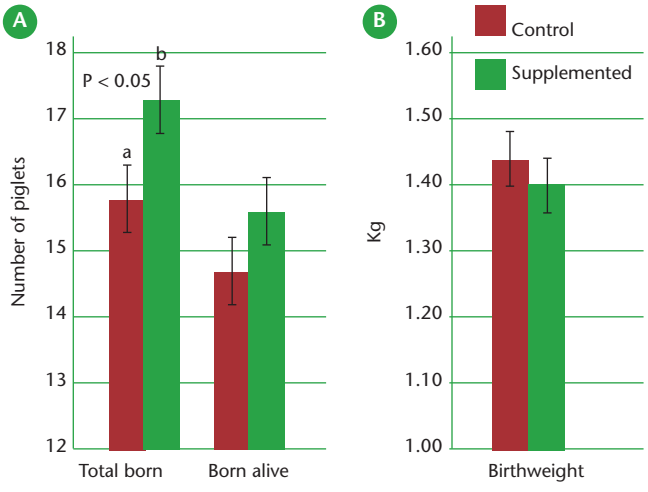


FIGURE 1: (A) Experiment 2 – Effect of sow dietary treatment on the total number of piglets born and on the number of piglets born alive. Superscript letters (a, b) indicate a difference of P < 0.05 between dietary treatments. (B) Experiment 2 – Effect of sow dietary treatment on piglet birthweight.

Results

In Experiment 1, the number of piglets born and piglet birthweight were similar between treatments. Contrary to expectations, piglets from CAR-supplemented gilts had a lower pre-weaning average daily gain than piglets from control gilts (185 v 196 ± 3.8 g/day). However, CAR-supplemented gilts tended to rear more piglets to weaning than control gilts (12.9 v 12.2 ± 0.31 piglets). At slaughter, pigs from gilts fed CAR had heavier liveweights (113.1 v 111.3 ± 0.64 kg) and carcass weights (86.6 v 85.1 ± 0.46 kg), and increased carcass muscle depth (51.3 v 50.5 ± 0.20 mm) than pigs from control gilts. CAR supplementation has been shown to increase muscle fibre number and size, and thus the results seen at slaughter could be due to hyperplasia of muscle fibres in the progeny of CAR-supplemented gilts.

In Experiment 2, CAR supplementation to sows during gestation increased litter size at birth (**Figure 1a**), without compromising piglet birthweight (**Figure 1b**). These findings suggest that CAR has the potential to be utilised as an effective feeding strategy to mitigate against low birthweight progeny in large litters. We also observed a tendency towards a greater total number of muscle fibres in the STM of piglets born to sows supplemented with CAR during gestation (144 v 120 ± 8.9 x 10^4 fibres). This finding confirms our hypothesis that CAR supplementation can improve muscle development in neonatal progeny. We observed no benefit in supplementing CAR during lactation.

Benefits to industry

The CAR supplementation strategies applied in these two studies could be utilised by commercial pig producers to increase litter size in sows, improve offspring muscle development at birth and, as a consequence, increase carcass weight at slaughter. We carried out a cost–benefit analysis of CAR supplementation to sows and gilts during gestation using the calculator from the Teagasc Pig Production Model. At the CAR inclusion rates used in our studies (125 mg/day) and using the current cost of CAR (€15,000/tonne), the financial benefit at farm level from the additional carcass weight of pigs sold at slaughter is €0.59/pig, where gilts in the herd were supplemented with CAR during gestation (Experiment 1). The financial benefit of the increase in sow litter size at birth due to supplementing multiparous sows with CAR during gestation is €1.85/pig (Experiment 2). Thus, supplementation of CAR to gestating gilts and sows will provide a financial benefit to the industry.

Conclusions

- CAR supplementation to gilts increased the liveweight, carcass weight and carcass muscle depth of progeny at slaughter.
- CAR supplementation to sows increased litter size at birth, without compromising piglet birthweight.
- CAR supplementation to sows increased muscle fibre number in progeny at birth.

Acknowledgements

Both studies were conducted as part of the OPTIPIG project, which was funded by the Department of Agriculture, Food and the Marine (DAFM) FIRM/RSF/CoFoRD 2013 Research Call (grant no. 13S428).

Authors

Hazel Rooney
Postdoctoral researcher, Teagasc Pig Development Department, Moorepark, Fermoy, Co. Cork
Correspondence: hazel.rooney@teagasc.ie

Keelin O'Driscoll
Research Officer, Teagasc Pig Development Department, Moorepark, Fermoy, Co. Cork

Peadar Lawlor
Principal Research Officer, Teagasc Pig Development Department, Moorepark, Fermoy, Co. Cork

John O'Doherty
Professor of Animal Nutrition, University College Dublin

Piece of cake?

TEAGASC research aims to comprehend the influence of ingredient and process manipulations on the sensory quality of bakery products.

Background

Baked confectionery products (cakes, biscuits, etc.) are highly appreciated by consumers across all populations. Ingredients such as sugar (sucrose) and fat (conventional butter/margarines) contribute to the desired aroma and flavour, and therefore drive consumer liking. However, excess sucrose consumption is a major contributor to the prevalence of obesity and type II diabetes worldwide (Hashem *et al.*, 2016). This has led to the demand and market for more nutritious and sustainable options. Volatile organic compounds (VOCs) are responsible for the characteristic aroma of baked confectionery products; therefore, in order to produce healthier confectionery products that retain their sensory appeal to consumers, it is important to understand the formation of these compounds.

'Clean label' sugar reduction

Trends of sucrose reduction/replacement have consisted of incorporating artificial sweeteners and/or sugar alcohols (polyols) due to their ability to mimic sucrose in terms of functionality and sweetness. However, current trends have shifted towards a more 'clean' mechanism of sucrose reduction, with consumers having high regard for the use of food by-products and functional ingredients. We explored the use of 'clean label' sucrose replacers on the sensory quality and aroma profile of sponge cakes. Six sponge cake formulas were employed: sucrose control (SC100); sucrose reduced 70% (SC70); sucrose reduced with apple pomace powder (APP), a by-product of the cider industry; sucrose reduced with whey protein permeate (WPP), a by-product of whey purification; sucrose reduced with polydextrose (PD), a non-digestible oligosaccharide; and, sucrose reduced with oligofructose (OLIGO), a fructan derived from vegetables and plants, with the ability to confer a prebiotic effect in the gut.

WALSH SCHOLARS

EMER GARVEY was the winner of the best food research presentation, and the Institute of Food Science and Technology Ireland (IFSTI) medal, at the recent Teagasc Walsh Scholarships seminar.

Sensory analysis of the 'clean label' reduced sucrose sponge cakes, by 30 consumers, identified some prominent differences between the formulas, with APP and OLIGO differentiating most from the control (SC100) (**Figure 1**). In terms of liking and acceptability, APP was ranked lowest for colour, flavour, texture, aroma and overall acceptability. APP was perceived to be significantly darker in colour for crust and crumb compared to all other formulas, due to the inherent reddish/brown hue of the raw material, but also explained by the higher levels of simple sugars (monosaccharides and disaccharides) (Milner *et al.*, 2020) present in the APP ingredient, which accelerate browning reactions such as Maillard reaction and caramelisation. Similarly, APP and OLIGO were perceived to have a stronger 'nutty' and 'roasty' odour compared to the control, and APP had the strongest 'off flavour'. The control was perceived as the sweetest and associated with the strongest 'fresh cake' odour.

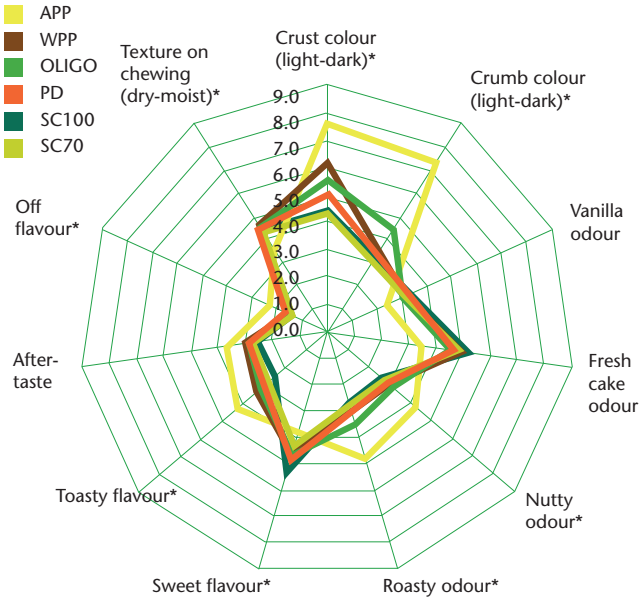


*FIGURE 1: Sensory analysis results of control and reformulated sponge cakes. Attributes marked with * indicate statistically significant difference.*

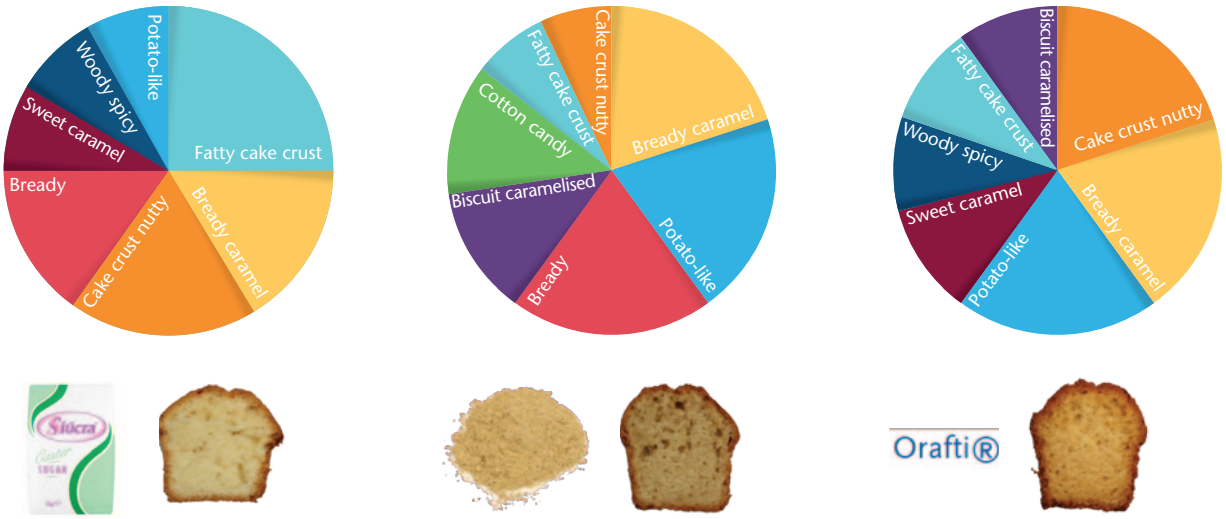


FIGURE 2: Odour active profiles of (from left) control (SC100), apple pomace powder (APP) and oligofructose (OLIGO) sponge cakes analysed by gas chromatogrpahy-olfactory.

Understanding differences in flavour perception

Gas chromatography-olfactometry (GCO) is an analytical technique that allows assessors to evaluate the VOCs in a product that are contributing to the overall aroma. GCO was used to investigate volatile compounds responsible for differences in sensory quality of the sponge cake formulas SC100, APP and OLIGO (**Figure 2**). It is apparent that the compositional changes are influencing the contribution of specific aromatic compounds to the overall aroma, and thus sensory perception, of the final product. For instance, the control cake SC100 demonstrated higher amounts of: 'fatty/cake crust' (heptanal), a compound originating from the fat proportion of the sponge cake; 'bready/ caramel' (furfural); and, 'cake crust/nutty' (2,5-dimethylpyrazine) compounds originating from caramelisation/Maillard reaction. Although APP and OLIGO had similar levels of 'bready/ caramel' (furfural), both formulas showed lower levels of 'fatty/cake crust' (heptanal) and increased levels of 'potato-like' methional, contributing to the overall aroma of these formulas. These differences in aroma profiles could potentially explain the reason for the higher 'roasty', 'nutty' aroma impression in the APP and OLIGO sponge cakes, as well as the low liking score for APP. In addition, the lower scores for 'fresh cake odour' could be explained by the lower amounts of 'fatty/cake crust' heptanal.

Conclusion

The practical findings of this research outline the importance of understanding the volatile compounds responsible for the desirable aroma and flavour of baked confectionery products. Knowledge of their generation pathway can lead to informed application of ingredients capable of reproducing similar sensory profiles to traditional formulas, and aid in a novel approach to sucrose and fat replacement.

Acknowledgements

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Authors

Emer C. Garvey
Teagasc Walsh Scholar, Teagasc Food Research Centre, Moorepark, Fermoy, Co. Cork, and UCC

Kieran Kilcawley
Principal Research Officer, Teagasc Food Research Centre, Moorepark, Fermoy, Co. Cork
Correspondence: kieran.kilcawley@teagasc.ie

FEATURE

Detecting the undetected

New TEAGASC research is measuring veterinary pharmaceuticals in our groundwater for the first time.

Background

Due to increased intensification of food production systems in Ireland, and more broadly within Europe, veterinary pharmaceuticals have become a critical component in animal husbandry. Administration of these products can potentially lead to their occurrence in environmental waters, such as groundwater. This has led to them being considered as potential emerging groundwater contaminants of concern. In Ireland, groundwater accounts for approximately 26% of the public and private drinking supply, with some regions relying on groundwater for up to 75% of their drinking water. This research focuses on investigating the groundwater occurrence of two groups of veterinary pharmaceuticals commonly used in Irish agriculture: anthelmintics (used in food-producing animals to treat helminths, which are parasitic worms); and, anticoccidials (used primarily in poultry production for treating coccidiosis, an intestinal parasitic disease).

Challenges

The term 'emerging contaminant' refers to both chemical compounds that are newly developed, and chemicals whose fate and toxicity in the environment is unknown. Anthelmintics and anticoccidials fall into the latter category, with limited information available on their environmental occurrence, fate and ecotoxicity, particularly in groundwater. A common factor thought to contribute to this shortage of information is the lack of suitably sensitive and comprehensive analytical methodologies for detecting these contaminants at environmentally relevant concentrations. The majority of methods available relate to the detection of these pharmaceuticals in foods of animal origin, with very few methods applicable to water, and those that are applicable only include a limited number of compounds (<12). There is also no regulatory monitoring of these pharmaceuticals in environmental waters, with no definitive legislative limits specific to groundwater or drinking water. This is despite the fact that up to 90% of the administered dose can be excreted by the animal into the environment. Once in the environment, these drugs can further break down into transformation products (TPs), which can be more harmful than the parent product. The main objective of this research was to develop comprehensive analytical methods and apply them to investigate the occurrence of these contaminants in Irish groundwater.

WALSH SCHOLARS

DAMIEN MOONEY was the Crops, Environment and Land Use Programme finalist at the 2019 Teagasc Walsh Scholarships seminar.

Analytical methodologies

Two comprehensive, highly sensitive analytical methods were developed, validated and applied to investigate the occurrence of 40 anthelmintic compounds (including 13 TPs) (Mooney *et al.*, 2019) and 26 anticoccidial compounds (Mooney *et al.*, 2020), respectively, in groundwater samples. The main approach to analysis is summarised in **Figure 1**. Once collected, the contaminants were extracted from water samples using a technique called solid phase extraction (SPE), which allows for the simultaneous extraction and purification of the contaminants from large volumes of water sample. Following extraction, the contaminants were detected and quantified by liquid chromatography tandem mass spectrometry (LC-MS/MS), which is considered the most powerful technique for the quantitative determination of veterinary drugs in complex matrices. Both methods were extensively validated and deemed fit for purpose. The method limits of detection (LODs) ranged from 0.5-20 ng/L for the anthelmintics and 0.1-20 ng/L for the anticoccidials.

Occurrence studies

The methods were applied in two separate studies to investigate the occurrence of anthelmintics and anticoccidials throughout Ireland. For each study, sampling sites were selected to be representative of different animal production systems and hydrogeological settings. In 2017, 106 sites were sampled for the 40 anthelmintics, with 16 different compounds detected across 22% of sites. Detections were of the order of 1-41 ng/L. Temporal studies suggest that an increased frequency of

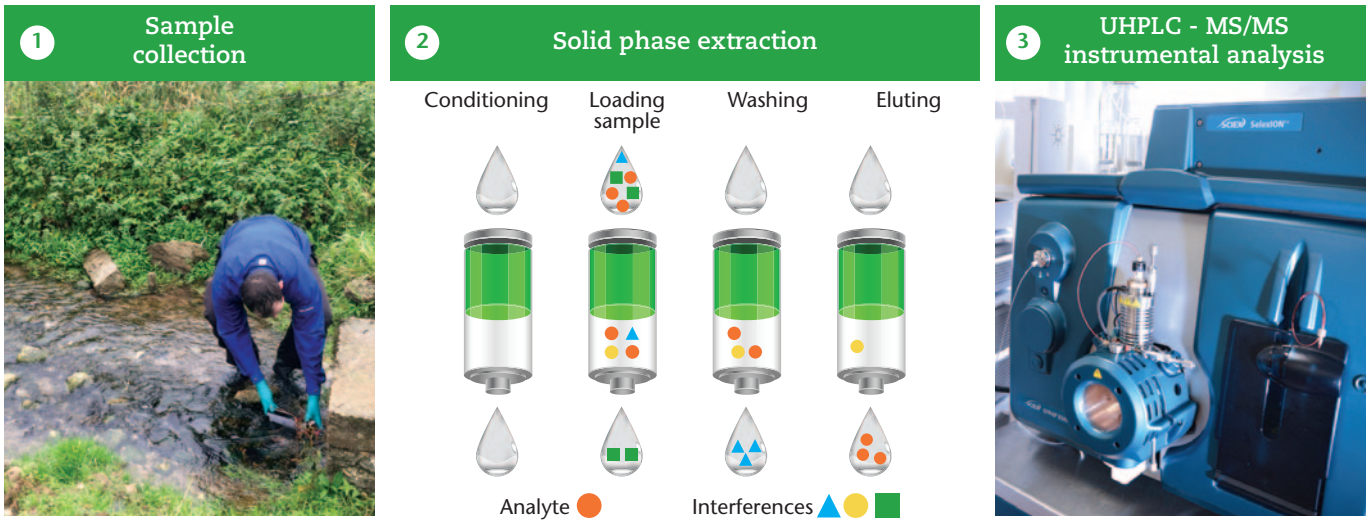

FIGURE 1: Three main steps of the analytical approach.

anthelmintic detections between February and March may coincide with the end of the closed period for winter. In a separate study in 2018, 109 sites were sampled for the 26 anticoccidials, and seven different compounds were detected at 24% of sites, with concentrations in the range of 1-385 ng/L. Statistical analysis has shown that the presence of poultry activity (poultry farms and poultry manure landspreading) is a significant driver of the occurrence of anticoccidial compounds. Both studies are the first of their kind in Ireland, and report on the first occurrences of these veterinary compounds in Irish groundwaters.

Conclusion

The two developed methods are considered the most comprehensive currently available for application to environmental water samples. These methods will allow for more comprehensive occurrence studies to be carried out, providing more information to better inform on the environmental fate and occurrence of anthelmintics and anticoccidials in environmental waters. Overall, this study highlights that these veterinary pharmaceuticals are occurring in our groundwater, and therefore may require more appropriate consideration with regard to potential groundwater quality and environmental concerns, given that their use is anticipated to continue, if not increase, as a result of agricultural intensification and climate change.

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Acknowledgements

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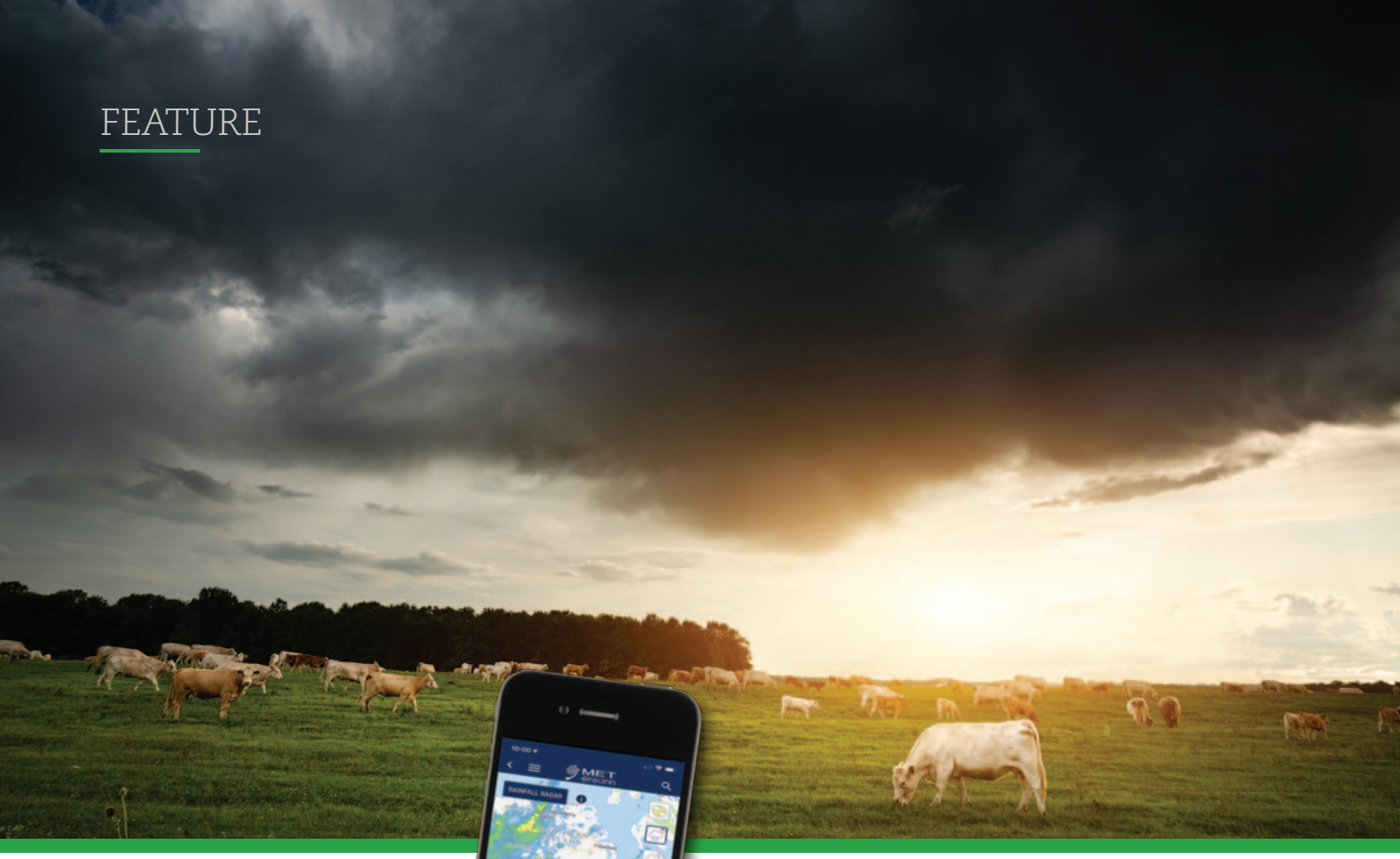
Authors

Damien Mooney
Teagasc Food Research Centre, Ashtown, Dublin 15, and Trinity College Dublin

Martin Danaher
Research Officer, Teagasc Food Research Centre, Ashtown, Dublin 15
Correspondence: martin.danaher@teagasc.ie

Karl Richards
Research Officer – Water Quality, Teagasc Johnstown Castle Research Centre, Wexford

Catherine Coxon
Trinity Centre for the Environment, Trinity College Dublin



Stormy weather

TEAGASC research is assessing the impact of extreme weather on farm-purchased concentrate feed on Irish dairy and beef farms.

Introduction

Grass productivity is key to farm profitability in Irish livestock production and farmers plan their farm operation to match grass growth rates. Farms make the most of grass from mid spring to mid autumn, and when grass growth exceeds cattle demand in summer, the extra grass is taken out as silage and hay for the winter. If bad weather disrupts this pattern, pasture production, and thus farm competitiveness and animal performance, are threatened. In a normal year, feed costs (concentrates, pasture and forage) account for 40% and 75% of the total direct costs in dairy and beef farms, respectively. This research aims to understand and quantify the relationship between variations in purchased supplementary concentrate feed and seasonal weather extremes on Irish dairy and beef farms.

WALSH SCHOLARS

MOHANA LOGAKRISHNAN was the Rural Economy and Development Programme finalist at the 2019 Teagasc Walsh Scholarships seminar.

Research approach

Using the Met Éireann climate reanalysis dataset (MÉRA), in combination with the Irish National Farm Survey (NFS), we could relate extreme seasonal weather events to farm feed use using econometric regression models. We used NFS farm data from 125 specialist spring-calving dairy farms and 87 specialist beef farms for the period 2001-2015. Climate indices are widely used to identify the moderate to severe extreme weather events on long-term climate data. In this study, a percentile-based method was used to determine the seasonal number of very warm days (maximum temperature > 95th percentile), very cold days (minimum temperature < 5th percentile) and very wet days (precipitation > 95th percentile), with respect to a baseline climate. We hypothesised that the purchase of concentrate feed is a function of both the current spring weather and the previous grass-growing season's weather. Therefore, the farm statistics from May to April were used instead of the calendar year (January to December) statistics as given in the NFS. Variation in purchased feed across farms and over time in relation to weather and other important farm variables, such as livestock units and farm size, was analysed using a panel model.

Results

Our research revealed that seasonal extreme weather has a negative effect on Irish dairy and beef farms as it increases concentrate feed purchases (**Table 1**). While effects differ between farming systems, with dairy farms generally purchasing more supplementary feed as a result of extreme weather when compared to beef farms, the research reveals that extreme weather at the end of the housing period in spring, but also in the year preceding the housing period (November to April), is significantly affecting feed purchase in both farming systems.

This highlights the importance of the previous year's summer and autumn weather, and its effects on grass growth, the length of the grazing season, and silage stores for the current year.

Conclusion

The increased dependency on concentrates, together with the increase in the frequency of local and global extreme weather, could affect dairy farm costs considerably in the coming years. The relationship between extreme weather and farm feed purchases described in this research can be used to develop a forecast model to quantify and anticipate the fodder needs for the national herd, thus allowing better preparation for fodder shortages as a result of extreme weather, and development of more robust spatio-sectoral farming strategies to adapt to weather variations.

Table 1: The extreme seasonal weather that significantly affects feed purchases on Irish dairy and beef farms. The size of the effect was estimated with a panel model and significance was established if the fit of the model had a p value < 0.05. LU = livestock unit.

SEASONS	DAIRY FARMS	BEEF FARMS
Previous year's summer weather (May-July)	One very wet day in summer increases housing period concentrate usage by 4.42 kg/LU	
Previous year's autumn weather (August-October)	One very warm day in autumn decreases housing period concentrate usage by 3.57 kg/LU	One very warm day in autumn decreases concentrate usage by 2.78 kg/LU One very wet day in autumn increases concentrate usage by 3.6 kg/LU
Current year's spring weather (March-April)	One very cold day in spring increases housing period concentrate usage by 8.76 kg/LU	One very warm day in spring decreases concentrate usage by 1.92 kg/LU

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Authors

Mohana P. Logakrishnan
Agrifood Business and Spatial Analysis, Teagasc, Ashtown, Dublin 15, and School of Biology and Environmental Science, UCD.

Stuart Green
Research Officer, Agrifood Business and Spatial Analysis, Teagasc, Ashtown, Dublin 15
Correspondence: stuart.green@teagasc.ie

Tamara Hochstrasser
Lecturer/Assistant Professor, School of Biology and Environmental Science, and Earth Institute, University College Dublin

Reamonn Fealy
Research Officer. Agrifood Business and Spatial Analysis, Teagasc, Ashtown, Dublin 15

Something old, something new

Research funded by TEAGASC and SFI into grassland management histories has led to the discovery of a number of new archaeological sites.

FIGURE 4: Settlement at Cloonastiallas, Co. Roscommon.

The Irish countryside is dotted with tens of thousands of ancient sites and monuments, many of which are recorded in the archives of the Archaeological Survey of Ireland (ASI). Only a small number of these are in the ownership of the State; the vast majority are on privately held farmland and survive, as they have for centuries, through the awareness and careful stewardship of farmers. There are deeply held traditions respecting ancient monuments, and agri-environment schemes like the Rural Environment Protection Scheme (REPS) and Green Low-carbon Agri-environment Scheme (GLAS) have given guidance to farmers on securing and preserving archaeological sites. Teagasc has collaborated with the ASI in the past to produce a guide for farmers to minimise damage to archaeological sites ('Good Farming Practice and Archaeology' – available on the Teagasc website). Nevertheless, modern farming methods can still pose a risk to unidentified sites, particularly during reseeding, hedge/scrub clearance, and land drainage.

Golden age of archaeological discoveries

New archaeological sites are being identified all the time through archaeological excavation, chance discoveries on farms, and by identifying new sites in online satellite imagery. Evidently, it is a golden age for new archaeological discoveries, with over 1,500 reports of new sites to the ASI during last year alone. This boom has been fuelled by online image archives, the growing use of drones, and the extensive drought conditions in 2018. Cropmarks are traces of a monument that no longer appear at the surface but may still be visible in aerial images through differential crop growth, and are particularly obvious during dry spells.

Chance discoveries

As part of an ongoing Teagasc/Science Foundation Ireland (SFI) VistaMilk project looking at grassland management histories, the Spatial Analysis Unit in Ashtown has been examining old photographic archives from Ordnance Survey Ireland (OSI) taken 15-30 years ago (1995, 2000, 2005), as well as more recent Google Earth (GE) images from the last decade. In doing so, they have identified over a dozen 'new' archaeological sites, including cropmarks and standing monuments. Evidence of these sites can be ephemeral, visible only for a short time or under very specific conditions. The standing monuments all had earthworks that were best seen in winter when a low sun angle cast long shadows.

The newly identified archaeological sites are a mix of burial and settlement sites, possibly from the prehistoric or medieval periods, a selection of which are described here.

Burial site

Barrows were burial sites used from the Neolithic (approximately 2,500 BC) until the Christian period (about AD 500). One such barrow was identified in Co. Kerry, where a 16 m diameter bank surrounds a low mound (which likely covers cremated or inhumed remains). This site epitomises the proper stewardship of archaeological sites, where the farmer has avoided impact during farm operations and drainage. When discoveries are reported, official confirmation must await a site visit by an ASI archaeologist. In this instance, there was ready-to-go validation in data from the EU Land Use/Cover Area frame Survey (LUCAS). LUCAS is a pan-EU field survey to collect land-use and land-cover data at selected points. Fortuitously, the barrow was located on a LUCAS point, which was visited and photographed by a LUCAS surveyor in 2018. **Figures 1a** and **1b** show the raised curving bank and low internal mound that are characteristic of this class of site.

Larger enclosed sites are broadly classified as 'enclosures'. These are enclosed areas of various shapes and sizes that possess no other diagnostic features (**Figures 2a**, **2b** and **2c**). They can date to any

FIGURE 1: *(a) Aerial view of Co. Kerry barrow (top); and, (b) LUCAS photo (bottom).*

period from prehistory onwards, but on excavation many are dated to the early medieval period (AD 500-1,000).

Two deserted medieval settlements were identified, which is fortuitous as Teagasc is currently supporting research into archaeological features like deserted medieval settlements and their role in agro-tourism through Walsh Scholar Daniel O'Mahony (co-supervised by Tadhg O'Keefe in UCD and Stuart Green in Teagasc). There are only about 300 deserted medieval settlements known in Ireland, so finding two in one week is unusual! Many rural settlements from this period developed into our modern towns and villages. Some were abandoned due to war or disease, while others succumbed to the impact of a changing climate, soil exhaustion, or changing agricultural practices. At Kilcurly, Co. Limerick, previously unidentified earthworks were identified over several hectares adjacent to a medieval church. In **Figure 3**, north of the farm access road, relict field boundaries, several circular enclosures, and rectangular building foundations are visible. South of the road is a substantial oval enclosure (190 m x 150 m) with internal subdivisions and structures. Records from the 17th century associated with this church mention dwellings and structures, some of which may relate to these earthworks. A second deserted settlement was identified at Cloonastiallas, Co. Roscommon (**Figure 4**), where several rectangular house plots flanked a 170 m long 'street'. Behind these house plots larger fields covered an area of approximately 14 ha.

All sites have been reported to the ASI and have been added to its database of sites and monuments. ASI records are updated continuously as new sites are discovered, so landowners should inform themselves of all sites on their land before carrying out works that may damage archaeological remains. Under the National Monuments Act 1930 (amended) there are severe penalties for unlawful interference with or damage to archaeological monuments.

Acknowledgments

All satellite images are courtesy of Google Earth: © Google/Maxar Technologies 2020. The Kerry barrow ground image is from the Eurostat LUCAS survey. These archaeological findings arose as a result of research funded by the Teagasc and SFI VistaMilk Research Centre.

FIGURE 2: *Enclosures in: (a) Limerick (top); (b) Mayo (middle); and, (c) Roscommon (bottom).*

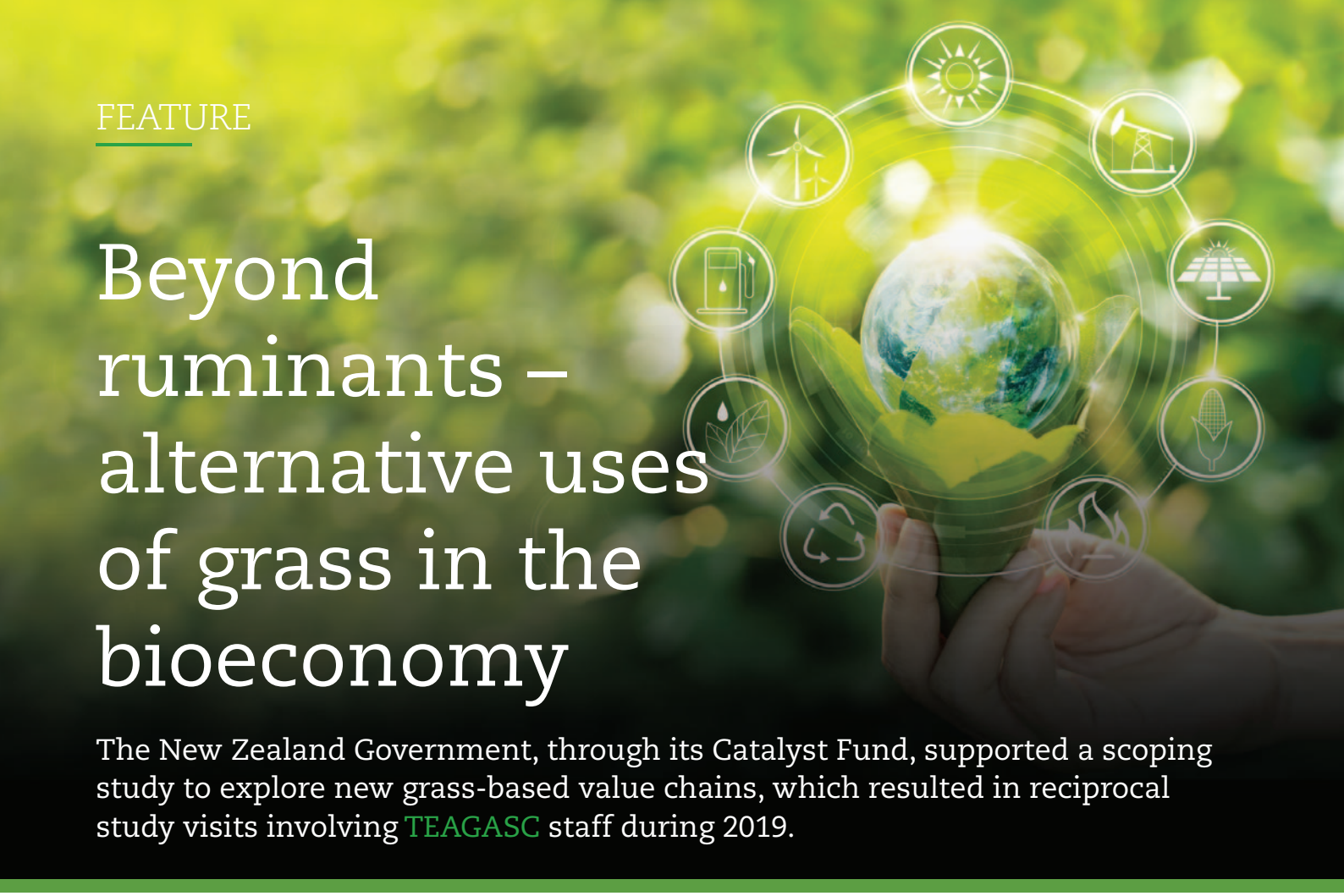
FIGURE 3: *Settlement in Kilcurly, Co. Limerick.*

Author

Robert O'Hara
Post-doctoral researcher, Teagasc and SFI VistaMilk Research Centre
Correspondence: rob.ohara@teagasc.ie

FEATURE

Beyond ruminants – alternative uses of grass in the bioeconomy



The New Zealand Government, through its Catalyst Fund, supported a scoping study to explore new grass-based value chains, which resulted in reciprocal study visits involving TEAGASC staff during 2019.

The Irish and New Zealand Governments both have ambitious goals for growth in agricultural output, as well as commitments and targets relating to carbon emissions and other environmental challenges. Another common denominator is that grass grows well in both countries. This suggests both an opportunity and an obligation to develop new ideas for grass-based production systems as a means to increase output and exports, while reducing environmental impacts. A delegation from Ireland recently visited New Zealand as part of a scoping study to explore adding value to grass. At the heart of the project is the concept of a green biorefinery, which can provide alternative or complementary uses for grass. A biorefinery is a facility, or a series of processes, that converts biomass into a spectrum of value-added products. The key challenge is to get the highest possible value from the biomass in a sustainable manner.

Biobased products from grass

Lene Lange from the Technical University of Denmark (DTU), who participated in both tours, argues that grass can be used to produce many bio-based products, including upgraded protein for pig and poultry feed, bioactive peptides (Dotsenko and Lange, 2017) and natural fibres as an alternative to cotton. Grass is also a good feedstock for energy production in an anaerobic digester (Lucci *et al.*, 2019). A green biorefinery has already been operated at pilot scale in Ireland as part of the 'Biorefinery Glas' project, an EIP-Agri Operational Group (OG) funded by the Department of Agriculture, Food and the Marine (DAFM). The New Zealanders met James Gaffey from IT Tralee, who co-ordinates the OG, at Teagasc Oak Park, and James joined the group through video conference on the reciprocal visit. This EIP project includes Barryroe Co-operative, the Carbery Group, GRASSA B.V. and UCD, and demonstrates, in a hands-on way, how the circular bioeconomy approach can work, starting from farm level.

History of dried grass in Ireland

The use of grass as a protein source for monogastrics is not new in Ireland. There was an animal feed protein industry based on dried grass prior to the arrival of soya beans as a preferred protein source, and **Table 1** shows the extent of the industry. High oil costs, combined with the availability of soya beans, led to the demise of the grass-drying industry. Research on the mechanical extraction of the protein fraction from the grass feedstock was undertaken by An Foras Taluntais at Ashtown in the early 1980s, and this idea is receiving renewed attention.

Recent research

The EU 'GrassMargins' project demonstrated that green biomass from grass can be produced very efficiently from grasslands on wet and heavy soils and tillage fields with a range of grass species (Meehan *et al.*, 2017). In Ireland, another EIP project, 'Biomass to Biochar for Farm Bioeconomy', produces high-value biochar from biomass from grasslands with many rushes (*Juncus spp.*) to pilot the conversion of unutilised agricultural biomass to a stable form of recalcitrant biocarbon to improve soils and provide ecosystem services.

Adding value to grass

The New Zealand interest in the green biorefinery concept is to reduce the environmental impact of livestock production as much as to add value. They have done some research that finds feeding cows the 'cake', which is the solid that remains after grass has been screw-pressed to separate the liquid and solid fraction, results in lower levels of nitrogen leaching. This is because the cows take in lower levels of protein (containing nitrogen) than would be the case with fresh or ensiled grass (Lucci *et al.*, 2019). The Danish have a strong focus on high-value opportunities. DTU has already developed a

Grass harvesting in the 1970s in Lucan, Co. Dublin. Shackleton Grass Driers processed 3,000 t of dried grass per annum, In 1972, 47,000 t of dried grass was produced in Ireland.

process that extracts protein from the liquid fraction, which is then dried into a protein powder, and has developed products for human consumption that contain up to 10% grass-based protein.

The New Zealanders have done a considerable amount of work in adding value to wood-based waste streams. Such thinking could help to stimulate and progress ideas for grass-based systems. SCION – a New Zealand Crown Research Institute, which converts wood and fibre into a range of renewable and sustainable products and energy using research, science and technology – has considerable expertise that could be transferred into grass-based chains, e.g., in relation to bio-based fibres and bio-chemicals. AgResearch New Zealand has expertise in relation to life cycle analysis, which would enable a comparison to be made between different value chains in terms of different sustainability credentials.

The opportunities presented by grass, beyond a feed for ruminants, are immense. Research by Teagasc shows that the existing land base can produce 1.7 million t of dry matter (DM), surplus to requirements for meat and milk production (McEniry *et al.*, 2013). The challenge now is to identify a small number of potential value chains for further research and preliminary feasibility analysis.

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Table 1: Land utilisation and production of dried grass in Ireland in 1972.

Provincial Grass Driers Association and independent producers (1972) Company name	Acres	Annual t dried grass
John Nicholson Balrath, Kells, Co. Meath	750	5,000
Sir Richard Musgrave Dublin Airport	1,000	6,000
Gallaghers South Slob, Wexford	1,000	6,000
Shane Jameson Cappoquin, Co.Waterford	1,000	6,000
Shackleton Grass Driers Lucan, Co. Dublin	500	3,000
Alex Tong Edenderry, Co. Offaly	700	3,000
Louis McAuley Balrath, Kenstown, Co. Meath	1,000	6,000
Gowna Grass Driers Ballinasloe, Co. Galway	1,000	6,000
Geesala Grass Driers Killala Co. Mayo	1,000	6,000

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Authors

Maeve Henchion
Research Officer, Teagasc Food Research Centre, Ashtown, Dublin 15
Correspondence: maeve.henchion@teagasc.ie

Susanne Barth
Research Officer, Crops, Environment and Land Use Programme, Crop Research, Oak Park, Co. Carlow

J.J. Lenehan
Building Officer, Animal Bioscience Research Centre, Grange, Co. Meath

OVERALL WINNER: *Spike architecture – Dheeraj Rathore*

Vision of Research 2020

The winners of the fourth annual TEAGASC 'Vision of Research and Innovation' image competition were announced at Teagasc Head Office, Oak Park, Carlow, as part of Teagasc's Science Week activities in November.

The competition is open to all Teagasc staff and students, who are invited to submit digital images created in the course of their work, with the aim of finding the most innovative and compelling images showing the range of research and innovation activities taking place across Teagasc. Selected images are used to promote Teagasc research and also feature in an annual calendar.

The panel of judges for the competition comprised Jim Carroll (Editor, *RTÉ Brainstorm*), John Beeching (University of Bath, UK), and Catriona Boyle (Teagasc, editor of *TResearch*).

The overall winner was Dheeraj Rathore's image *Spike Architecture*, taken during his research as part of a Horizon 2020-funded project BEST4SOIL – Boosting 4 BEST practices for SOIL health in Europe (grant no. 817696). The image shows the six-row architecture of a barley spike, a key component of grain yield. From a total of 76 entries, 12 winners were selected, which are featured in this article.

Teagasc Director Gerry Boyle congratulated all of the entrants for the extremely high standard of images submitted and, in particular, thanked the judges for their care and attention to detail in selecting the winning images. Speaking about the competition, Frank O'Mara, Teagasc's Director of Research, said: "The competition is a great opportunity to show the high calibre of research and innovation activities carried out by Teagasc staff and to promote the scientific concepts underpinning our research to a wider audience".

The next 'Vision of Research and Innovation' image competition launches in May 2020 and will close in September 2020.

Author

Catriona Boyle

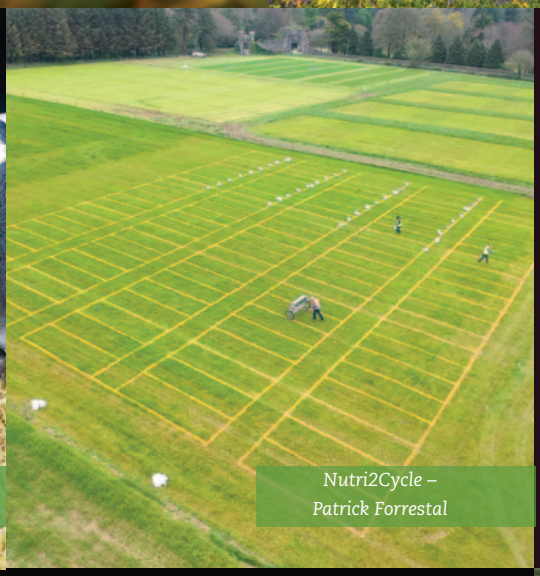
Research Officer – Science Communications and Outreach, Teagasc, Oak Park, Carlow

Correspondence: catriona.boyle@teagasc.ie

Hunting for aphids – Aisling Moffat

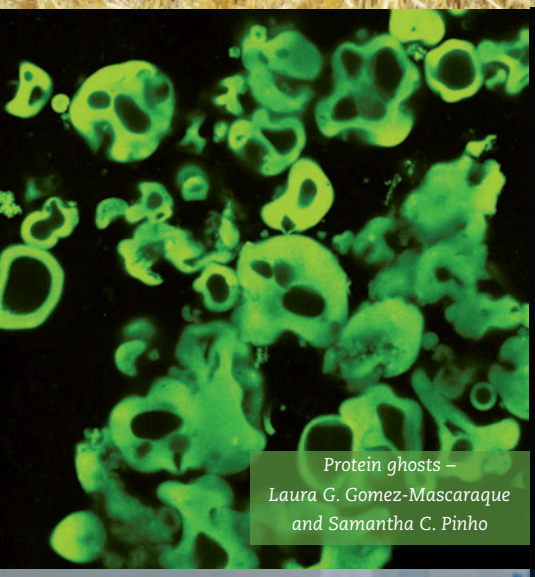
Bluebells – blue sky – Ian Short

Labour of love – Alison Sinnott

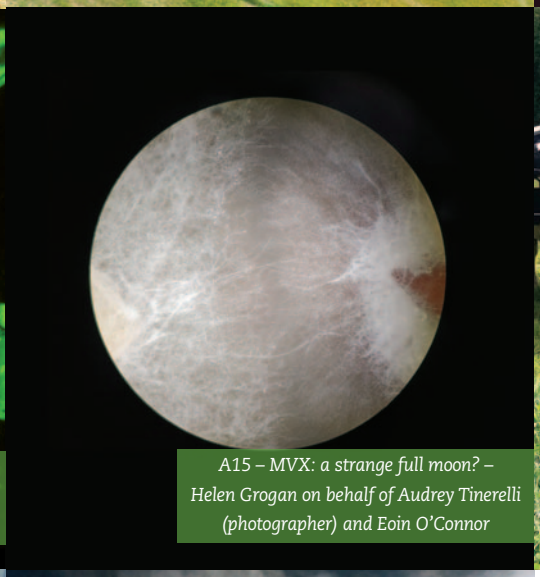


Nutri2Cycle – Patrick Forrestal

Flower in the glume – Dheeraj Rathore



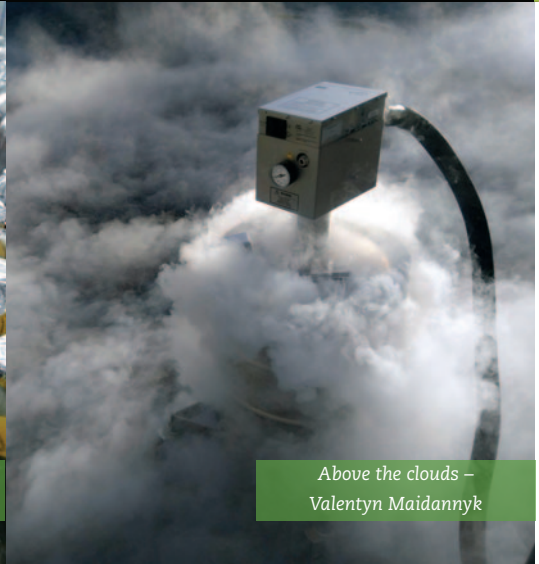
Protein ghosts – Laura G. Gomez-Mascaraque and Samantha C. Pinho



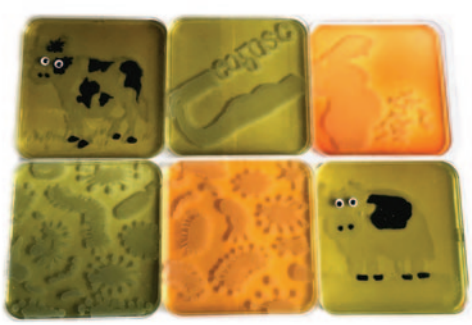
A15 – MVX: a strange full moon? – Helen Grogan on behalf of Audrey Tinerelli (photographer) and Eoin O'Connor

Cows and carbon – Iris Nonhebel

Potential denitrification – Kerry Ryan



Above the clouds – Valentyn Maidannyk



Bacteria-revealing research – Elaine Lawton and Cathy Lordan

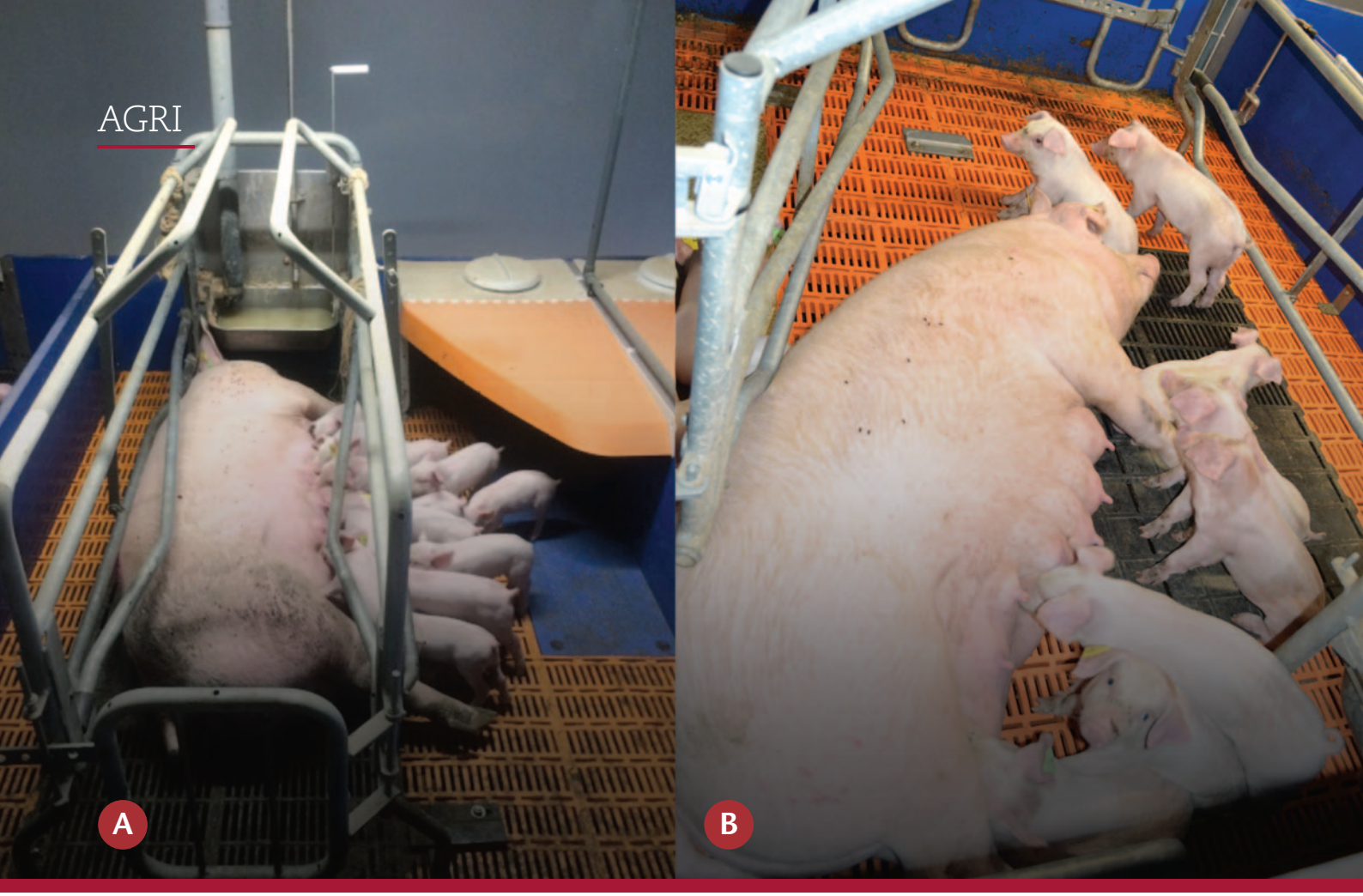


FIGURE 1: Pen layout for A) crate, and B) free treatments. In crate, sows are continuously crated. In free, the crate can be opened or closed; when opened, the sow can turn 360°.

Free crates creating better outcomes

TEAGASC researchers examined if removing farrowing crates could improve piglet health and performance.

The farrowing crate was originally introduced as a management tool in pig farming in the 1960s. It is still widely used in Ireland to improve ease of management, allow higher stocking densities of sows, and to reduce piglet mortality. In crated systems the sow is confined from about seven days prior to farrowing until piglets are at least 28 days old. However, concerns about animal welfare have meant that several European countries have introduced legislation restricting the use of farrowing crates, and 'free-farrowing' pens are being encouraged in many others. These allow sows to move around and perform normal mothering behaviour, and piglets to interact more with the sow. However, there is a greater risk of piglet crushing in these systems, particularly during the first three days after birth. An intermediate option is to confine the sow to a crate only from the onset of farrowing until three days afterwards. This system has potential to be more widely adopted in Ireland prior to conversion to entirely uncrated systems, as the risk of excessive mortality is reduced. This study compared the welfare and performance of both sows and piglets in conventional crated and 'free-lactation' systems.

Experimental set-up

This study was carried out in the Moorepark Pig Development Department pig unit between September 2018 and August 2019. Sows (n=48) were assigned to either standard crates (crate) or crates that could be opened to allow the sow to turn around (free), approximately seven days prior to farrowing (**Figure 1**). Crate sows were confined until weaning, whereas in the free group, crates were open for the first five days, after which they were closed at night. The free sows were closed in continuously from approximately one day prior (onset of lactation), to three days post farrowing, then opened until weaning.

Animal performance

Treatment did not affect sow liveweight, back fat, feed intake, or subsequent performance. There was no difference in piglet mortality percentage between treatments (crate = 14.42 ± 2.15 %; free = 15.95 ± 2.31 %). However, when it came to the causes of mortality, more piglets in free than in crate were crushed after day three (i.e., after the crate was opened; $P < 0.05$). Numerically, more piglets in crate than free died from other causes (e.g., hunger; $P = 0.14$). There tended to be an interaction between treatment and day ($P = 0.08$) for pre-weaning weights, with piglets from free numerically heavier than crate on days 14 and 21, and tending to be heavier at weaning ($P = 0.1$; **Figure 2**). Post weaning, pigs from the free treatment had a higher average daily gain to finish ($P < 0.05$), took fewer days to reach slaughter weight ($P < 0.05$), and had a heavier final weight ($P < 0.05$) than pigs from crate.

Animal behaviour

In free, sows increasingly utilised all orientations in the pen as the study progressed. Locomotory ability deteriorated more in crate sows than free between confinement and weaning ($P < 0.01$), and as there was no difference in hoof condition between treatments, it is likely that the lack of movement could have caused stiffness. Even with additional movement in free, piglets were observed more often at the udder in this treatment than in crate ($P < 0.05$). They also tended to perform less damaging behaviour (e.g., tail-biting; $P = 0.07$), which is positive for welfare throughout life. These behaviours could have been a contributing factor to the increased lifetime performance of free piglets.

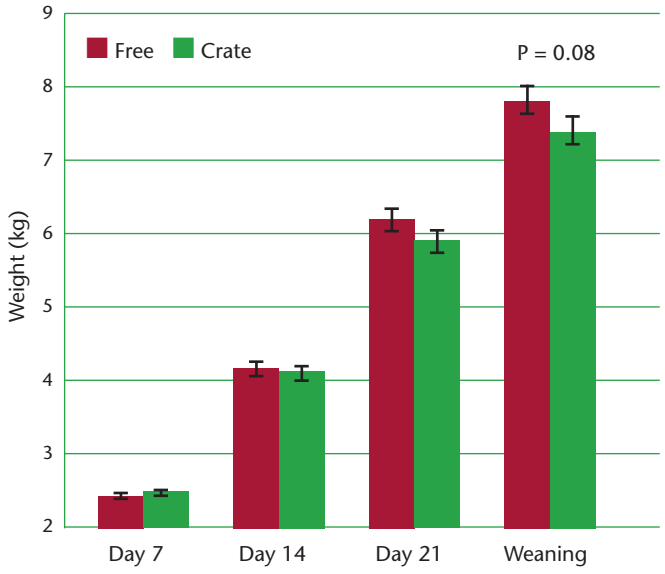


FIGURE 2: Piglet weights on days seven, 14 and 21 after birth and at weaning, for piglets born and reared in free lactation pens (free) or in pens with conventional farrowing crates (crate).

Indicators of stress

At weaning, free sows had less tear staining around the left eye than control ($P = 0.05$). Tear stain scoring has been adopted and validated in pigs from laboratory science as an indicator of chronic stress. However, salivary cortisol levels tended to be higher in free sows ($P = 0.06$), particularly after initial confinement ($P < 0.05$), and on day four after farrowing, when the crate was opened again ($P = 0.09$). Although often associated with stress, cortisol can also rise with excitement or increased activity, which could explain this result. There was no overall effect of treatment on piglet faecal cortisol level, yet at seven days of age this also tended to be higher in piglets in free ($P = 0.07$). This timing coincides with when the sows in free are first released, and could be reflective of injuries or increased movement.

Conclusions

- Restricting movement of the sow for only three days post farrowing, compared to the entire lactation, did not result in additional mortality compared with crated sows.
- The free pens were associated with improved welfare, as indicated by reduced lameness in sows, reduced performance of damaging behaviour in their offspring, and a tendency for more time observed at the udder.
- Overall, free pens had significant benefits for sow output, with regard to growth rate and efficiency of their offspring.

Acknowledgements

This study was funded by Teagasc and the Irish Pig Health Society. Fidelma Butler (UCC) also contributed by supervising this work. We would like to thank the farm staff in the Moorepark Pig Development Department: Marie Souquière; Gregoire Gaudin; Tomas Ryan; and, David Clarke, for their input in this project.

Authors

Keelin O'Driscoll
Research Officer, Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork
Correspondence: keelin.odriscoll@teagasc.ie

Orla Kinane
MRes student, Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

White clover use in dairy systems

A four-year study by TEAGASC in Clonakilty Agricultural College has shown the potential production and economic benefits of incorporating white clover into perennial ryegrass swards for Irish dairy farmers.

Ireland enjoys a competitive advantage in milk production over other European countries, due to its temperate climate and ability to grow and utilise grazed herbage over a long grazing season, as grazed grass is the cheapest source of feed for animal production. Perennial ryegrass (PRG) is the predominant forage species used in grazing systems in Ireland. However, there has been increased interest in the use of forage legumes to increase forage yield and nutritive value, and substitute inorganic nitrogen (N) fertiliser inputs with symbiotic N fixation. White clover is the main forage legume used in temperate grazing systems due to its ability to withstand grazing and its complementary growth habit to PRG. White clover is nutritionally superior in comparison to PRG, can improve animal performance and facilitate a reduction in N fertiliser use, or act as an additional source of N in the sward for herbage production. Research on including white clover in intensive dairy systems was undertaken in Clonakilty Agricultural College from 2014 to 2017 and results are presented here.

Grazing experiment and results

The grazing experiment investigated four separate grazing treatments, two PRG-only treatments and two PRG-white clover treatments established in 2012 and 2013. Each grazing treatment had a separate farmlet of 20 paddocks for the four years, was stocked at 2.75 cows/hectare and received 250 kg N/ha annually. Target concentrate supplementation was 300 kg/cow per year. The physical and economic performance of the PRG-only and PRG-white clover treatments is presented in **Table 1**. On average over the four years, sward white clover content was 23.1 %; however, there was a large variation between paddocks, seasons and years, with sward white clover content generally low in the spring and peaking in late summer/autumn (**Figure 1**). Perennial ryegrass-white clover treatments grew an extra 1.2 tonnes DM/ha herbage compared to PRG-only treatments (**Table 1**). Organic matter digestibility was greater (+ 21 g/kg) and neutral detergent fibre was lower (- 40 g/kg) for PRG-white clover treatments compared to PRG-only treatments. Cows grazing PRG-white clover treatments produced 597 kg more milk (5,818 vs 5.221 kg/cow) and 48 kg more milk solids (485 vs 437 kg/cow) than cows grazing PRG-only treatments. The increase in milk and milk solids production for cows grazing

Table 1: Physical and economic performance of PRG-only and PRG-white clover treatments in Clonakilty (2014-2017).

	PRG-only	PRG-white clover
Herbage production (t DM/ha)	15.6	16.8
Organic matter digestibility (g/kg DM)	776	797
Neutral detergent fibre (g/kg DM)	441	401
Gross output/farm[1] (€)	255,867	273,090
Costs/farm (€)	161,555	166,702
Net profitability/farm (€)	94,774	106,964
Net profitability/hectare (€)	2,369	2,674

[1]*Modelled on a 40 ha farm at a base milk price of 29 c/l using the Moorepark Dairy Systems Model.*

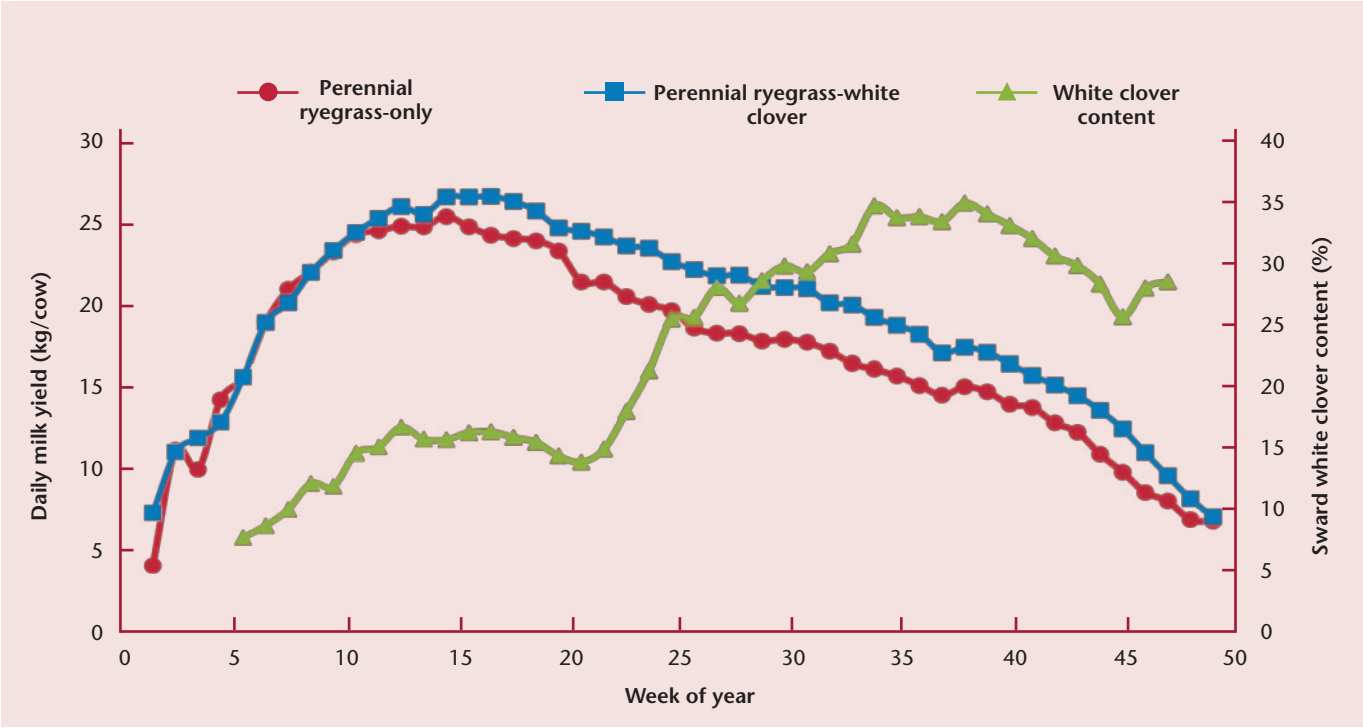


FIGURE 1: Daily milk yield for perennial ryegrass-only and perennial ryegrass-white clover treatments and average sward white clover content by week of year.

PRG-white clover swards generally took place from mid-April onwards, as sward white clover content increased (**Figure 1**). The economic performance of the PRG-only and PRG-white clover treatments was modelled (based on a 40 ha farm and a base milk price of 29 c/l) using the Moorepark Dairy Systems Model (Shalloo *et al.*, 2004) and the biological performance of the treatments as described above. Gross output was greater on the PRG-white clover swards due to the higher milk production from these treatments (**Table 1**). Costs were higher on PRG-white clover swards, due to higher silage supplementation requirements in spring (due to lower over-winter growth), higher labour and housing requirements, and the requirement to include bloat oil for the prevention of bloat. However, profitability was greater on a whole-farm basis (+ €12,190) and on a per hectare basis (+ €305) with PRG-white clover treatments, compared to PRG-only treatments.

Implications

The results of this experiment have shown the benefits of white clover inclusion in PRG swards in terms of herbage production, herbage nutritive value, and animal and economic performance. Future work will continue to investigate the use of white clover in conjunction with reduced N fertiliser usage.

Acknowledgements

The authors acknowledge the contributions of Clare Guy, Michael Dineen, Laurence Shalloo and the farm and technical staff at Clonakilty and Moorepark. We also acknowledge funding from the Dairy Levy Trust and the Teagasc Walsh Scholarships Programme.

Reference

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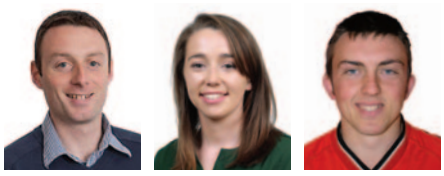
Authors

Brian McCarthy
Research Officer, Grassland Science Department, Teagasc Animal & Grassland Research and Innovation Programme, Moorepark, Fermoy, Co. Cork
Correspondence: brian.mccarthy@teagasc.ie

Bríd McClearn
PhD student, Grassland Science Department, Teagasc Animal & Grassland Research and Innovation Programme, Moorepark, Fermoy, Co. Cork

Fergal Coughlan
Farm manager, Clonakilty Agricultural College, Darrara, Clonakilty, Co. Cork



3D mammalian cell culture models in toxicology testing

3D cell culture can be successfully used as an alternative to laboratory animals, and as a cost-effective and time-saving tissue culture technique, which also reduces the trial period for drug testing.

Toxicology testing is performed to understand the adverse effects of drugs and chemical substances on humans and other living organisms. In the EU, the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation (EC 1907/2006) applies a "no data, no market" rule, and responsibility has been placed on industry to manage the risks from new chemicals and to provide safety information on them.

What is 3D cell culture?

3D cell culture (**Figure 1**) describes a number of techniques to grow cells in three dimensions, such as in a spheroid, using an artificially created microenvironment. Cells in 3D cell culture have physiological cell-cell interactions and cell-extracellular matrix component interactions, which allow cells to grow *in vitro* in an environment that closely resembles *in vivo* conditions. For example, spheres possess a hypoxic (oxygen-deprived) core resembling solid tumours with cells at the centre of the sphere having extremely low oxygen and nutrient concentrations. Spheres also show complex transport dynamics by creating diffusion gradients of drugs, oxygen, nutrients and waste, and also show resistance and drugs/chemical substances show low potency as an *in vivo* condition. The neighbour geometry and cellular support found in 3D cell cultures can improve gene expression, cellular communication, migration, differentiation, survival and growth similar to *in vivo* tissues, which provide better representation for toxicological testing. Mixed-cell populations can also be cultured in 3D to closely model human tissues. Hence, 3D cell culture plays a vital role in measuring biological responses to new chemicals.

Why should I use it?

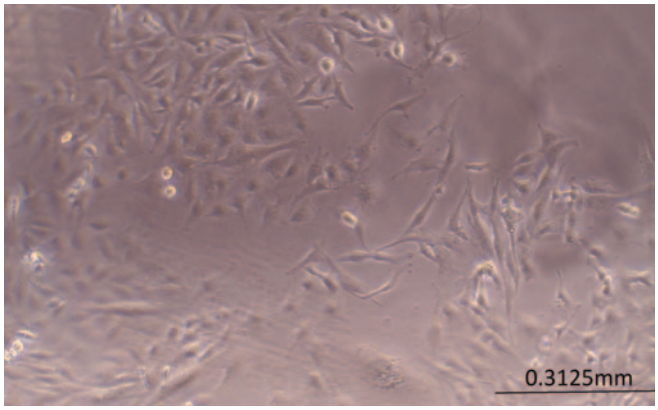
Use of animals in toxicological research has been reduced due to the ethical concerns, expense, time consumption, and misleading results due to differences between human and animal physiology. The REACH regulation's stated aim is: "to ensure a high level of protection of human health and the environment from effects of hazardous chemicals. It strives for a balance: to increase our understanding of the possible hazards of chemicals, while at the same time avoiding unnecessary testing on animals" (European Chemicals Agency, 2020). 3D cell culture is a much better technique, which supports the '3Rs' of animal research (replacement, reduction and refinement) and the REACH recommendation to perform humane animal toxicology research.

Conventional 2D cell cultures (**Figure 1**) are unable to detect organ-specific toxicity and have inadequate representation of cell migration, differentiation, signal transduction, survival and growth. A 2D cell culture does not reveal toxicological resistance (**Figure 2**), architecture as *in vivo* tissues, accurate depiction of cell polarisation or gene expression. It also provides unreliable predictions of *in vivo* drug efficiency and toxicity, which leads to low success rates in clinical trials. 3D cell culture can overcome the disadvantages of *in vivo* animal testing and conventional 2D cell culture by providing a more accurate platform for short- and long-term studies, demonstrating the long-term effects of the drugs.

How is it done?

Different 3D culture techniques such as anchorage independent, anchorage dependent, hydrogels based and specialised culture platforms can be used.

Anchorage-independent/scaffold-free techniques rely on non-adherent cell-to-cell aggregation to form spheroids, which show cell-cell interactions and secrete their own extracellular matrix. These spheroids are formed without a physical support resulting in consistency of shape and size, which provides better understanding about cellular cytotoxicity. Low-adhesion plates



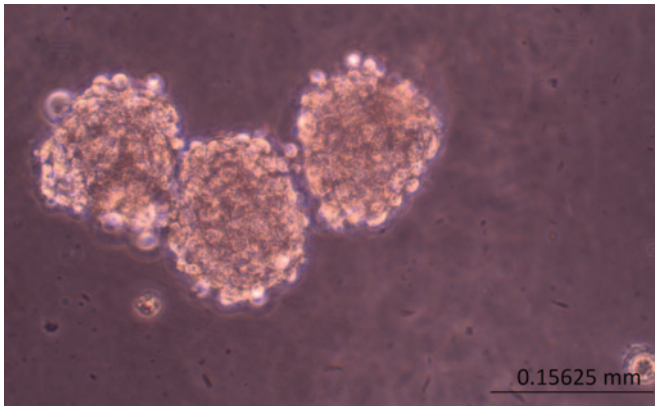


FIGURE 1: 2D (left) and 3D (right) cell cultures of U373MG cells.

are specialised culture plates with ultra-low attachment coating (polyhydroxyethylmethacrylate/agarose), which promote cell aggregation to form spheroids. Hanging drop plates are open bottomless wells, which promote the formation of droplets of media that provide space to form spheroids. In magnetic levitation, cells are preloaded with magnetic nanoparticles and external magnetic fields to provide non-adhesion, plate-like properties to form uniform tumourspheres. A rotational stirrer has a container to hold cells and impeller, stirring continuously. Liquid flow prevents cell adhesion and distributes nutrition and oxygen uniformly to form tumourspheres.

The anchorage-dependent technique provides physical support by using engineered porous membranes, polymeric fabric meshes called 'scaffolds'; these scaffolds can be made of natural or synthetic components. This physical support can provide structures from simple mechanical up to extracellular matrix-like structures. Cells are embedded in extracellular components and are able to initiate cell-cell and cell-matrix interactions, and physical support for cell growth, adhesion and proliferation. Natural scaffolds have higher biocompatibility and lower toxicity when compared to synthetic polymers.

Hydrogels can be defined as water-swollen networks of a polymer, which is a liquid at room temperature and forms a gel-like structure at 37°C. Cells can be embedded inside hydrogels and provide a similar microenvironment to an extracellular matrix. Animal- and plant-derived hydrogels can be used in 3D cell culture. Specialised 3D cell culture platforms, such as microfluidic devices, can equally distribute oxygen and nutrients, while removing waste to facilitate spheroid formation. Micro-patterned plates are micro-space, low-adhesion plates that promote the formation of spheres.

Conclusion

3D cell culture can be successfully used as an alternative to laboratory animals, as a cost-effective and time-saving tissue culture technique, and also to reduce trial periods for drug testing. Moreover, they can be used as an alternative to 2D cell culture, since they give an accurate outcome for toxicological testing. 3D cell culture reduces the gap between *in vitro* and *in vivo* drug testing and its effects at the clinical level.

Acknowledgment

This study has been supported by Science Foundation Ireland (SFI) under grant number 17/CDA/4653.

DMSO cytotoxicity assay for U373MG

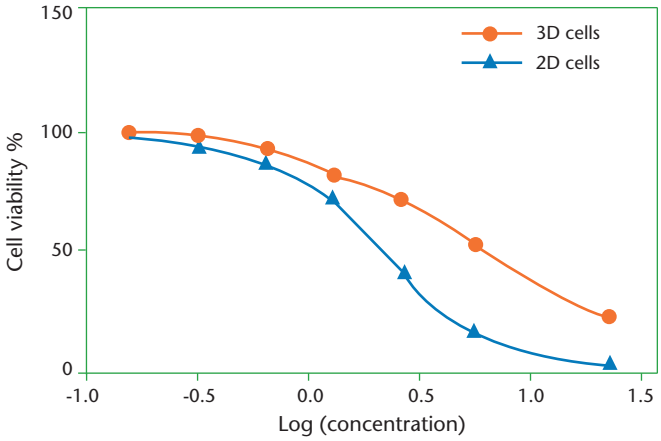


FIGURE 2: Different concentrations of dimethyl sulfoxide (DMSO) cytotoxicity towards 3D and 2D cell culture.

Reference

European Chemicals Agency. (2020). 'Animal testing under REACH – ECHA)'. [Accessed February 23, 2020]. Available from: https://echa.europa.eu/animal-testing-under-reach.

Authors

Janith Wanigasekara
Doctoral researcher, Teagasc and School of Food Science and Environmental Health, Technological University Dublin

Brijesh Tiwari
Research Officer, Teagasc Food Research Centre, Ashtown, Dublin 15
Correspondence: brijesh.tiwari@teagasc.ie

James Curtin
Head of the School of Food Science and Environmental Health, Technological University Dublin

DAIRYDRY

TEAGASC researchers are developing protein-enriched spray-dried dairy powders with enhanced hydration properties.

The global dairy market is continuing to expand at an estimated annual growth rate of 5 % per annum, amounting to ~ $ 703.5 billion by 2024 (Cobbe, 2019). High-protein dairy powders have gained popularity as an essential ingredient in value-add nutritional products and beverages to improve both functionality and nutritional properties, particularly in products designed for early-stage life and healthy ageing. Aside from the requirement for high-protein ingredients, the move towards low-lactose products is also expanding rapidly, with an estimated turnover of €9 billion by 2022. However, there are a number of challenges associated with high-protein ingredients, one of which is their poor solubility, causing major problems both in manufacturing and with the end user. Poor hydration of high-protein powders is a generic problem and frequently results in the presence of surface flecks or sediment in the final product. Despite much research into milk composition, seasonality, functional properties and spray-drying technology, little is known of the mechanism of dairy powder hydration at the molecular and microstructural scale and the relationship between processing conditions and final product functionality. Issues regarding powder solubility usually commence when manufacturing powders with a protein content > 65 %, w/w, dry matter, and are likely to be a result of greater hydrophobic interactions between casein proteins and a lower concentration of lactose and soluble minerals. Typically, high-protein powder particles have a compact shriveled surface morphology (**Figure 1**), which can further hinder the transfer of water into and through particles during rehydration.

Despite much research into milk composition, seasonality, functional properties and spray-drying technology, little is known of the mechanism of dairy powder hydration at the molecular and microstructural scale.

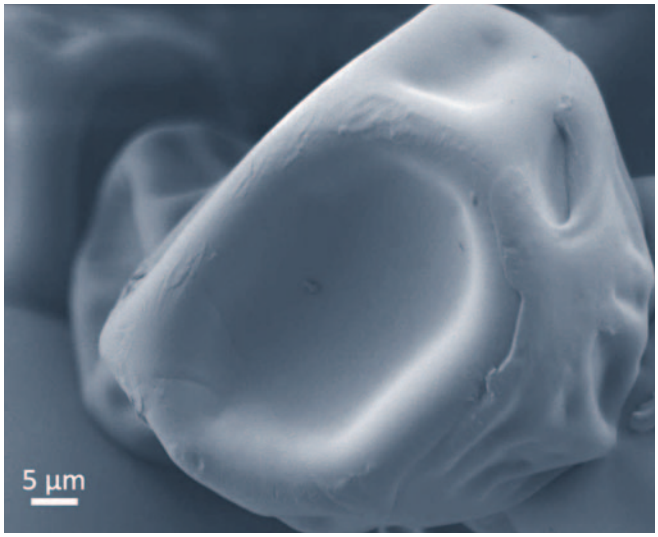


FIGURE 1: Scanning electron microscope image of a dense/compact high-protein powder particle produced using the Niro Tall-Form spray dryer at Moorepark Technology Limited.

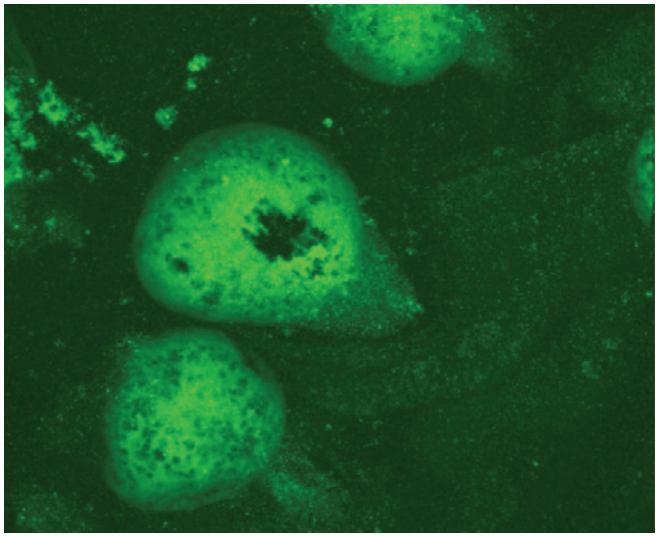


FIGURE 2: Confocal laser scanning microscope image of high-protein milk powder particles after hydration.

A complex interplay

New methodologies and data are needed to study the complex interplay between physical and chemical events that occur during particle wetting, dispersion and hydration (**Figure 2**). The standard industry-accepted test for powder solubility is based on crude sedimentation and there is a need to develop more accurate and informative standard tests for powder hydration. This project is an innovative major collaboration bringing together Ireland's leading research centres in the areas of dairy science, ingredient and process dehydration technology, photonics, and imaging expertise. Projects to date have focused on protein chemistry and bulk functionality; however, the DAIRYDRY project, through an integrated approach, is combining existing food chemistry expertise (Teagasc and University College Cork), advanced imaging expertise (Teagasc, University of Ulster and Waterford Institute of Technology), new processing technology (Teagasc), and sensors leveraged from the ICT industry (Centre for Advanced Photonics & Process Analysis (CAPPA) at Cork Institute of Technology). The project aims to identify the precise cause of insolubility in high-protein powders and to address issues both in the liquid concentrate and during spray drying. Considering the difficulties associated with hydrating high-protein powders, the project is investigating the effects of solvent composition, calcium chelating salts, electrodialysis, ion exchange, inlet/outlet drying temperatures, and modification of particle structure through air porosification. A unique focus of the project is capturing the nano/microstructural changes that occur for individual particles in real time using state-of-the-art imaging techniques.

Spectroscopy

In parallel with this work, CAPPA-CIT has been developing new photonics-based spectroscopic tools to characterise powder hydration in real time by infra-red and Raman fingerprinting. Advanced nano-imaging techniques (University of Ulster) and 3D X-ray microtomography (Waterford Institute of Technology) are being used to characterise powder hydration events at nano- and micro-scales. Results will eventually be used to reverse engineer easily dispersible protein-enriched powder formulations optimised for hydration by the end user.

Funding

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Authors

Noel McCarthy
Research Officer, Department of Food Chemistry and Technology, Teagasc Moorepark, Fermoy, Co. Cork
Correspondence: noel.mccarthy@teagasc.ie

Sharon Montgomery
Research Officer, Department of Food Chemistry and Technology, Teagasc Moorepark, Fermoy, Co. Cork

Valentyn Maidannyk
Postdoctoral researcher, Department of Food Chemistry and Technology, Teagasc Moorepark, Fermoy, Co. Cork

Searching for a cure

TEAGASC research has found that plasma technology has potential as an alternative source for curing meat.

Plasma is considered an emerging non-thermal technology. Plasma can be described as the fourth state of matter and results from applying energy (heat, voltage or light) to a gas, initiating a breakdown of individual gas molecules into free electrons, ions and metastable species.

Plasma-activated water

When plasma is applied to water-based liquids, it changes their characteristics (pH and electrical conductivity) and the resulting liquids are called plasma-activated water (PAW). Depending on the nature of the discharge gas, reactive oxygen species (ROS – ozone, O_3; hydrogen peroxide, H_2O_2; hydroxyl radical, ·OH) and reactive nitrogen species (RNS – $ONOO^-$, peroxynitrite; NO_3^-, nitrate; NO_2^-, nitrite, and the corresponding acids, nitrogen oxides NO_x) are generated in the PAW.

Potential in meat products manufacture

Recently, applications of this technology have been used in food products such as fresh produce, grains and meats with the aim of inactivating enzymes and foodborne pathogens. Nitrites have been used as a curing agent since they were discovered to play a role in the development of the distinctive cured meat colour, in the inhibition of lipid oxidation, and in the control of spoilage and pathogenic microorganisms.

The growing concern among consumers about the potential carcinogenic risks of synthetic curing agents, and the increased popularity of 'all-natural' and 'clean-labelled' food products, have led the food industry to search for alternative curing methods and ingredients. Teagasc researchers are investigating the application of plasma technology as a potential source of nitrite for viable application in the meat industry. A study carried out by Teagasc researchers examined the quality characteristics of plasma-cured beef jerky, and evaluated its suitability as an alternative nitrite source in the production of cured meat products (**Figure 1**).

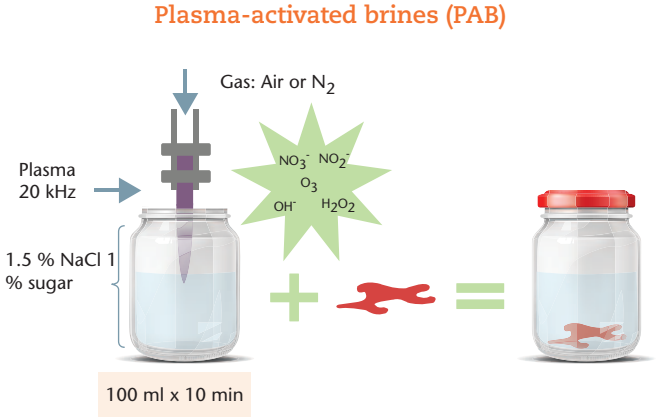


FIGURE 1: Scheme of the methodology used to generate the plasma-activated brine for the curing of jerky.

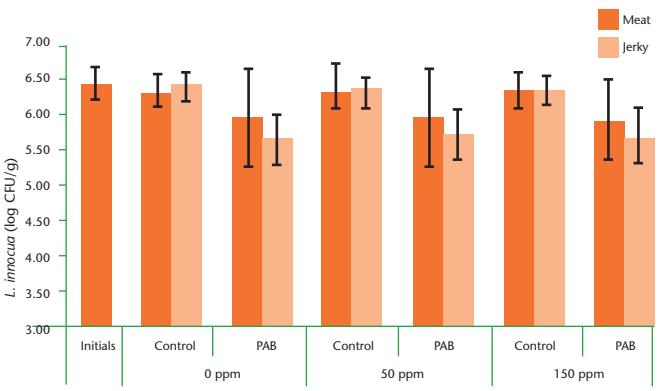
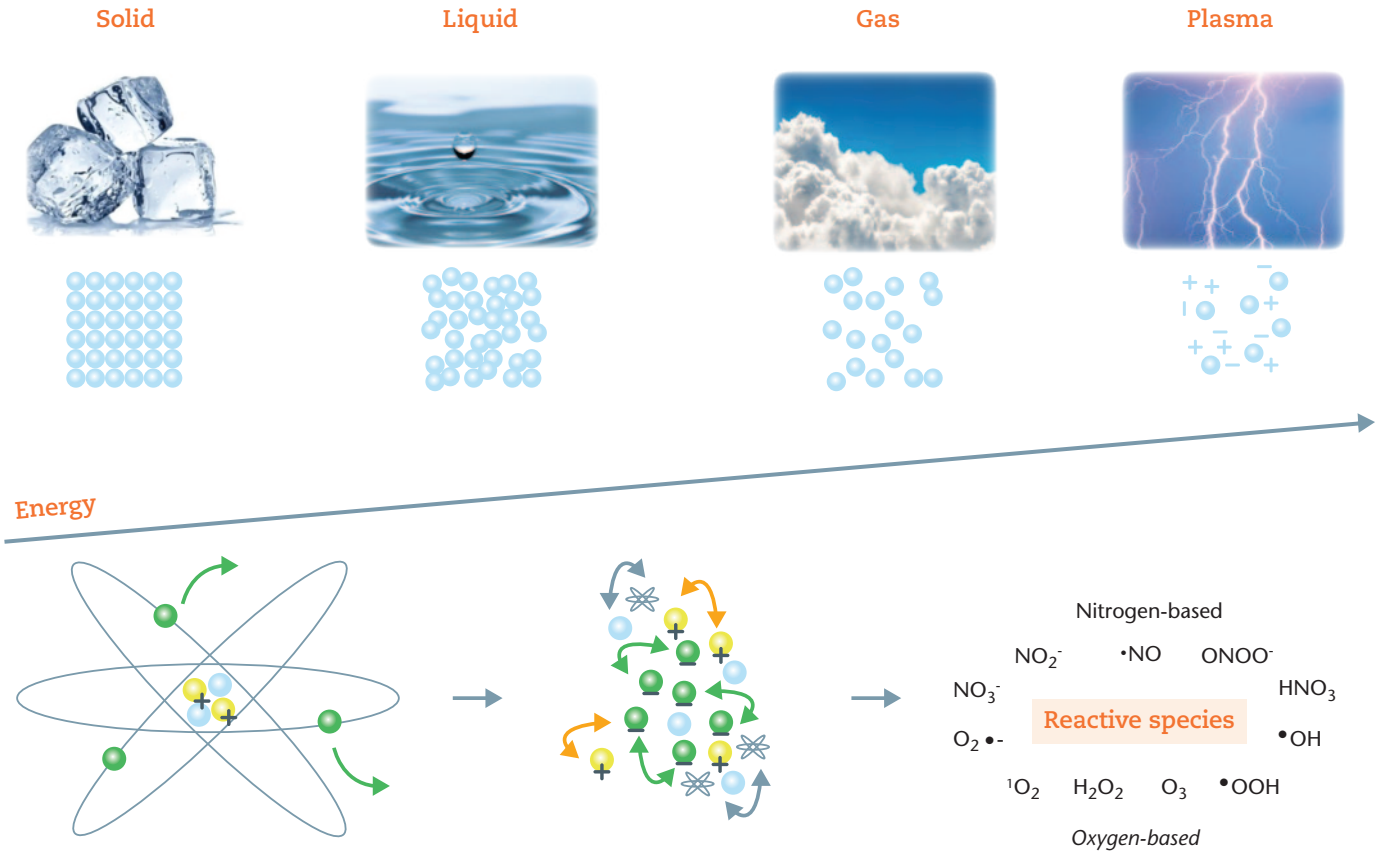


FIGURE 2: Population of L. innocua *(CFU/g) in the meat after curing and in the jerky: control (no plasma) and plasma-activated brine (PAB) with addition of sodium nitrite at 0, 50 and 150 ppm.*



Plasma can be described as the fourth state of matter and results from applying energy to a gas.

Results showed that brine solutions produced by the air plasma system contained sufficient nitrites to be used as a nitrite source for curing beef jerky. When beef jerky was cured with air plasma, no differences were observed in the texture and lipid oxidation of jerky compared to the control samples cured with higher concentrations of added, chemical-based nitrites. In terms of colour, a significant increase in the redness of plasma-cured jerky was observed.

The research also monitored the effect of the plasma curing on meat inoculated with *Listeria innocua* during the curing process.

A significant reduction of 0.85 log CFU/g in the spiked population of *L. innocua* was achieved in jerky produced in plasma brine, compared to the traditionally cured jerky (**Figure 2**). These results showed that plasma technology has the potential to be used as an alternative nitrite source with minimal impact on product quality; moreover, the results of the microbiological study showed that further optimisations of plasma technology could be a successful strategy for meat decontamination.

Acknowledgments

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Authors

Elena Sofia Inguglia
PhD Student, Food Chemistry and Technology Department, Teagasc Food Research Centre, Ashtown, Dublin 15

Márcia Oliveira
Postdoctoral Researcher, Food Chemistry and Technology Department, Teagasc Food Research Centre, Ashtown, Dublin 15

Brijesh K. Tiwari
Principal Research Officer, Food Chemistry and Technology Department, Teagasc Food Research Centre, Ashtown, Dublin 15
Correspondence: brijesh.tiwari@teagasc.ie

A Q-tree (marked with a white band) in a 'graduated density' thinning plot at Ballycullen Forest, Co. Wicklow. Competitors to Q-trees are marked for removal at each thinning (orange marks) to provide space for crown expansion. Additional light is reaching the forest floor, which will encourage natural regeneration. Photo: Edward Wilson.

Transforming Sitka spruce plantations

The TranSSFor project is comparing conventional thinning in Sitka spruce plantations with two alternative thinning regimes.

A contemporary challenge in Irish forestry is the need to sustain timber production while increasing forest ecosystem resilience to threats from pests, diseases and climate change. Evidence from studies elsewhere has shown that forests composed of mixed-species and irregular structure stands can be highly resilient and deliver diverse ecosystem services. Most forests in Ireland, however, are composed of young, single-species plantations managed on the clearfell silvicultural system. Alternative silvicultural systems that create more diverse forest structures are largely untested (Wilson *et al.*, 2018). To address this issue, the Teagasc Forestry Development Department and University College Dublin (UCD) are delivering a five-year research study called the TranSSFor project that focuses on an approach called continuous cover forestry (CCF).

Continuous cover forestry

CCF is a collective term for several silvicultural systems that avoid clearfelling. A permanent forest cover is maintained where individual or small groups of trees are harvested at each stand intervention and natural regeneration is relied on for forest renewal. CCF is a standard forestry system in many regions of Europe, including Belgium, Germany and France. A strong evidence base supports best practice based on four guiding principles: adapt the forest to the constraints of the site; adopt a holistic approach that embraces soil, water, carbon, biodiversity and the trees; maintain a permanent forest habitat (by avoiding clearfelling); and, develop the forest structure, so that timber harvesting and natural regeneration can take place simultaneously. Nevertheless, research is required to apply these principles to Irish forests, where the major species and environmental conditions are different from elsewhere in Europe.

Pathways for transforming forest stands

The immediate research priority is to identify appropriate pathways for transforming forest stands from uniform to irregular forest structures. The TranSSFor project is addressing this by comparing conventional thinning in Sitka spruce plantations with two alternative thinning regimes less commonly applied at the present time. Two productive forests, both planted in the early 1990s, were selected for the study. One is based on a gley soil and at a relatively high altitude (300 m) in Co. Laois. The other is on a more sheltered site with a brown earth soil at a lower altitude (250 m) in Co. Wicklow. In each forest, experimental blocks were laid out to facilitate the comparison of the three thinning regimes over a medium- to long-term management period (to date 10 years).

Conventional stand management

In sustainable forestry, thinning is required to maintain control over the growth and development of the forest stand. Stand interventions take place every three to five years, depending on site productivity and exposure, from stands aged 15-20 years. In Ireland, the conventional form of stand density management is called 'low' thinning. This removes small and poor-quality trees at each stand intervention; remaining trees are more uniform in size and quality, and have adequate space for continuing growth. In the alternative thinning approaches, a balance must be achieved between timber production and the ecological requirements for natural regeneration. Rather than uniformity, suitable trees must be nurtured for seed production and small gaps must be created for seedling establishment.

Crown and graduated density thinning

The two alternative regimes being assessed in the TranSSFor project are 'crown' and 'graduated density' thinning. The key difference between these and 'low' thinning is that trees with superior quality attributes are selected after the first and second thinning interventions, in the 'crown' and 'graduated density' regimes, respectively. These are called Q-trees (main image). The trees marked for removal are generally those that are competitors to Q-trees (**Figure 1**). By removing competitors, the Q-trees are given additional space into which their crowns can expand. Providing space around the Q-trees leaves other areas where fewer trees are removed. This promotes a more irregular spacing between trees (**Figure 1**) and different tree size distributions in the forest stand (**Figure 2**).

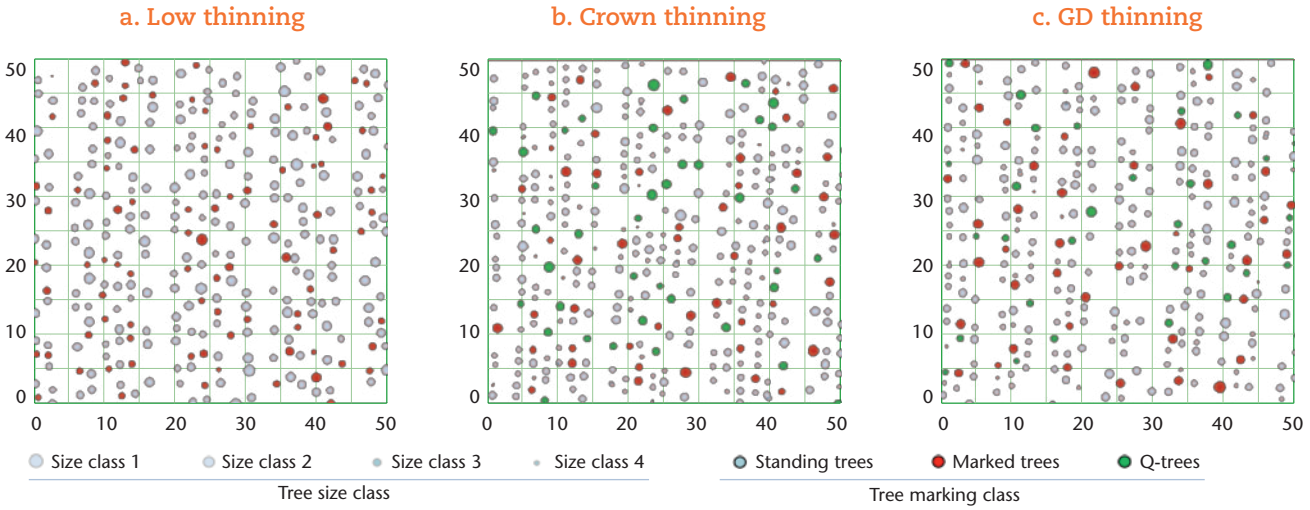

FIGURE 1: Plot maps illustrating changes in stand structure following three thinning interventions in stands managed under (a) low, (b) crown and (c) graduated density (GD) thinning regimes, in Ballycullen Forest, Co. Wicklow. Each plot is 50 × 50 m. Trees are mapped according to four size classes, based on stem diameter at 1.3 m height. Class 4 are the smallest trees; Class 1 the largest trees. Q-trees are labelled in green and trees marked for removal at the third thinning intervention are labelled in red.

Assessing tree growth and quality

The research involves traditional and novel techniques to assess tree growth and quality attributes. Drones have been used to capture aerial images and Light Detection and Ranging (LiDAR) scans of each plot. These data have made it possible to assess tree and stand productivity, competition indices, understorey light regimes and a range of environmental conditions. Initial results indicate that the mean volume of trees harvested at the second and third intervention was greater in the 'crown' and 'graduated density' thinning treatments compared with the 'low' thinning treatment. Variation in stand structure is also evident, as a result of alternative thinning regimes. Individual tree growth models are being used to project future stand development, and to predict patterns of natural regeneration within each thinning treatment.

Benefits to industry

The TranSSFor project and its predecessor are the first studies on stand transformation in Sitka spruce plantations in Ireland. Results are expected to inform the management of forest stands on sites suitable for CCF. The current project will conclude in 2022, following the fourth stand intervention. CCF is becoming more widely adopted in Ireland and the TranSSFor project will continue to generate important information in future years.

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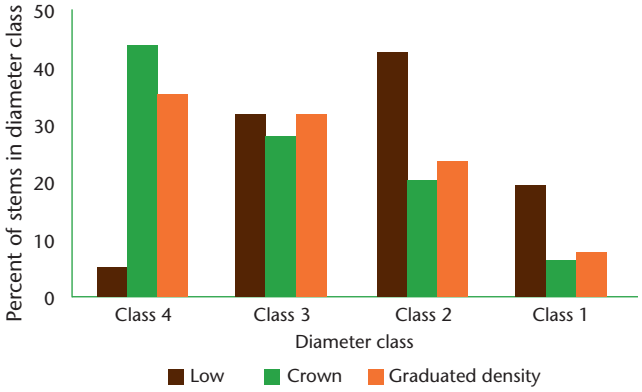

FIGURE 2: The stem class distributions in the 'low', 'crown' and 'graduated density' thinning plots after the third thinning intervention, Ballycullen Forest, Co. Wicklow. Class 4 are the smallest trees; Class 1 the largest trees.

Authors

Edward Wilson
Teagasc Walsh Scholar, Forestry Development Department, Teagasc Ashtown Research Centre, Dublin 15, and UCD Forestry, School of Agriculture and Food Science, UCD, Belfield, Dublin 4
Correspondence: ted.wilson@teagasc.ie

Áine Ní Dhubháin
Professor, UCD Forestry, School of Agriculture and Food Science, UCD, Belfield, Dublin 4

Ian Short
Research Officer, Forestry Development Department, Teagasc Ashtown Research Centre, Dublin 15

Genetic characterisation of Sitka spruce in Ireland

TEAGASC research investigates whether information from DNA can be used to support the Irish Sitka Spruce Tree Improvement Programme.

The global forest resource is increasingly becoming challenged by the effects of climate change. In Ireland, new diseases in ash and larch trees have posed great challenges to our forests. However, significant potential exists to utilise tree-breeding strategies to select trees that may be more adapted to future climates or have more resilient characteristics. Significant advancements in genomics have taken place in recent years and these are being used to provide a better understanding of the differences in the genetic makeup of populations of trees and have widespread applications to assist tree-breeding efforts.
A new project called GenESIS featuring researchers from Teagasc, UCD, Trinity College Dublin, NUI Galway and the National Botanic Gardens, hopes to document the genetics of Sitka spruce forests in Ireland. The proposed research involves the development of a new genotyping platform that will be utilised for assessing genetic diversity, DNA fingerprinting, and if genomic selection can be used to accelerate tree-breeding efforts.
Tree breeding aims to select the best trees to use as parents to produce the next generation. Desirable traits include faster growth rates, straightness, and increased wood properties, all of which offer the potential to increase productivity, carbon sequestration, and ultimately the most efficient use of wood-based products. The objectives of a tree-breeding programme can range from yield improvement and adaptation to particular conditions, pest resistance, improvement of wood characteristics, etc. More recently, tree-breeding efforts have focused on selecting populations or individuals that may be more adapted to future climates.

Special characteristics

As certain populations of trees may have evolved under increased disease pressure or in isolated areas, they may have genes that

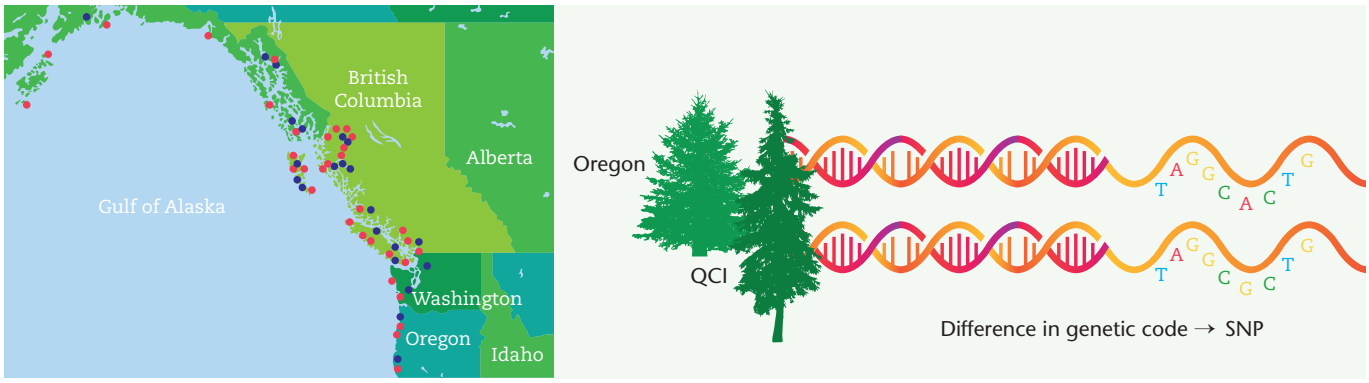

FIGURE 1: Sitka spruce has a geographic distribution covering 3,000 km. Certain populations may display genetic differences, which may contain valuable traits that can be used to breed trees that are taller, stiffer, straighter, more resistant to insect pests and more adapted to future climates.

control the production of metabolites, which affords them increased protection from insect pests and diseases, or conveys increased tolerance to drought events. Sitka spruce is a species that has a wide range of over 3,000 km and occurs from Alaska to California. It is an ideal study species as it has evolved over a wide latitudinal gradient, with some populations isolated by physical geography; these populations may differ in their genetic makeup and may contain these valuable traits (**Figure 1**).

The first step is to assess the genetic diversity of Sitka spruce, and the GenESIS team has taken cambium samples for DNA isolation from the JFK conservation collection representing Sitka spruce's indigenous range. Thereafter, an assessment of the variability in DNA among trees will be carried out to determine if trees from different geographic regions differ in their genetic composition. This information can ultimately be used for genetic fingerprinting, where a tree of unknown origin can be associated to a particular region based on its DNA profile.

This will provide a template in which to assess the levels of genetic diversity in the Irish Sitka Spruce Tree Improvement Programme, currently operated by Coillte. This programme has been in operation since the late 1970s and is comprised of trees selected for favourable height growth and timber density; however, to date these have undergone limited genetic characterisation.

Genomic selection

There is increasing interest in using genomic selection (GS) in tree breeding to select faster-growing trees with desirable timber properties at a very early age, speeding up the process of tree improvement. GS offers the potential to accelerate the selection of improved progeny using DNA markers, and without having to wait for the traits to manifest. Genetic characterisation is intended to not only examine traits related to timber production but also the possibility of either expanding resistance to pests and climate tolerance traits, or whether it is necessary to introduce these traits into the Improvement Programme from external sources. Genetic characterisation of Irish Sitka spruce would therefore help to ensure continued improvement of the Irish Sitka spruce population and inform crossing decisions to recombine trees to produce the next generation of elite trees. The GenESIS project will lay the groundwork to enable GS to be utilised in tree breeding in Ireland. Genotyping will also be deployed to assess the efficiency of current seed orchards and help to design the next generation of seed orchards to support timber production in Ireland.

Given the Government ambition of planting 440 million trees, equivalent to 8,000 hectares per annum, in the next 20 years, the sustainable use of genetic resources is critical to the achievement of this objective. As many forests in Ireland contain Sitka spruce, these forests are a critical reservoir of carbon (stored in biomass and soils) and an important source of renewable raw material for the circular bioeconomy. It is important that the next generation of trees is suitably adapted to fulfil these functions, and that future forests are suitably resilient so that their maximum benefit to society can be realised.

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Author

Niall Farrelly

GenESIS Co-ordinator, Senior Research Officer, Forestry Development Department, Teagasc, Athenry, Co. Galway

Correspondence: niall.farrelly@teagasc.ie

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