TEAGASC
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Sustainable dairy expansion

Optimum milk production systems post-quota
New markets in food from dairy
Soil fertility and dairy expansion

Teagasc
Agriculture and Food Development Authority

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Agriculture and Food Development Authority

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

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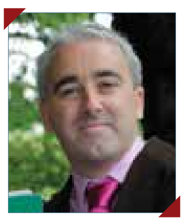
Building a sustainable dairy industry founded on science and innovation

The Food Harvest 2020 report proposed a 50% increase in milk output for the Irish dairy industry using smart green technologies by the end of this decade. A 50% increase in milk production will require milk deliveries to increase from an average of 5.1 billion litres over the 2007 to 2009 period to 7.66 billion litres by 2020. The expansion in Irish milk production will increase the profitability of Irish dairy farms and create valuable new jobs within the national dairy industry. Combined with the value-added at processing level, this will be worth in excess of €1 billion to the Irish agri-economy in the next decade.

World demand for dairy products is expected to increase in the coming decade due to global population growth, increased disposable income and increased urbanisation, especially in developing countries. This must be achieved against a backdrop of issues such as climate change, water and soil depletion and possible yield plateaus in key production crops. The removal of EU dairy quotas represents a long-term opportunity for the Irish dairy industry to increase milk production. Ireland can now plan to exploit our competitive advantage in milk production.

Internationally, agriculture technology is progressing on a range of fronts to address the world's growing food security issues. These include the use of precision farming technologies, genomic technologies in animal and crop breeding and advanced farm management techniques. Ireland has a comparative advantage in milk production due to its ability to grow high yields of grass during a long growing season. Excellence in science and innovation also gives us a competitive advantage. The continued competitiveness of the Irish dairy industry will depend on the development and application of new innovations. This special issue of TResearch focuses on the technologies that will help dairy farmers to grow more sustainable farm businesses, overcome the challenges of milk price volatility and provide an adequate reward to their farm families. Additionally, these technologies will ensure that milk production systems will continue to meet the highest international standards of food safety and quality, be animal welfare friendly and environmentally sustainable.



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

Cathal O'Donoghue,
Head of Rural Economy and Development Programme, Teagasc

Tionscal déiríochta inbhuanaithe bunaithe ar eolaíocht agus ar nuálaíocht a thógáil

Mholadh sa tuarascáil Fómhar Bia 2020 go ndéanfaí méadú 50% ar aschur bainne thionscal déiríochta na hÉireann faoi dheireadh na ndeich mbliana seo trí leas a bhaint as teicneolaíochtaí cliste glasa. Má tá méadú 50% le déanamh ar tháirgeadh bainne beidh sé riachtanach seachadtaí bainne a mhéadú ón 5.1 billiún lítear ar an meán a bhí ann le linn na tréimhse ó 2007 go 2009 go 7.66 billiún lítear faoi 2020. Cuirfidh an méadú seo i dtáirgeadh bainne na hÉireann le brabúsacht fheirmeacha déiríochta na hÉireann agus cruthóidh sé poist luachmhara nua sa tionscal déiríochta náisiúnta. Nuair a chuirtear san áireamh an breisluach ar an leibhéal próiseála, b'fhiú níos mó é sin ná €1 billiún d'agrai-eacnamaíocht na hÉireann sna deich mbliana atá romhainn.

Táthar ag súil go dtiocfaidh méadú ar an éileamh domhanda ar tháirgí déiríochta sna deich mbliana amach romhainn mar gheall ar fhás dhaonra an domhain agus de bharr méadú ioncaim, agus toisc go mbeidh níos mó daoine ag cur fúthu i gcathracha agus i mbailte, go háirithe sna tíortha i mbéal forbartha. Ní mór é seo a bhaint amach i gcomhthéacs fadhbanna mar athrú aeráide, ganntanas uisce, ídiú ithreach agus an chaoi go b'fhéidir go mbainfear amach an bhuaic maidir le táirgeadh príomhbharraí. Tá deis fhadtéarmach ag tionscal déiríochta na hÉireann táirgeadh bainne a mhéadú ó cuireadh deireadh le cuótaí déiríochta an AE. Is féidir le hÉirinn pleanáil a dhéanamh anois chun leas a bhaint as an mbuntáiste iomaíoch atá againn i dtáirgeadh bainne.

Tá teicneolaíocht na talmhaíochta á cur chun cinn ar fud an domhain i réimsí éagsúla le déileáil le saincheisteanna shlándáil bhia mhuintir na cruinne. Ina measc siúd tá úsáid teicneolaíochtaí cruinne feirmeoireachta, teicneolaíochtaí géanómaíocha i bpórú ainmhithe agus barraí agus ardteicnící bainistíochta feirme. Tá buntáiste comparáideach ag Éirinn maidir le táirgeadh bainne toisc go bhfásann mórchuid féir sa tír le linn séasúir fhada fáis. Tugann an barr feabhais atá againn san eolaíocht agus sa nuálaíocht buntáiste iomaíoch dúinn freisin. Braithfidh iomaíochas leanúnach thionscal déiríochta na hÉireann ar fhorbairt agus cur i bhfeidhm nuálaíochtaí. Dírítear san eagrán speisialta seo de TResearch ar na teicneolaíochtaí a chuideoidh le feirmeoirí déiríochta gnólachtaí feirme níos inbhuanaithe a fhorbairt, na dúshláin a bhaineann luaineacht praghsanna bainne a shárú agus luach saothair leordhóthanach chun ar fáil do theaghlaigh feirme. Ina theannta sin, cinnteoidh na teicneolaíochtaí sin go leanfaidh na córais táirgthe bainne ar aghaidh ag sásamh na gcaighdeán idirnáisiúnta is airde ó thaobh sábháilteachta agus cáilíochta bia agus go dtacóidh siad le leas ainmhithe agus le hinbhuanaitheacht chomhshaoil.

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Ceannaire ar Chlár Taighde agus Nuálaíochta Ainmhithe agus Féaraigh, Teagasc

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Scan with QR code reader

Kevin Brennan

Kevin Brennan is a Principal Research Scientist based in the Food Industry Development Department at the Teagasc Ashtown Food Research Centre in Ashtown, Dublin 15. Here he works in the role as a food safety and quality consultant and trainer. His primary area of expertise is in the area of food assurance standards. Food assurance nowadays entails complex and technical standards which cover everything from animal welfare to food traceability and authenticity to food safety and quality. Recent food safety scares such as the emergence of verotoxigenic *E. coli* O157, dioxin contamination of pigmeat and the horsemeat crisis, to name but a few, have not only damaged customer confidence but heightened the awareness of protecting a highly valuable and prized Irish meat export market. Much of food products sold both nationally and internationally are contractually compelled to meet the stringent requirements of quality assurance standards.

Kevin completed an MSc at the University of Reading (Food Science) in 1990. He subsequently went on to work in a joint venture project between Biotechnology Ireland (UCC) and Teagasc (AFRC), where he was responsible for coordinating the dissemination of outputs of the non-commissioned food research programme to industry and state agencies.

Kevin's current client profile includes many of Ireland's large multinational food and beverage companies but also several small-to-medium-size enterprises (SMEs) and an increasing number of start-up companies. SMEs and start-ups are potentially Ireland's next multinationals and recent initiatives, such as the food works programme (www.foodworksireland.ie) involving close collaboration between Bord Bia, Enterprise Ireland and Teagasc, have resulted in some new exciting and innovative food products being launched on the market. Kevin has also built up strong working and strategic alliances with other key government agencies such as Bord Bia, Department of Agriculture, Food and the Marine (DAFM) and Enterprise Ireland. Kevin has worked with Bord Bia for in excess of 20 years on its food assurance programmes. Kevin and his colleagues in partnership with veterinary specialists in the Registered Board of Assessors Ireland (RBAI) and DAFM, have recently rolled out a national training and assessment programme for the entire meat industry on animal welfare. Animal welfare is a critical precursor to meat quality and safety, as well as being a legal requirement.

Kevin has published widely in the area of quality assurance and produced several guidance documents for the food industry on the interpretation and meeting of complex legal standards in the area of food safety and microbiological criteria.

Teagasc Fulbright awards

Mary Carey, a part-time Teagasc Walsh Fellow and a PhD candidate at University College Dublin, and Ruairi Robertson, a Teagasc/Marine-Institute Fulbright awardee and PhD student in nutrition and microbiology in University College Cork, were among 31 Irish recipients of Fullbright awards to the US.

Since 1957, the Fulbright awards are given annually by the Irish and US governments and provide Irish students, scholars, and professionals with the opportunity to study, lecture, and research at top universities and institutions throughout the US.

Mary, who is also an economist with the Department of Finance's Economic and Evaluation Service, will use her Fulbright award to research the impact of agri-businesses on the rural economy at the University of Missouri. Ruairi will carry out research at Harvard University examining the role of dietary omega-3 fats on intestinal and brain health.

The next round of applications for Irish Fulbright Awardees will open on August 31, 2015. Interested applicants in all disciplines are encouraged to visit the Fulbright Commission's website, www.fulbright.ie, for more information. Applications for the 2016-2017 academic year are due on October 30, 2015.

Pictured at the 2015 Fulbright Awards Ceremony in Iveagh House, Dublin, are the winners of the Teagasc-Fulbright awards, Ruairi Robertson, and Mary Carey, along with Dr Lance O'Brien (centre).

Gateways event – Prepared Consumer Foods

A Teagasc Food Innovation Gateways event on Prepared Consumer Foods (PCF) was held in Teagasc Ashtown in June. The latest research, technologies available and expertise from Teagasc, UCC and other state organisations was on display for industry to engage with. A new portfolio of technologies was published and is available at http://www.teagasc.ie/events/2015/20150603.asp

Speaking at the event, Pat Daly, Teagasc said: "Food Harvest 2020 has laid out ambitious growth targets for the sector over coming years. The PCF sector currently employs in the region of 20,000 people with the potential to increase this number significantly over coming years. The PCF sector operates in a very competitive and fast changing market place where innovation is a critical factor in success. Effective utilisation of high-level skills in science and engineering will be a critical factor for success in the sector."

Each year, Teagasc provides research, training and consultancy services to approximately 250 food sector businesses. The food development pilot plants at Teagasc Moorepark, Cork, and at Teagasc Ashtown in Dublin have been critical anchors in the innovation process.

Editor-in-Chief role for Teagasc researcher

Brijesh Tiwari has been named incoming Editor-in-Chief for the *Journal of Food Processing and Preservation*. He will share the role with Professor Charles Brennan, Director, Centre for Food Research and Innovation, Lincoln University, New Zealand.

The international journal is described as the only journal dedicated to publishing both fundamental and applied research relating to food processing and preservation; benefiting the research, commercial and industrial communities. The journal is published by global publishing company, Wiley.

Exploring African opportunities for sustainable food systems

Representatives from all 23 African and European project partners at the EU-funded PROIntensAfrica kick-off meeting at FARA Headquarters in Accra, Ghana in April. Teagasc's representatives on the project are: Catriona Boyle, Lance O'Brien and Rogier Schulte.

Twenty-three African and European research partners are collaborating on a long-term research and innovation partnership focusing on sustainable intensification of the agri-food system in Africa.
PROIntensAfrica is new initiative that will see researchers from 21 countries explore, collaboratively, the effects of the agri-food system on the environment and population.
While current food production systems have enabled a substantial increase in food production, the farming practices have also impacted the environment. In addition, many people still do not have enough to eat and cannot escape poverty.
Dr Yemi Akinbamijo, Executive Director of the Forum for Agricultural Research in Africa (FARA), says the PROIntensAfrica initiative will go beyond the debate of best systems for sustainable intensification in Africa. "We will combine elements of different systems, yielding into innovative systems to optimally meet specific requirements."
Pooling African and European research resources is perceived as the best way to align existing research and instigate new research initiatives. Also, joint programming is one of the main instruments of the European Commission to accomplish more synergy and increase the effectiveness of resources.
The ambition of PROIntensAfrica is to formulate a universal research agenda and co-develop mechanisms for an effective long-term partnership. Therefore, pooling resources for PROIntensAfrica is not only about science, but also about policy and funding. Subsequently, the partnership proposal for IntensAfrica will need to meet the national and international policies.
Consultation, case studies and stakeholder panel workshops are a major part of the activities of ProIntensAfrica. A wide range of strategic stakeholders will be invited to contribute to the activities and the agenda.
The PROIntensAfrica project began with a workshop in Accra, Ghana, in April 2015. The project will develop into the IntensAfrica programme within two years.

LANDMARK to unearth pathways to sustainable land management

LANDMARK is a brand new consortium of European researchers and advisors that will seek to unearth practices and policy pathways that make the most of Europe's rich and diverse heritage of soils, which are key to so many ecosystem services. It was launched in May and receives €5 million in European funding from the European Commission as part of its Horizon 2020 Research Programme.
At the launch, Teagasc Director Gerry Boyle explained that LANDMARK addresses one of the most urgent challenges for European agriculture: "The number of mouths to feed from each parcel of land continues to rise. But the ecological footprint that we can afford ourselves continues to shrink. Last autumn, the UN revised its projections for population growth: the world's population is no longer expected to stabilise after 2050, instead it is now expected to continue to grow and approach 11 billion people by 2100. These new figures will certainly fuel the debate as to whether the world, including Europe, is 'running out of land'."
The LANDMARK coordinator, Dr Rachel Creamer from Teagasc added: "Not only do we expect Europe's agricultural land to provide a nutritious diet for all; we also expect it to provide clean water, to store carbon, recycle our waste and provide a home for biodiversity. These competing demands have now brought soil science sharply back into focus. If we are to make the most of our land, we need to understand the 'engine room' of agriculture in all its diversity."
LANDMARK aims to do exactly this: it will open up the soils of Europe and assess farm practices and policies that optimise the delivery of food and other ecosystem services. LANDMARK has taken an international approach: it will bring together all the knowledge on land management from European farmers, advisers, scientists and policy makers.

Two appointments to Teagasc Authority

Cliona Murphy, Glounthaune, Co Cork, and Liam Woulfe, Adare, Co Limerick have been appointed to the Teagasc Authority for five-year terms by the Minister for Agriculture, Food and the Marine, Simon Coveney TD. At the Teagasc board meeting in May, Teagasc Chairman, Noel Cawley welcomed both new members and congratulated them on their appointment.
Cliona Murphy is Vice President Technical for PepsiCo Worldwide Flavours, with global responsibility for Research & Development, Quality, Engineering, Environmental Health & Safety, and Global Quality Services. Liam Woulfe is Managing Director of Grassland AGRO and of Freshgrass Group.

Teagasc shares in €30m research investment

Minister for Skills, Research and Innovation, Damien English TD, recently announced over €30 million of research funding for 23 major research projects. The funding will be delivered by the Department of Jobs, Enterprise & Innovation through the Science Foundation Ireland (SFI) Investigators Programme. The Programme will provide funding over a four-to-five year period, for 23 research projects involving over 100 researchers. Funding for each project will range from €500,000 to €2.3 million.
Teagasc's Donagh Berry received funding for his research proposal to help achieve the Irish Government's strategy of increased animal production through: 1) greater exploitation of more precise genetic information; 2) more precise estimation of how each genetic variant affects performance; and 3) development of precision mating plans. The results will be disseminated to industry through low-cost, customised tools and resources, which are also applicable to other species and breeds.

SuperValu awards excellence in food microbiology research

The second-annual SuperValu Award for Excellence in Food Microbiology has been presented to Damhan Scully at a ceremony in UCC. Damhan, originally from Blackrock in Dublin, finished top of his class in the Masters of Food Microbiology course. As part of the award, Damhan will receive a bursary of €2,000 to continue his research. Damhan has also recently been awarded a Walsh Fellowship to undertake his PhD research jointly with UCC and Teagasc later this year in the area of food safety.

Open Access and Research Data Management: Horizon 2020 and Beyond

This recent training event in UCC Library explored the concepts of Open Research and Research Data Management (RDM) within the context of Horizon 2020. The event was organised jointly by UCC Library together with UCC Research Support Services, Teagasc, HSE and Repository Network Ireland (RNI). The event was made possible through funding from the FP7-funded FOSTER project, which aims to set in place sustainable mechanisms for EU researchers to implement open science in their daily workflow.

The event brought speakers from across Ireland and the UK to share their experiences with RDM. Martin Donnelly, Digital Curation Centre, UK, provided an overview of open science and open data in Horizon 2020. Open access via repositories to all publications arising from the projects funded is mandated in Horizon 2020. There is also an Open Data Pilot whereby the data resulting from projects in certain areas will be made openly available. The benefits of open data are seen as transparency, efficiency and accessibility.

Martin also spoke about RDM Plans – policies, requirements, resources and examples. The IP challenges were addressed by Joe Doyle of Enterprise Ireland. Several case studies were presented, which further explained the issues around RDM from the planning stages to long-term preservation and accessibility, with the overarching aim being to record data effectively and make it available for validation, re-use and re-purposing.

The implications of RDM for research institutions were addressed, particularly in the context of infrastructure and support services for researchers. The Data Management Plan (DMP) toolkit from DCC was mentioned favourably by several speakers as was the concept of a Data Asset Register. Collaboration and co-operation between Library, ICT and Research Office staff will be vital for successful implementation of RDM policies, with their roles spanning the research data lifecycle including compliance, guidance, selection and preservation.

The presentations from the event are available on the FOSTER website or on the RNI (Repository Network Ireland) wiki.

New Innovation Centre for Grassland and Dairying opened

Over €4.5 million has been invested in a new Innovation Centre for Grassland and Dairying at the Teagasc campus in Moorepark, Fermoy, Co Cork. The Paddy O'Keeffe Innovation Centre, funded by FBD Trust and the Department of Agriculture, Food and the Marine, will be used by the researchers, specialists and advisers involved in the delivery of the Teagasc Animal & Grassland Research and Innovation Programme, and in the delivery of part of Teagasc's Education programme. Specifically, it will support the research programme on grassland, animal breeding and health, and farming systems.

Speaking at the official opening, EU Commissioner for Agriculture and Rural Development Phil Hogan said: "The late Paddy O'Keeffe really is one of the legends of Irish agriculture. His passion for innovation, for change, for development, for productivity and, ultimately, for the sustainability of Irish agriculture and the rural way of life are values more important today than ever before, as we enter a new era of Irish, and indeed European, agriculture."

Also present for the official opening was EU Commissioner for Research, Science and Innovation, Carlos Moedas. Commenting on the investment, he said: "I am delighted to see this major new investment in the future of farming, food and rural communities. This is a good case where science and research are 'down to earth'. Faced with an emerging risk to our future food security, Europe needs to step up research and innovation across the agri-food chain to meet the challenges and opportunities ahead."

Teagasc Chairman, Dr Noel Cawley, thanked FBD Trust for its generous financial support, which facilitated the establishment of the Paddy O'Keeffe Innovation Centre. He also acknowledged the funding contribution from the Department of Agriculture, Food and the Marine towards the Centre. "As we enter this new post-quota era in milk production, and as we strive to increase our utilisation of grass in beef and sheep systems, this new Innovation Centre, the researchers working here and the young people educated here, will play an increasingly important role in developing Irish agriculture in the future."

Minister for Agriculture, Food and the Marine, Simon Coveney TD, said: "Paddy O'Keefe was a much admired figure who spent his life seeking out new knowledge that would ultimately help improve the agri-food sector here in Ireland. His commitment to education, research and the dissemination of information to the farming community remained constant over the decades and this Innovation Centre is a truly fitting tribute to his legacy."

Water use and waste-water treatment workshop

Teagasc, along with the Society of Dairy Technology and Engineers Ireland (Ag & Food Division) held a workshop on water usage and waste-water treatment across the dairy sector in Moorepark in April. This was followed by a site visit to Dairygold's anaerobic digester effluent treatment facility.

Technology Foresight Project launched

Teagasc has launched a new Technology Foresight Project, which will focus on the identification of the key technologies that have the potential over the next 20 years or so to underpin competitiveness, sustainability and growth in the Irish agri-food sector. This study will be of major importance in prompting Teagasc to look beyond the standard three to five-year timeframe, to think about what is possible in the long-term and to develop strategies, policies and roadmaps for its research and innovation programmes.

The overall objective is to provide a comprehensive and well-researched source of evidence for policy decisions relating to Teagasc's future science and technology programmes. It will aim to assist the organisation in identifying the new areas of technology that it should prioritise for the long term and the resulting implications for investment in new skills, equipment and infrastructure. It will also bring together a wide diversity of people from different backgrounds to explore new ideas and to achieve consensus on the long-term challenges confronting the Irish agri-food and bioeconomy sector and its future technology needs.

A Steering Committee comprising leading national and international experts is responsible for guiding the project. The first meeting took place in Teagasc Ashtown in May. The chairman of the Steering Committee, Tom Moran, former Secretary General of the Department of Agriculture, Food and the Marine, stated: "It is recognised that the opportunities and risks associated with new technologies must be fully evaluated on a case-by-case basis against the specific problem or issue the technologies can address. It will be vital for our scientists to fully communicate the outcomes of these evaluations to consumers, as, among other socio-economic considerations, consumer attitudes will be critical in determining the ultimate application of these technologies in agri-food".

Dairy ingredients and processing innovation collaboration for GII and Teagasc

A new collaboration agreement was announced between Glanbia Ingredients Ireland (GII) and Teagasc in the areas of dairy ingredients and processing. The arrangement focuses on the development of scientific capability to support the generation of added value in the cheese and dairy ingredients space.
Speaking at the launch, Teagasc Director Professor Gerry Boyle said: "We are delighted to extend our existing excellent working relationship with GII to the food research area. With the abolition of milk quotas and an increasing milk pool, there is a need for rapid transfer of scientific know-how for development of dairy ingredients with new end uses in export markets. This collaboration combines Teagasc's extensive capability in dairy chemistry and processing with GII's knowledge and expertise in dairy and nutritional ingredients with the goal of bringing new innovative products to export markets."
To support this initiative, a scientific programme has been agreed between the two parties that will support delivery of the latest developments in dairy science and technology at GII, the largest private shareholder in Moorepark Technology Ltd. At the heart of the new programme is collaboration between Glanbia and Teagasc research and technology staff, working together to capture the latest dairy chemistry and processing know-how from around the world.
Jim Bergin, CEO of GII said: "This collaboration has the potential to deliver the next generation of dairy ingredients for a range of applications globally. As part of the collaboration, Glanbia have located research staff on-site at Moorepark and they will carry out the day-to-day activities on the programme working closely with key Teagasc staff. This endeavour will be one of the core contributors to GII's extensive innovation platform over the next five years"
The programme will benefit from access to scientific instrumentation at Moorepark and the extensive pilot plant facilities of Moorepark Technology Limited, which are capable of fully replicating the commercial operations at Glanbia. The ability to scale up the science ensures the delivery of real commercial applications nd adds an important dimension to the existing Glanbia cheese and ingredients programme.

Commercialisation of Teagasc's Birch Improvement Programme

The next stage in Teagasc's Birch Improvement Programme: The Commercialisation of the Teagasc Birch Improvement Programme, was recently launched.
Teagasc and None so Hardy Nurseries are currently discussing a joint commercialisation plan to support and ensure exploitation of improved birch resulting from the Teagasc-led tree improvement programme at a national level, with potential expansion to cover alder and sycamore in due course. There is a clear commitment from both parties on partnering, with a view to long-term exploitation of outputs from the state-supported tree improvement programme coordinated by Teagasc.
Nuala Ní Fhlatharta, Head of Teagasc's Forestry Development Department said: "This announcement is the result of 17 years of tree improvement research initiated and led by Teagasc with collaboration from UCC and UCD, and has been mostly funded through the DAFM. The research is now at the exciting stage of starting to build strategic alliances with commercial seed producers/nurseries to ensure that Teagasc's research output is brought to the next level by making improved planting stock available to landowners."

Dairymaster Rural Innovation Awards 2015

Winners of the Dairymaster Rural Innovation Awards 2015 were: Recovery Haven Kerry, Fresh Extend and SAMCO.

The Dairymaster Rural Innovation awards took place in Tralee in May. Organised in association with Dairymaster, DARD, the *Irish Farmers Journal* and Teagasc, these awards aim to encourage, motivate and improve business ideas. This year, there were three categories: Community Focused Innovation, Farm Innovation and Rural Business Innovation. The overall winner was Recovery Haven Kerry – Cancer Support House, Tralee, Co Kerry. It also won in the Community Focused Innovation category. Recovery Haven is based at St Martin's Aughamore, Causeway in Tralee.
The Farm Innovation category winner was Fresh Extend owned by Brian Hampton based at Kilmore, Co Armagh. SAMCO, owned by Samuel Shine from Adare in Co Limerick, won in the Rural Business category.

UK Agricultural Economics Society award

Professor Cathal O'Donoghue, Head of Teagasc's Rural Economy and Development Programme, was presented with an award by the UK Agricultural Economics Society at its recent annual meeting held at the University of Warwick. The award was made in recognition of the role he played in leading the Commission for the Economic Development of Rural Areas, the adoption of the report as Government policy and the appointment of a Minister for Rural Affairs with specific responsibility for the implementation of the report.

Sensory Food Network to support Irish food

Sensory food science is the study of how we, as consumers, perceive foods with each of our senses. The importance of a scientifically sound approach to the sensory evaluation of food has received increasing recognition by the food industry in Ireland.
A new network of excellence in sensory food science, Sensory Food Network Ireland was officially launched in April. Sensory Food Network Ireland has been established to promote the integration of sensory science activities on the island of Ireland and includes 10 leading institutions with expertise in sensory science. This sensory network will become an integral part of the food and beverage industry, in supporting new product development by providing services such as product matching, consumer acceptance and flavour chemistry. Achieving the potential for growth within the Irish food industry requires a two-way partnership between the scientific community and the food industry. Facilitating this partnership, as well as delivering comprehensive and excellent sensory science services, are key elements of the network's vision.
Dr Eimear Gallagher, Teagasc Food Researcher, who is the lead coordinator of the network, also emphasised the need to communicate with food companies: "The network is proactively seeking interaction with industry and other research institutes to grow and develop the field of sensory science on the island of Ireland."

APC Science Quiz at iWISH

Katie Cody, Loreto Secondary School Fermoy is the winner of the APC Science Quiz at iWISH which took place in Cork City Hall recently. Katie received her prize from Dr Elaine Patterson, APC Microbiome Institute at Teagasc Moorepark Food Research Centre, Fermoy. "The science quiz proved to be a real hit at iWISH, promoting lots of interaction with APC scientists, giving students a chance to demonstrate their scientific knowledge and resulting in hundreds of entries," said Dr Orla O'Sullivan, APC Microbiome Institute and SIRG Research Fellow at Teagasc.
iWish is a city and regional schools initiative to inspire Women in Science, Technology, Engineering and Maths (STEM). The idea is to promote greater female participation in STEM to ensure that Ireland maximises its talent pool and continues to attract high skilled jobs. APC participated in iWISH in Cork City Hall where it had a stand. Dr Sally Cudmore, General Manager APC, gave a presentation at the Mallow regional pod where students had the opportunity to visit Alimentary Adventures, APC's inflatable tunnel model of the gastrointestinal tract.

Genomic selection in dairy cattle

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Recent advances in genomic selection are highlighted in this article and other uses for DNA-based technologies in dairy cattle breeding are outlined.

Genomic selection is the supplementation of pedigree information with genomic information, with the goal of increasing the accuracy of prediction of genetic merit. Because all animal characteristics are governed to a greater or lesser extent by genetic makeup of the animal, genomic selection can be used to accelerate genetic gain in all performance characteristics. Since DNA remains the same throughout life, genomic selection can be optimally applied at birth, thereby providing early knowledge on the most appropriate usefulness of the animal. Genomic predictions work equally well in both male and female animals.

Genomic predictions

Genomic predictions of Irish dairy cattle were launched in spring 2009. The uptake of genomically tested bulls has risen from 34% in 2009 to 59% in 2014 (Figure 1a). This statistic is relatively consistent with trends in most countries (e.g., the US, France, the Netherlands), although usage in Ireland is greater than in both New Zealand (about 25%) and the UK (about 30%) but lower than in Nordic countries (about 80%). The rapid uptake in Ireland and most other countries owes itself to the far superior genetic merit of the young genomically tested bulls, compared to the traditional daughter-proven bulls. In Ireland, the Economic Breeding Index of the genomically tested young bulls is approximately one standard deviation superior to the traditional proven bulls. The population of animals with both genotype and phenotype (i.e., performance) information is increasing year on year (Figure 1b), thereby providing more accurate genomic evaluations. More recently, the reliability of genomic evaluations has reduced as breeding companies attempt to further accelerate genetic gain by marketing genomically-tested bulls from genomically-tested sires and even grandsires.

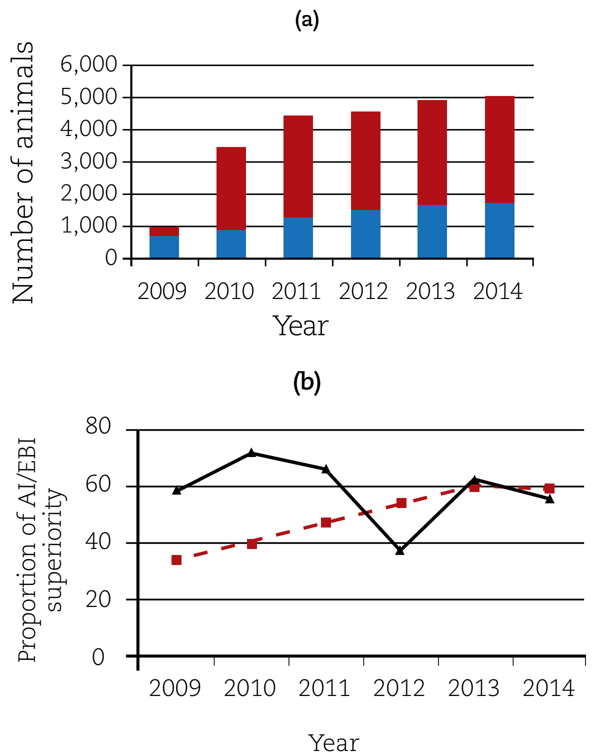

Figure 1. (a) Number of animals included in the training population generated within Ireland (blue bars) or from bilateral sharing (red bars); (b) proportion of semen sales from genomically tested sires (%; broken line) and genetic superiority (€) of used genomically-tested sires relative to used proven bulls (continuous line).

Sufficient information now exists to retrospectively evaluate how accurately genomic predictions of years ago reflect the genetic evaluations of bulls today based on daughter proofs. Genomics did not, on average, over-estimate genetic merit of bulls (Table 1) as is often documented in other populations (e.g., New Zealand). Moreover, genomics was up to 54% more accurate in ranking bulls compared to the traditional method of genetic evaluation based on pedigree index (Table 1). Additionally, individual bull fluctuations from their original genomic evaluation as young bulls was generally small, with most varying by ≤€15 for the milk subindex and ≤€15 for the fertility subindex. Nonetheless, the reliability of genomically-tested sires is still not 100% and, thus, risk should be minimised by always using a team of, at least, four to five genomically-tested bulls.

Table 1. Mean (reliability) daughter-based predicted transmitting ability (PTAs) from the most recent genetic evaluation, as well as past parental average (PA) or genomic-based PTAs; also included is the correlation with the most recent daughter PTA for both PA and genomic PTAs.

	Mean			Correlatioins	
Trait	Daughter	PA	Genomic	PA	Genomic
Milk (kg)	116 (90)	168 (41)	108 (61)	0.71	0.79
Fat (kg)	10.4	11.9	10.2	0.55	0.70
Protein (kg)	7.8	9.6	7.7	0.63	0.75
Fertility (days)	-4.5 (71)	-3.1 (30)	-3.7 (46)	0.60	0.63
Survival (%)	2.01	1.52	1.7	0.41	0.63

Other uses of DNA-based technologies in dairy cattle breeding

1. **Major genes**

   Genetic mutations that can result in conception failure, embryo/foetal death or periparturient mortality include complex vertebral malformation (CVM), bovine leukocyte adhesion deficiency (BLAD), deficiency of uridine monophosphate synthase (DUMPS) and Brachyspina. The frequency of carriers of these lethal mutations in the Irish Holstein-Friesian population is 2.28%, 0.00%, 0.53% and 1.75%, respectively. Although low frequency, these carriers in the commercial population are undoubtedly contributing to reduced reproductive performance. For example, there is a 25% chance that a mating of two carriers will result in pregnancy failure. Heretofore, known carriers were culled, thereby minimising the likelihood of carrier animals mating. Recent evidence, however, suggests that individuals (including human) are carriers of between two to 20 lethal mutations. Thus, strategies are being put in place to provide advice on potentially incompatible matings rather than blanket culling of carriers, which will reduce the impact on genetic gain. Interest is also increasing in the frequency of mutations in other major genes (e.g., the A1-A2 beta casein genotype). Of the Irish Holstein-Friesian cattle genotyped, the frequency of animals with the A1A1, A1A2 and A2A2 variants of beta-casein were 14%, 45% and 41%, respectively.

2. **Parentage**

   Accurate pedigree is vital to achieve genetic gain and reduce inbreeding. Parentage was, heretofore, undertaken using microsatellite technology, which was resource intensive. Moreover, the information generated could only be used for parentage verification and assignment and was not always completely accurate. Ireland has now almost exclusively transitioned from microsatellite technology to SNP-based technologies. Not alone is the latter less expensive, but additional information can be garnished from the SNP genotype. In particular it can be used for genomic predictions. Based on recent genotyping initiatives, parentage errors in Irish Holstein-Friesian cattle are approximately 8.5%. Where incorrect parentage exists, the SNP genotypes can be used to assign the true parents.

3. **Breed composition**

   The breed composition of an individual, from at least one crossbred parent, cannot be known with certainty, other than through the examination of the genotype of an individual. Knowledge of breed composition might be of interest in crossbreeding strategies to maximise the benefit of heterosis by availing of information on the actual breed composition of the parents. Breed composition of individuals is also important for some export markets (heifers certified above some threshold level of Holstein-Friesian genetics) but also for quantifying the proportion of genetics from a particular beef breed (e.g., Angus and Hereford) to qualify for a high value-added market.

4. **Precision mating**

   Genomics can also be used to more accurately quantify the relationship between two possible mates. This provides valuable information not only on the mean inbreeding of the resulting progeny, but also the likely locus-specific inbreeding of the resulting progeny. Designer matings will be the future and will be genomic-based – this will arguably be the next biggest gain from genomic information after genomic predictions. This is already becoming a reality as almost all AI and natural mating Holstein-Friesian bulls are genotyped and the frequency of genotyping of dairy females is intensifying. Some breeders are passionate about following family lines. Without genomics it is not possible to quantify the proportion of an ancestor's genome (excluding the direct parents) in an individual; genomics can help resolve this.

Conclusions

Genomic selection is now the method of choice for prediction of genetic merit in most developed national breeding programmes in dairy cattle. Retrospective analysis from Ireland clearly shows that genomic predictions are up to 54% more accurate than traditional pedigree-based predictions for young animals. Additional exploitable genomic information exists in dairy cattle breeding programmes to further advance gains in profit.

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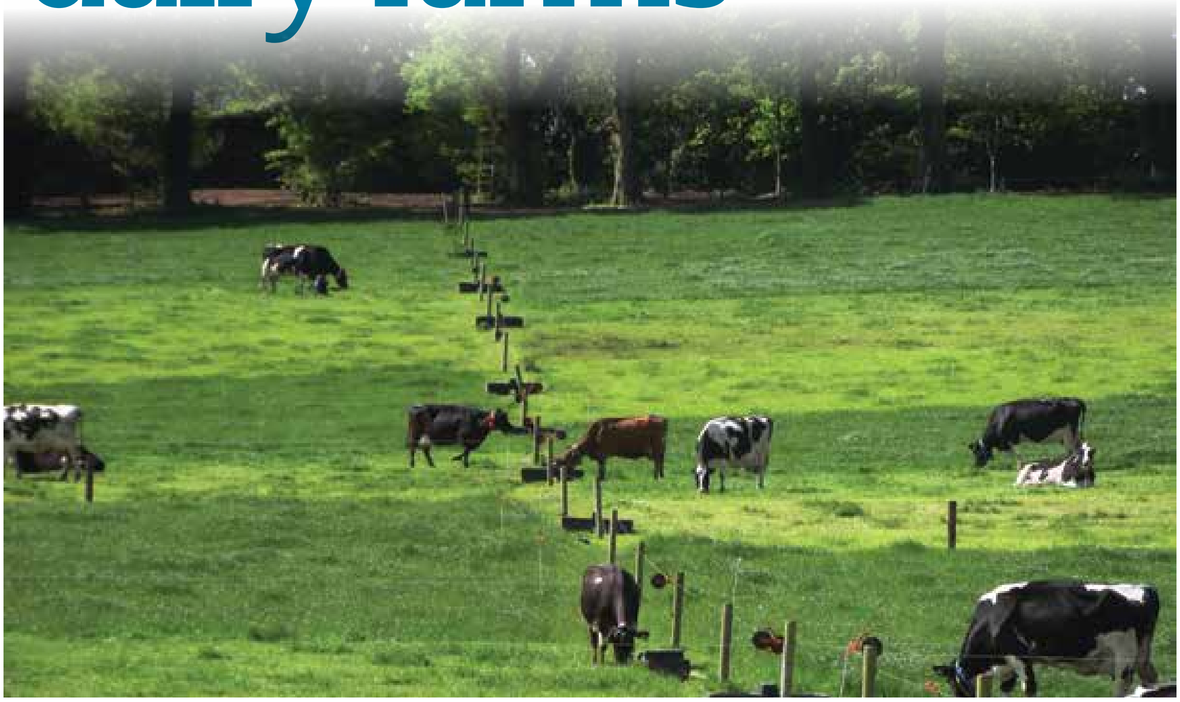
Water use on Irish dairy farms



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A study of water usage on 25 commercial dairy farms will help to inform both farmers and policy makers about the freshwater demands for milk production.

There is a rising demand for animal-sourced foods driven by increasing global populations, rising incomes and urbanisation. Seventy per cent of freshwater demands are attributed to agricultural practices. Quantifying the water footprint of agricultural outputs and identifying hot-spots of water consumption along the food production process is the first step towards reducing freshwater demand from agriculture. The water footprint of a product – defined by the Water Footprint Network – is the sum of the volumetric water use along the entire supply chain of a product. This is comprised of ground and surface water (blue water) and soil moisture due to evapotranspiration (green water). The total water used in the supply chain can also be regarded as direct and indirect water use. For milk production, indirect water use includes evapotranspiration of growing grass and crops and water used producing energy, fertilizers and concentrates. Direct water use is water used on-farm to facilitate milk production processes such as drinking water for livestock, washing procedures and milk pre-cooling. Direct water, although a small proportion, is often the first place water savings can be identified and implemented. Irish agriculture generally does not suffer water shortages due to our temperate maritime climate. On the global scale, however, water availability is limited. Since the Irish dairy industry exports 85% of its annual production, information about water consumption in the production chain of Irish milk is important for international markets, as it demonstrates milk production in Ireland is sustainable and resource-efficient.

Study of 25 commercial farms

Twenty-five commercial dairy farms were selected from the Teagasc advisory database, which are hereafter referred to as study farms. Data were collected from May 2012 to April 2013. Data on farm infrastructure were collected by means of a survey. This included information relating to sources of water for each farm (well/mains), types of milk cooling equipment and washing procedures for the milking machine and cow collection area. Water meters were installed on each farm measuring the volume of water used throughout the farm enterprise. Up to eight water meters were installed on each farm to record total direct water use, including water used in the milking parlour and water consumed by livestock. Domestic water consumption was measured separately and subtracted from the total water supply to calculate water supply to the farm only. Water

Direct water use is water used on-farm to facilitate milk production processes.

meter data (m^3) were recorded on a monthly basis via an online survey.

All data were analysed in spreadsheets and summed by water use. The water-meter data were categorised from the supply (source) into parlour and other uses. Parlour readings were further categorised to include the water heater, plate cooler and wash-down readings. 'Other' consists of livestock drinking water and miscellaneous water use on the farm. Milk production data was sourced from the Irish Cattle Breeding Federation (ICBF) database.

Commercial farms of the future

The average herd size in the study was 104 dairy cows, and ranged from 45 to 194. Herd size was calculated as the average number of cows milked from June to October; this represents the average number of cows milked during the grazing season. Average farm milk production was 519,324L (range 275,409L to 875,267L). The selected herds were chosen to represent future commercial dairy farms after quota abolition, and hence were larger and had greater milk production than the national average (66 cows and 316,000L, respectively). The average volume of water used per farm was 3,121,242L, and ranged from 1,115,000L to 7,041,310L. Table 1 indicates the average volume of water required for each farm process. The average volume of water consumed per litre of milk produced was 6.4L.

Table 1. Direct water use on 25 commercial dairy farms between May 2012 and April 2013.

Process	Total water use (L)	Specific water use (L/L)[a] (range)
Supply	3,121,242	6.40 (1.16-12.01)
Livestock & miscellaneous[b]	2,090,783	4.38 (1.18-9.51)
Parlour	1,030,459	2.02 (0.2-4.59)
	Within parlour[c]	
Plate cooler	918,469	1.69 (0.0-4.36)
Water heater	91,045	0.17 (0.0-0.42)
Wash-down	685,103	1.28 (0.2-3.02)

[a]Litres of water/Litres of milk; [b]consumed by livestock and other miscellaneous use; [c]Sum of parlour processes does not equal parlour, due to the reuse of water within the parlour network (i.e. recycling plate cooler water).

Water use on dairy farms

Consumption by livestock and other miscellaneous use accounted for two thirds of water use on farms. The second largest use of water was the plate cooler, with 1.69L of water per litre of milk (L/L). From an energy consumption perspective, the optimum ratio of water:milk in the plate cooler is 2:1. Efficient recycling strategies for this plate-cooler water will be important in reducing direct water use while maintaining energy efficiency. Plate-cooler water can be collected and reused for wash-down procedures and animal drinking water (provided the bacterial load of the source is low). The result of 6.4L/L is similar to the direct water use figure of 5.4L/L in a Dutch study (De Boer *et al*., 2013), which examined water use on a single farm. A study carried out on Irish dairy farms by Bord Bia and Cranfield University (Hess *et al*., 2012) reported that direct water consumption of between 7.2L-8.6L is required for production of 1L of milk on intensive dairy systems. These figures were not directly measured and were calculated from assumptions regarding the water requirements for livestock and water required for cleaning services. Our approach of measuring each process separately on multiple farms gives a more accurate account of the water demands for milk production. Another factor affecting the efficiency of water use on a farm is the maintenance of the water supply network. Unchecked leaks can add to the pumping cost of water. Leaks of 10L/min cost up to €526/annum in pumping costs. A hot water leak of 60mL/min (1 drip/sec) could cost up to €240/annum in associated pumping and heating costs.

With this knowledge, it will be possible for Teagasc to inform both farmers and policy makers about the freshwater demands for milk production and the effect of dairy production on water demands in Ireland. This work is the first of its kind in Ireland and can be used in strengthening the sustainability of Irish agriculture.

Unchecked leaks can add to the pumping cost of water around the farm.

Acknowledgements

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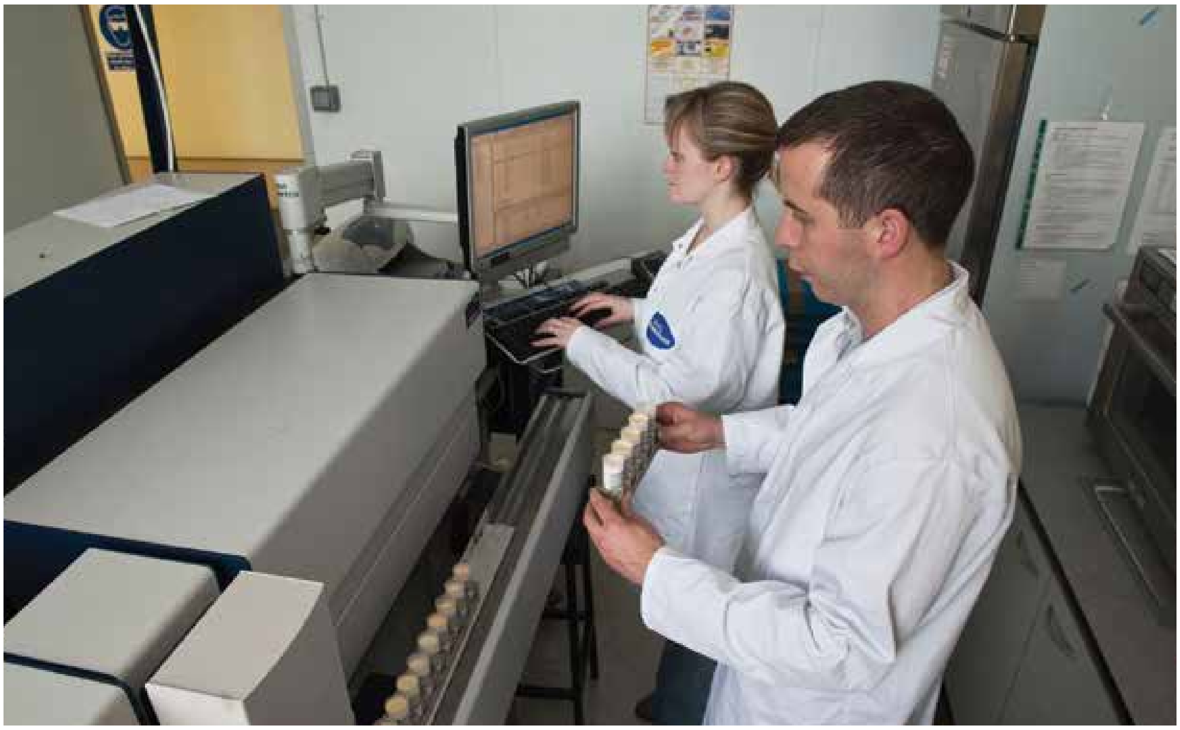
Milk quality and animal characteristics



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Use of mid-infrared (MIR) technology to predict milk quality and animal characteristics is one approach to generate low-cost phenotypic data.

Accurate genetic evaluations rely on the routine availability of a large quantity of accurate data on individual animals. Important traits are often not considered in breeding programmes, because of the cost or inconvenience associated with their measurement. Milk quality and animal feed intake are two such traits, which normally require laborious and expensive measurement techniques prohibiting the collection of a large quantity of individual cow data from commercial farms. Both suites of traits impact farm profit and, thus, must be considered within the framework of holistic, profit-based breeding goals such as the Economic Breeding Index (EBI).

MIR spectroscopy

MIR spectroscopy is the method used during routine milk recording to determine the quantity of fat, protein and lactose in milk samples. It has recently been discovered that this routinely implemented laboratory technique contains much more potential than just quantifying the gross milk-fat, protein and lactose content. Research conducted in collaboration with Teagasc Moorepark demonstrated that the most abundant individual milk fatty acids could also be quantified with high accuracy. Today, several projects are ongoing, both in Ireland and in collaboration with other international research groups, to further quantify the potential of MIR spectroscopy. Since all individual cow and bulk tank milk samples are subjected to milk MIR analysis, a huge bank of phenotypic data is now being generated at negligible additional cost. These data may have applications in decision support systems for routine day-to-day farm management or use in breeding programmes.

Predicting individual animal intake with milk MIR

Teagasc Moorepark has compiled the world's largest database of individual animal feed intake recorded at grass. A subset of this database, using records from over 1,000 Holstein-Friesian cows recorded between 2008 and 2012 was used to develop algorithms to predict individual animal intake directly from the milk sample using MIR spectroscopy. The equations can predict energy intake with an accuracy of 75% in cross validation; the equations have been validated in other populations and emerging research from France also substantiates the ability of milk MIR to predict feed intake. Predictions of energy intake from MIR are considerably better than predictions based on milk yield and fat and protein concentrations, suggesting that additional information in the MIR exists over and above that used to predict fat and protein concentrations. The genetic association between energy intake recorded, using the standard laboratory measurements, and energy intake predicted using the milk sample is 0.84. This clearly illustrates that both traits are genetically almost identical or, in other words, genetic selection based on the predicted measure of intake would yield responses in true feed intake. Furthermore, the heritability of true and predicted intake is similar. The heritability of both measures varies from 0.20 to 0.35; the variability in feed intake is just slightly less than that for milk yield. This signifies that genetic change in feed intake is indeed possible.

Moorepark Next Generation Herd

Two approaches were used to further validate the accuracy of prediction of energy intake in real-life scenarios. The first evaluation used MIR data on milk samples collected from Holstein-Friesian cows in the Moorepark Next Generation Herd research trial. Animals in the Next Generation Herd research trial are allocated one of three diets that differ in the amount of concentrate and grass offered. One third of cows are on a control diet and fed 300kg concentrate with a target post-grazing residual of 4.5cm; one third are on a high concentrate (HC) diet and fed 1,200kg concentrate with a similar post-grazing residual target; and the remaining third are on a low grass allowance (LGA) diet with a post-grazing residual of 3.5cm and receive 300kg concentrate. Figure 1 shows that the energy intake predicted using just MIR spectroscopy for cows on the HC diet was greater across lactation than for cows on either the LGA or on the control diet. This corroborates the expected differences in energy intake of these groups.

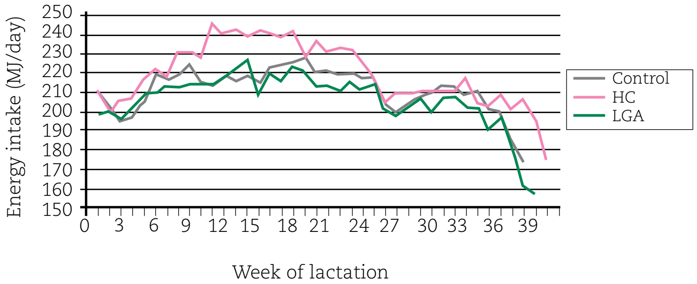

Figure 1. MIR-predicted energy intake of Holstein-Friesian cows in the Next Generation Herd trial on three diverse feeding systems.

The second evaluation involved the stratification of Holstein-Friesian cows divergent in genetic merit for MIR-predicted energy intake and the subsequent quantification of their true energy intake. Cows ranked in the lowest 33% for predicted feed intake ate 5% less than cows with average genetic merit for energy intake. This adds further justification to use MIR-predicted intake as a predictor of true energy intake, since animals genetically selected to have lower MIR-predicted intake have lower actual intakes.

Predicting milk quality with milk MIR

The national dairy breeding objective (the EBI) includes milk fat, protein and somatic cell count as the sole measures of milk quality. However, a plethora of other technological, compositional and functional measures of milk quality exist. The exclusion of detailed milk quality traits from the EBI to date has been due to a lack of routine access to the necessary phenotypes with which to make selection decisions. A Delphi survey of stakeholders as part of the Research Stimulus-funded project, BreedQuality (11/SF/311), verified that stakeholders wanted detailed milk quality traits included in the EBI with a relative emphasis of approximately 6%. Another objective of the BreedQuality project is to evaluate the potential of the milk MIR spectrum to predict these detailed quality traits such as individual fatty acid content and protein fractions in milk. Other traits under investigation included the free amino acid content, coagulation properties, casein micelle size, pH, and mineral profile of milk.

A large database of 730 milk samples collected between August 2013 and August 2014 representing a range of dairy breeds, parities and diets was used to develop the necessary equations to predict milk quality. Moderate prediction accuracy of protein fractions and milk processability was achieved. This research has subsequently progressed to quantify the genetic variability in these quality attributes, and indications are that they are indeed heritable.

Conclusions

MIR data on individual milk samples is generated on >0.5 million Irish cows annually. The generated spectra can now be harnessed to produce accurate phenotypes for a range of other milk quality and animal level characteristics.

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Genetic influences on cow fertility

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Excellent fertility is vital in seasonal-calving, pasture-based systems. Selecting for a high fertility sub-index within the Economic Breeding Index (EBI) will yield long-term dividends in the form of better calving patterns, fewer late-calving cows and reduced requirement for interventions.

Cows with high genetic merit for milk production have generally been reported to have poorer fertility than cows with average genetic merit for milk production. However, it is unlikely that high phenotypic milk production, *per se*, is directly responsible for poor fertility. Indeed, a number of studies have indicated similar, or even superior fertility in high yielding cows compared to lower-yielding cows (e.g., Bello *et al*. 2013). As a result, it is difficult to identify specific mechanisms under genetic control responsible for poor fertility, using lactating cow models that differ in phenotypic milk production potential, in addition to a wide range of associated phenotypes (milk composition, body weight, feed intake capacity, etc.).

To address this issue, a lactating cow model, with similar genetic merit for milk production, but either good (Fert+) or poor (Fert-) genetic merit for fertility traits, was recently developed and validated at Teagasc, Moorepark. A schematic outline of how the animals were assembled is outlined in Figure 1. These animals have similar proportions of Holstein genetics, and similar body weight, milk yield and milk composition. Fertility performance, however, is markedly poorer in the Fert- cows compared with the Fert+ cows. The research conducted to date with this animal model has clearly demonstrated that the causes of reduced fertility in Fert- cows are multifactorial (Butler, 2013).

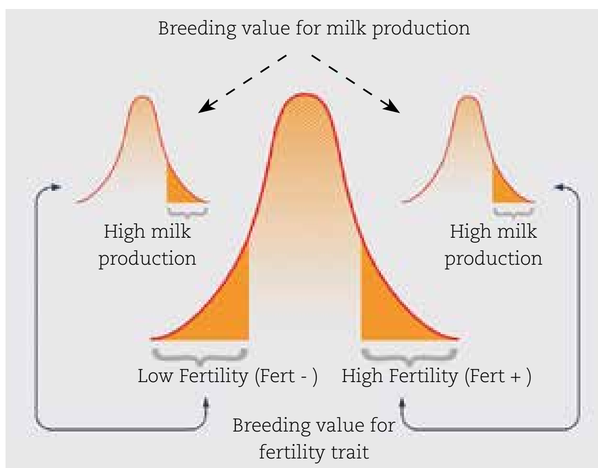

Figure 1. Schematic outline of the derivation of the animal model. Pregnant heifers with good (Fert+) or poor (Fert-) breeding values for fertility traits were identified within the national herd database. Within these two extremes, animals with similar breeding values for high milk production were identified and purchased.

Metabolic status and BCS

Insulin-like growth factor-1 (IGF1) is an important metabolic hormone, and circulating concentrations of IGF1 are a good indicator of bioenergetics status. Circulating IGF1 concentrations are greater in Fert+ cows throughout lactation. In addition to greater IGF1, Fert+ cows also have greater circulating insulin and glucose concentrations during the immediate postpartum period. Elevated glucose in the immediate postpartum period has been linked to likelihood of early ovulation and likelihood of conception at breeding. Consistent with their superior metabolic status, Fert+ cows maintained greater BCS during lactation and had reduced BCS loss after calving compared with Fert- cows. Maintenance of greater BCS in Fert+ cows is facilitated by greater dry matter intake during early lactation.

Uterine health

The reproductive tract of all cows becomes exposed to microbial pathogens, while the cervix remains open after delivery of the fetal-placental unit. The development of uterine disease depends on the type of bacteria involved and on the immune response of the cow. We examined uterine health in Fert+ and Fert- cows by assessing vaginal mucus scores weekly after calving and also by examining uterine cytology at three and six weeks postpartum. Both the vaginal mucus scores and uterine cytology results indicated greater incidence of clinical endometritis in the Fert- cows. Despite similar management and housing, Fert+ cows had a more rapid recovery in uterine health compared with Fert- cows. This likely indicates that the Fert+ cows were capable of mounting a stronger and/or timelier immune response following exposure to microbial pathogens.

The oestrous cycle

The oestrous cycle was 4.1 days longer in Fert- cows compared with Fert+ cows (25.1 vs. 21.0 days), and this was associated with Fert- cows tending to have more follicular waves (2.7 vs. 2.2 waves). Circulating progesterone (P4) concentrations were similar during the first five days of the oestrous cycle, but from day five to day 13, circulating P4 concentrations were 34% greater in Fert+ cows (5.15 vs. 3.84 ng/mL). This difference in circulating P4 was associated with 16% greater corpus luteum (CL) volume in Fert+ cows. There were no differences in metabolic clearance rate of P4 or hepatic mRNA abundance of genes responsible for P4 catabolism (CYP2C, CYP3A, AKR1C family). This suggests that the greater circulating P4 concentrations in Fert+ cows is primarily a result of greater luteal P4 synthetic capacity (larger CL size and greater P4 output per unit of CL tissue). Greater circulating P4 concentrations cause functional changes in the composition of histotroph ('uterine milk'), structural changes in endometrial glandular duct density, endometrial gene expression, maternal recognition of pregnancy and likelihood of subsequent pregnancy establishment. Inherent differences in circulating P4 concentrations likely represent a key phenotype responsible for fertility differences in these two strains of cow.

Oestrous behaviour

Oestrous behaviour was measured using automated activity meters and electronic mount detectors, and ovulation was verified using transrectal ultrasound. The main findings are summarised in Table 1. On average, oestrus intensity was greater in Fert+ cows. Fert- cows had more silent heats. In a dairy farm operation, these heats are missed, and at least three weeks are added onto the calving interval. A greater proportion of Fert- cows also displayed signs of oestrus, but subsequently failed to ovulate. In a dairy farm operation, these cows do get inseminated, but fertilisation cannot occur, again adding at least three weeks to the calving interval. Of the oestrus events recorded, 36% fell into the combined categories of silent heats and heats without ovulation in Fert- cows, whereas only 2% fell into these combined categories in Fert+ cows. Clearly, this is a major area of reproductive loss that doesn't presently receive adequate research attention.

Table 1. Summary of oestrus-related differences between Fert+ and Fert- cows.

	Fert+	Fert-	P-value
Silent oestrus	2%	22%	0.02
Oestrus without ovulation	0%	14%	0.04
Duration of oestrus (hr)	7.53	5.86	0.08
Peak oestrus activity	168	119	0.01

Conclusion

Compared with Fert- cows, Fert+ cows have greater dry matter intake after calving, greater BCS throughout lactation, more favourable metabolic status, earlier resumption of cyclicity and superior uterine health status. During the breeding season, Fert+ cows have stronger oestrous expression, are less likely to have silent heats, are more likely to ovulate after exhibiting heat, and have greater circulating P4 after ovulation. The next step is to delve deeper into the different tissues to identify the genes and gene networks that regulate these phenotypic differences. New markers can be rapidly incorporated into genomic selection techniques. After many decades of declining fertility, genetic merit for fertility and phenotypic reproductive performance now appears to be on the opposite trajectory.

Acknowledgements

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Developments in the Pasture Profit Index

The proportion of grassland reseeded in Ireland is very low, meaning a large opportunity to maximise our natural advantage is being lost. Teagasc's recently launched Pasture Profit Index (PPI) can help grassland farmers identify the most appropriate perennial ryegrass cultivar(s) for their farm.

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The Food Harvest 2020 report set clear production targets for Irish ruminant production systems. It is vital that Ireland maintains its grass-based competitiveness in the pursuit of these targets. There are improvements required in the areas of grass production and utilisation across dairy, beef and sheep enterprises. Currently, the proportion of perennial ryegrass within swards are below the required levels on commercial dairy farms (O'Donovan *et al*., 2013). The proportion of the farm that is reseeded annually in Ireland is very low (Grogan and Gilliland, 2010). Hence, as a temperate grassland country, a large opportunity is being lost. Total merit indices have previously been used to economically rank animals, including dairy cattle (Veerkamp *et al*., 2002), and have been successfully adopted in many countries. A number of studies were reviewed (Dillon *et al*., 1995; Drennan and McGee, 2009) to identify the most economically important traits affecting grass-based production systems. It was considered critically important that the traits selected could be: (i) easily measured in grass evaluations, and (ii) improved through plant breeding.

Teagasc's Pasture Profit Index

Teagasc developed and launched nationally the PPI in 2015. The purpose of the PPI is to assist grassland farmers identify the most appropriate perennial ryegrass cultivar(s) for their farm. The PPI is comprised of six sub-indices: spring; mid-season grass DM production; autumn grass DM production; grass quality (April to July, inclusive); first and second cut silage DM production; and persistency. The performance of a cultivar for each trait was calculated by determining the difference between the performance of each cultivar and the base value for that trait. This was then multiplied by the economic value for that trait which was calculated using the Moorepark Dairy Systems Model. The economic value of an extra kg of grass DM in spring and autumn was higher than mid-season because it supported an extended grazing season. The relative emphasis on each trait was as follows: grass DM yield (31%); grass quality (20%); silage yield (15%); and sward persistency (34%).

Grass evaluation trials

The performance values included in the PPI are based on data collected from the Department of Agriculture, Food and the Marine (DAFM) grass evaluation trials. Cultivars are evaluated over a minimum of two separate sowings, with each cultivar harvested for two consecutive years after the sowing year. The two harvested years include a six-cut system involving one spring grazing cut, followed by two silage cuts and then three grazing cuts; as well as an eight- to 10-cut system corresponding to normal commercial rotational grazing practice.

With the exception of three varieties (Clanrye, Rodrigo and Solas), all varieties in the recommended list have PPI values calculated. The PPI index values range from €54/ha to €208/ha per year for the 31 cultivars with the data available. The sub-indices present the opportunity to select cultivars for specific purposes.

For example, if selecting a cultivar for intensive grazing, the emphasis would be placed on seasonal DM yield and quality, with less importance placed on the silage performance. If selecting a cultivar specifically for silage production, then greater emphasis would be placed on the performance of that cultivar within the silage sub-index. It is likely, similar to all indexes, that new traits will be developed and will gain further importance in the future. Traits such as disease resistance and grazing utilisation are likely to be adopted into the index in the future.

Teagasc Pasture Profit Index (PPI) 2015

Cultivar details			Pasture Profit Index Sub-indices (€/ha per year)						Total €/ha/year
			Dry Matter Production			Quality	Silage	Persistency	
Cultivar	Ploidy	Heading date	Spring	Summer	Autumn				
Abergain	T	June 5	42	50	43	58	26	-11	208
Dunluce	T	May 30	43	45	58	35	24	-11	194
Aberchoice	D	June 10	24	52	47	57	9	-5	184
Abermagic	D	May 30	47	53	78	21	13	-28	184
Kintyre	T	June 8	29	40	58	25	14	0	166
Rosetta (*)	D	May 24	97	40	39	-2	19	-28	165
Astonenergy	T	June 2	10	41	43	54	12	0	160
Seagoe (*)	T	May 29	30	45	43	13	38	-11	158
Aberplentiful (*)	T	June 8	15	44	48	30	15	0	152
Magican	T	May 22	59	37	42	-5	28	-11	150
Giant	T	May 20	39	50	39	-2	22	0	148
Trend	T	May 24	25	41	30	3	38	0	137
Navan	T	June 6	14	41	50	21	10	0	136
Aspect (*)	T	June 5	26	45	29	30	10	-5	135
Carraig	T	May 24	42	40	38	-19	31	0	132
Solomon	D	May 23	66	32	35	-30	22	0	125
Drumbo	D	June 7	27	35	35	36	-4	-11	118
Delphin	T	June 2	13	42	27	10	21	0	113
Abercraigs	T	June 4	14	38	21	17	18	0	108
Glenroyal (*)	D	June 5	25	41	46	-2	6	-11	105
Majestic (*)	D	June 2	43	38	43	-23	0	0	101
Boyne (*)	D	May 22	42	39	33	-56	41	0	99
Glenveagh (*)	D	June 3	37	39	34	-22	7	0	96
Twymax (*)	T	June 7	-11	48	20	27	17	-5	95
Stefani (*)	D	June 1	25	34	27	-9	9	0	86
Piccadilly (*)	D	June 3	31	38	22	-30	16	0	77
Tyrella	D	June 4	41	23	19	-1	0	-11	71
Mezquita	D	June 6	22	30	18	-22	6	0	54

Guide to reading the table:
Cultivar details: Variety, Ploidy (T = tetraploid; D = diploid), Heading date.
PPI details (Total €/ha per year): indicates relative profitability difference when compared to the base values.
PPI sub-indices: DM yield (spring, summer and autumn), Quality (April, May, June and July), Silage (1st and 2nd cut), Persistency. This indicates the economic merit of each variety within each trait, summed together this provides the overall PPI figure. Cultivars with no PPI values - Varieties listed with no PPI values do not have enough agronomic data available for the PPI value calculation at present. These varieties should also be considered for variety selection given that they are present on the Recommended List. Data for all varieties will be available within the next two years. Actual performance data for each variety is presented in the DAFM Grass and Clover Recommended List Varieties for Ireland 2015.

The use of the total economic merit system enables the identification of cultivars that will provide the greatest economic contribution to ruminant grazing systems. The index illustrates the strengths and weaknesses of individual cultivars. It is expected that it will encourage increased usage of the recommended cultivar list and greater uptake of economically superior cultivars in the future.

Acknowledgements

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Robotic milking in pasture-based systems

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Today, there are about 10,000 automatic milking (AM) units in place across northern Europe, and at least 25,000 worldwide. Approximately 50% of all new milking parlours installed in many EU countries (except Ireland) are AM systems. It is envisaged that 20% of cows in the EU will be milked automatically by 2020. Thus, it is clear that dairy-industry stakeholders and dairy farmers consider robotic or AM systems to have significant potential on dairy farms in EU countries. It is suggested here that AM could play a similarly positive and significant role in Irish dairying if one fundamental difference in the operation of the robot, between other EU countries and Ireland, was addressed. That difference relates to the cow-feeding system. While indoor feeding systems (common in other EU countries) have been well adapted to AM, cow-grazing systems have not.

Milk production in Ireland is grass-based and up to 90% of the cow's diet during lactation is in the form of grazed grass. Thus, in order for automatic milking to become a realistic alternative to conventional, manual milking in Irish grass-based systems, the practical challenges of integrating AM and grazing must be researched.

Why is AM favoured in other countries?

A study conducted in England (Butler *et al.*, 2012) involving three case-study farms and interviews with a further 20 farms and with other stakeholders in the industry, concluded that having a robotic milking system did change the interviewees' lifestyles. In some cases, it did not lessen the workload but it changed the nature of the workload. Many farmers experienced a realisation that they were no longer 'tied' to a traditional dairy farming lifestyle. Other interviewees saw the robot as a means of prolonging their working life or as a system that would allow them to have an 'easier' working day once they were advancing in age. Other robotic users experienced less stress and a more relaxed working day with more time available for social activities. Generally, the robot was seen as a labour-saving device and a technology to allow more productive and profitable use of time. A key issue for many was that AM would make dairy farming more attractive to the next generation for lifestyle reasons and that farming traditions within families would be more likely to continue. For farmers with leased land, a mobile robot may provide a positive alternative to a fixed robot, since this would facilitate movement to a different land base at the end of the lease.

An Australian study by Kerrisk and Ravenhill (2010) similarly investigated the views of seven farmers with recently commissioned AM systems. All farmers involved in the study experienced a positive impact on aspects of labour and lifestyle. The reduced workload resulting from AM on-farm was captured by different indicators. For example, a reduced number of labour units, reduced number of hours worked per labour unit or continuation with the same number of labour units and hours worked but with an increase in the number of hours spent at other aspects of the business (or a combination of these). Five of the seven farmers indicated that they had either reduced the number of hours worked or labour units on the farm. Comments also included indications that the pressure and deadlines normally associated with conventional milking were reduced with AM, and that reduced stress levels were evident for both people and cows. In a previous study, Mathijs (2004) also reported that farmers found a 21% reduction in labour when they converted from conventional milking to AM.

Integration of AM in a grass-based system

To achieve voluntary movement of cows from a paddock to the AM system is a challenge. A three-way grazing management system is now in place at Moorepark. This promotes the voluntary movement of the cow to the milking unit at appropriate intervals. The farm is divided into three grazing sections, and cows graze defined areas of each of the three grazing sections during each 24h period. Cows move between the grazing sections in the trained knowledge that they will be rewarded with fresh grass in a new paddock. As they move between sections, the cows are diverted through the milking yard. This grazing system was operated at the Moorepark farm during 2014. A Fullwood Merlin AM system was used to milk a herd of 70 cows (average calving date was February 24). Cows were outdoors grazing on a part-time basis from calving until 27 February, after which cows were grazing full time. Cows received 400kg concentrates during the year. Milk volume and milk solids yield was 4,400kg and 380kg/cow, respectively, during the complete lactation. These yields were lower than average due to the presence of Jersey cows in the herd and experimental milking frequency (MF) treatments being applied to the cows. An average MF of 1.8 milkings/cow per day was achieved during the complete lactation.

The role of AM

From the few studies available (outlined above), it would be expected that AM could have a positive impact on both the work life and social life of the farmer and on the overall sustainability of the family farming system. While such studies have not been conducted in exclusively grass-based systems of milk production, it is likely that a similar response would be obtained. One significant difference is the greater daily labour required for grassland and grazing management; however, this would not exceed the overall reduction in labour requirement associated with AM (O'Brien *et al.*, 2015).

The decision to invest in AM requires prior investigation into system management, procedures, performance, and other skill sets required (e.g., grassland management and interpretation of data output). Farmers need to be in a position to make well-informed decisions, understand the technology, and have realistic expectations of the technology.

Conclusion

AM has been shown to have a positive impact on work – social life balance on farms operating partial and complete confinement systems. Integration of AM into pasture-based systems is challenging, but it has been achieved successfully. Thus, it is suggested that a similar potential role for AM exists within a grass-based system of milk production. Furthermore, it may represent a solution to farm fragmentation.

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Role of white clover

Clover can contribute to the sustainability of grass-based milk production systems. Teagasc Moorepark has developed a research programme exploring the role of clover in high stocking rate grass-based milk production systems.

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The Irish dairy industry relies on nitrogen (N) fertilised perennial ryegrass (*Lolium perenne* L.) swards to provide feed for dairy cows for most of their lactation. Nitrogen fertilizer use is limited under the Nitrate Directive. On farms with high stocking rates and, therefore, large demand for grass, there is a requirement for extra N for grass growth. One source of additional N is N fixed from the atmosphere by white clover (*Trifolium repens* L.). This fixed N is then available for herbage growth in a mixed grass clover sward. As well as fixing N, clover can increase sward nutritive value. Sward clover content increases as the year progresses and reaches a maximum in late summer and autumn, at a time when grass quality can be reduced. At this time of year, clover can increase the overall nutritive value of the sward for grazing livestock compared to a grass-only sward.

International research has shown that including clover in grass swards can increase milk production and herbage production when sward clover content is 20% or greater. Research at Teagasc Solohead Research Farm has demonstrated successful inclusion of clover in low stocking rate (<2.2 LU/ha) milk production systems, and reported similar milk production per cow on grass clover swards receiving 90kg N/ha and grass-only swards receiving 250kg N/ha. Despite the benefits described above, clover is not widely used on Irish dairy farms. Little research has been undertaken examining the role of white clover in high stocking rate systems (>2.2 LU/ha), where the requirement for grass for grazing is high. In recent years, Teagasc Moorepark has developed a research programme exploring the role of clover in high stocking rate grass-based milk production systems in a number of experiments at Moorepark and Clonakilty Agricultural College.

Farm systems research

At Moorepark, a farm systems experiment is comparing herbage and milk production from a perennial ryegrass sward receiving 250kg N/ha per year (Grass250), and a perennial ryegrass clover sward receiving 250kg or 150kg N/ha per year (Clover250 and Clover150, respectively). Each treatment is stocked at 2.74 LU/ha. All swards received similar N fertilizer until May. They have similar rotation lengths and target pre-grazing herbage mass in mid-season is 1,300-1,500kg DM/ha and target post-grazing sward height is 4cm. Results are available for the two-year period 2013-2014. Herbage production was similar across the three treatments – 14.3t DM/ha per year. Annual average sward clover content was 27% and

24% on the Clover150 and Clover250 treatments, respectively. Milk solids production was greater on the clover treatments (485kg MS/cow and 489kg MS/cow on the Clover150 and Clover250 treatments, respectively) compared to the Grass250 treatment (454kg MS/cow). The clover treatments produced an additional 85-96kg MS/ha compared to the grass-only treatment.

A farm systems experiment at Clonakilty is examining the effect of tetraploid and diploid swards sown with and without clover on the productivity of spring milk production systems stocked at 2.75 LU/ha. The 2014 results indicate that grass clover swards had an average clover content of 40% and grew an additional 2.5t DM/ha compared with the grass-only swards. Similar to Moorepark, milk solids production was greater on the grass clover swards (464kg MS/cow) than on the grass-only swards (409kg MS/cow) (Figure 1).

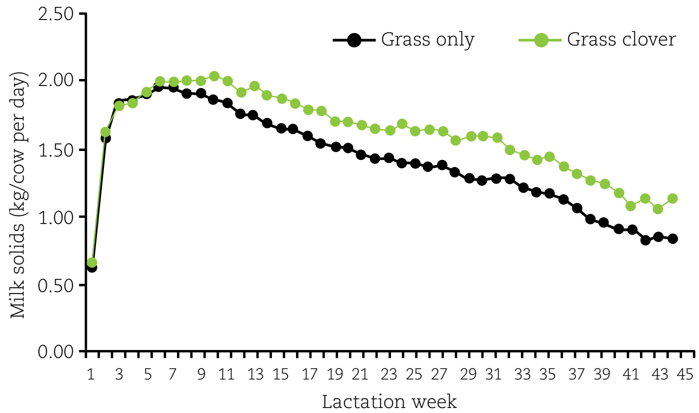

Figure 1. Daily milk solids yield for the grass-only treatments compared with the grass clover treatments by lactation week at Clonakilty in 2014.

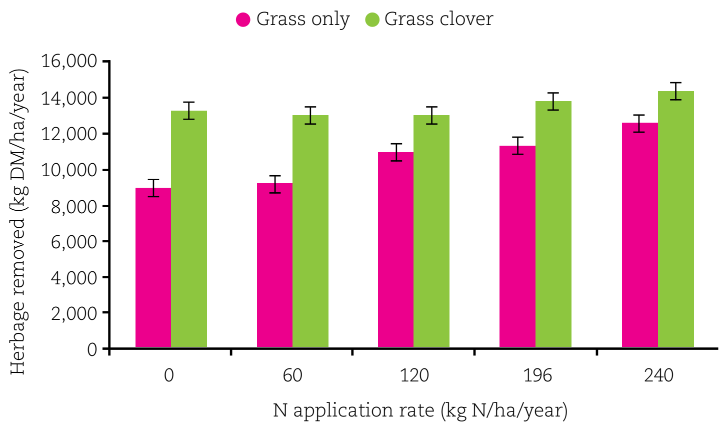

Figure 2. Herbage removed (kg DM/ha per year) from grass-only or grass white clover grazed plots receiving 0kg, 60kg, 120kg, 196kg and 240kg N/ha per year.

Plot experiment

Plot-based experiments are also being undertaken at Moorepark. One experiment examined the effect of a range of N fertilizer application rates on herbage production from grass-only and grass clover swards and examined the effect of fertilizer application rate on sward clover content. A series of grazing plots (8m × 8m) were established in May 2009. Treatments consisted of two swards (grass-only and grass clover) and five N fertilizer application rates (0kg, 60kg, 120kg, 196kg, 240kg N/ha per year). The grass-only sward was a 50:50 perennial ryegrass tetraploid and diploid cultivar mixture (Dunluce and Tyrella, respectively) sown at a rate of 37kg/ha. The grass clover sward contained the same perennial ryegrass cultivar mixture and a 50:50 medium-leaf clover cultivar mixture (Chieftain and Crusader) sown at a rate of 5kg/ha. Measurements were undertaken from 2010 to 2013 inclusive (from February to October each year) and included herbage production and sward clover content. Across the four years of this experiment, the results indicate that regardless of N fertilizer application rate, the quantity of herbage removed by grazing animals from the swards increased by 2,930kg DM/ha when clover was included in the grass sward (Figure 2). As N fertilizer application rate increased, average annual sward clover content declined from 33.3% when 0kg N/ha was applied to 19.6% when 240kg N/ha was applied.

Sustainability

Clover can contribute to the sustainability of grass-based milk production systems. Grass clover systems at Solohead produced 33% less nitrous oxide emissions and 16% less total greenhouse gas emissions compared to a conventional fertilised system. Lower methane emissions per kilogram of dry matter intake (DMI) were measured at Moorepark on a grass clover sward (21.5g methane per kg DMI) compared to a grass-only sward (24.5g methane per kg DMI). Nitrogen fixation rates of up to 170kg N/ha per year have been measured in grass clover swards at Moorepark and Solohead. Nitrogen fixation rates generally increase as sward clover content increases. Incorporating clover into N fertilised perennial ryegrass swards provides the potential to reduce N fertilizer application, particularly in the late summer period.

Conclusions

Incorporating clover into N fertilised grass swards can increase herbage production per hectare and milk yield and milk solids production per cow and per hectare. There may be potential to reduce N fertilizer application in summer when clover is included in swards. Clover can contribute to the sustainability of grass-based milk production systems.

Acknowledgements

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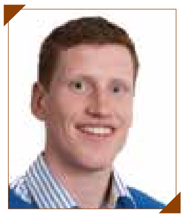
Importance of grass chemical composition



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Grass quality affects ruminant animal intake and production performance. Experiments to precisely measure grass quality, the factors that affect it and its impact on animal intake and performance are, therefore, important.

Grass-based ruminant production is based on the efficient production and utilisation of high quality grazed grass. Ruminants must ingest large quantities of high quality grass. The quality of the grass can impact not only the quantity of grass that the animal eats, but also the quantity and quality of milk and meat production. Due to the impact of grass quality on ruminant animal production, a series of experiments were conducted at Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, to precisely measure grass quality, the factors that affect it and its impact on animal intake and performance.

What is high quality grass?

The quality of grass is generally indicated by its organic matter digestibility (OMD). OMD can be measured using several methods. The wet chemistry laboratory method (of which there are several) and the near infrared reflectance spectroscopy (NIRS) method are the most commonly used. The development of the laboratory and NIRS methods is, however, based on having very precise data on a number of grass samples. These precise data are collected by conducting the very laborious but also very precise animal method, which is referred to as the in vivo method. The in vivo method involves housing the animal individually indoors for 12 days and, on a daily basis, measuring exactly how much feed the animal consumes and exactly how much faeces the animal produces. The digestibility of the feed can then be calculated. High OMD grass is desirable and is generally characterised as having higher crude protein concentration and lower fibre concentration than low OMD grass. High OMD grass has a higher leaf and pseudostem content and a lower true stem and dead content than low OMD grass. This means that long rotation, high pre-grazing herbage mass (PGHM) grass, which has a higher stem and dead content and lower leaf content, has a lower OMD than shorter rotation, lower PGHM grass, which has a lower stem and dead content and higher leaf content.

The experiment: effect of PGHM on grass OMD

The decision on what PGHM grass should be offered to grazing ruminants is an important tool in managing grass-based ruminant production systems. Pre-grazing herbage mass is also a key driver of grass OMD. Therefore the effect of PGHM on grass OMD was studied in detail. In spring 2014 (mid-April to mid-May), four cows were offered medium PGHM grass (1,700kg DM/ha) and four were offered high PGHM grass (4,000kg DM/ha) for 12 days. The cows then swapped treatments for a further 12 days. At the same time, four sheep were offered the same medium PGHM grass and four were offered the same high PGHM grass. The sheep then swapped treatments for a further 12 days. The eight dairy cows were mature animals (parity four to six) with a mean calving date of March 26, 2014. The eight sheep were one-year-old, castrated male Texels, weighing on average 51kg. The grass intake and faeces production of each individual animal was recorded daily. The experiment was repeated in summer 2014 (month of August).

Table 1. The effect of pre-grazing herbage mass, species and season on intake by sheep and dairy cows, and dairy cow milk production.

Season	Spring				Summer			
Species	Sheep		Cows		Sheep		Cows	
Pre-grazing herbage mass	Med	High	Med	High	Med	High	Med	High
DMI (kg/d)	1.46	1.24	14.4	14.6	1.47	1.17	17.3	14.5
Milk yield (kg/d)			25.7	25.4			19.4	14.6
Milk solids yield (kg/d)			2.21	2.21			1.53	1.13
Dry matter digestibility (g/kg)	783	756	774	745	740	730	739	697

In both spring and summer the sheep consumed more of the medium PGHM grass than the high PGHM grass. In summer, the cows too consumed more of the medium PGHM grass than the high PGHM grass. This was reflected in a higher milk production performance by the cows. In spring, however, the cows consumed similar quantities of medium- and high PGHM grass, and milk production performance on the two PGHM treatments was similar. For the cows, the similarity in spring was probably due to the cows being in early lactation when they have a limited intake capacity. Allied to that fact, they are not able to select grass to the same extent as the smaller-muzzled sheep. Detailed dry matter digestibility (DMD) figures were calculated for the sheep and cows. These data clearly show a strong effect of increasing PGHM on decreasing grass quality. The data also indicate a large seasonal effect, with grass quality being lower in summer than in spring.

Casting the OMD net a little bit wider

As a result of the large effect of season on grass quality that was measured in the experiment described above, a database of in vivo digestibility data spanning three years was compiled for further investigation. The samples available were collected from February to November and included a range of PGHM and grass cultivars. This investigation substantiated the seasonal finding. It showed that grass quality was indeed higher in spring than in summer, although the rate at which grass quality decreased as PGHM increased was similar in both seasons. Interestingly, however, the data showed the rate at which grass quality decreased as PGHM increased was faster in autumn than it was in spring and summer. This indicates that, in autumn, grazing higher than recommended PGHM could lead to a more pronounced decrease in grass quality, grass intake and animal production performance.

Future research

In the immediate future, the effect of PGHM in autumn on grass quality and animal production performance, will be investigated. In addition, all the in vivo data generated over the last three years of intensive research will be used to calibrate a more accurate laboratory method to predict OMD, which will then be used to calibrate an NIRS OMD prediction. This will enable rapid and accurate analysis of grass quality on-farm. Future work will also consider more species than just grass. Currently, there is substantial interest in introducing clover into Irish pastures in order to reduce nitrogen fertilizer costs. The incorporation of clover is purported to increase pasture quality, which should increase pasture intake and ruminant animal production performance. The precise effect of clover on pasture OMD must, therefore, be measured using a similar approach to that described above.

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Grazing post-quota

Dairy farmers must refine their grazing management practices to release additional performance from grazed grass over the coming years.

There is an increasing international awareness of the multifunctional benefits of grassland farming due to its capability for high productivity and profitability, and equally for the environmental and animal welfare benefits it confers to the Irish dairy industry. In comparison with mechanically harvested or purchased feeds, grazed pasture provides a relatively inexpensive and uniquely nutritious feed source for milk production. Consequently, the profitability of milk production on Irish farms is closely related to the amount of grass consumed (tonnes DM/ha) each year. On that basis, Irish dairy farmers invest significant time and effort each year in developing higher productivity swards. Despite the limitations of milk quotas, Irish dairy farmers are recognised internationally for the quality and attention to detail of our grazing systems. Notwithstanding these improvements, research studies continue to highlight the significant potential for additional productivity gains where best-practice grazing management is implemented (Table 1). On that basis, dairy farmers must refocus on this uniquely, cost-free potential within their farms and continue to refine their grazing management practices to release this additional performance from grazed grass over the coming years.

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Table 1: Key components of high-productivity grazing systems.

Based on 2013 statistics	Current average	Current top 10%	Target
Stocking rate (cows/ha)	1.9	2.1	2.5-2.9
Pasture growth (t DM/ha)	6-14	10-16	14-20
Pasture utilisation (t DM/ha)	4-9	10-12	11-16
Six-week herd calving rate (%)	59	70	90
Fat plus protein yield (kg/cow)	370	394	450
(kg/ha)	700	830	1,300

Grazing management principles for profitable expansion post-quotas

Grazing management for high animal productivity is based on a common sense approach to continuously present adequate high-quality grass to the dairy herd while ensuring that the sward is properly conditioned for future grazing events. The following basic management guidelines have the potential to dramatically increase animal performance at grazing.

Stocking rate and calving date

To capture the maximum benefits of grazed grass, the most fundamental management practice must be to have the correct number of cows calving compactly at the beginning of the grass growth season; thereby increasing herd feed demand in line with seasonal grass growth. Stocking rate (SR), traditionally expressed as cows or livestock units (LU) per hectare (ha), is the major factor governing productivity from a grass-based system. A recent review of SR experiments reported that an increase in SR of one cow per hectare will result in an increase in milk production per hectare of 20%. With a current average mean stocking rate of 1.9 LU per hectare, mean calving date of mid-March and six-week calving rate of 59%, the Irish dairy industry is missing out on significant additional grass utilisation and milk production. From a grassland management perspective, recommended best practice must be to have a stocking rate of 2.5 to 2.9 cows per hectare on the dairy platform with 90% of the herd calving in the 42 days after the planned start of calving. Table 2 outlines the recommended SR for dairy farms depending on the quantity of grass grown and the level of supplementary feeds utilised. The ideal mean calving date will vary with soil type ranging from mid-February on drier southern soils to early March on wetter northern soils.

Table 2. Recommended stocking rates for Irish dairy farms.

Grass growth (tonnes DM/ha)	10	12	14	16
Supplementary feed inputs (tonnes DM/cow)	Stocking rate			
0.25	1.7	2.1	2.4	2.8
0.50	1.8	2.2	2.5	3.0

Grazing swards to the ideal residual results in significantly increased sward productivity during the grazing season.

Grazing severity

Increasing SR is usually associated with an increase in grazing severity and many studies have attributed the increased productivity of higher SR systems to an improvement in herbage utilisation and increased pasture production and quality. Although pre-grazing herbage mass tends to increase within laxly grazed swards, net herbage production is actually reduced, as increased quantities of residual stem and decaying material are contained within the regrown material. Accelerated herbage regrowth following more severe defoliation results from an increase in leaf content and an increased number of developed vegetative tillers within the severely defoliated high SR swards. Indeed, it is also now widely acknowledged that where ryegrass swards are severely defoliated on a continuous basis, the sward adapts to maximise leaf area in the sub-grazing horizon to increase photosynthetic capability and accelerate regrowth during favourable climatic conditions. In addition to the beneficial effects on herbage regrowth, more severe grazing at higher SR in spring and summer results in the efficient harvesting of early reproductive tillers. This arrests the decline in sward nutritive value that is typically observed during midseason and, therefore, increases the potential for increased animal intake and performance from higher-quality mid-season swards.

Feed budgeting to extend the grazing season

Each additional grazing day achieved in spring has been shown to increase farm profitability by €2.70/cow. To continue to reap the benefits of extended grazing at higher SR, disciplined feed budgeting is required during autumn and spring. The resulting increased average farm cover (AFC) in spring, in conjunction with more intensive grazing severities, will allow dairy farms to carry higher SR while continuing to harness the benefits of a predominantly grass-based diet. Figure 1 illustrates the target AFC during spring to allow a farm operating at a SR of 2.7 to 2.9 LU/ha to turn freshly calved cows out full time to a predominantly grass diet and extend the first rotation to early April while still requiring a low level of concentrate supplementation per cow.

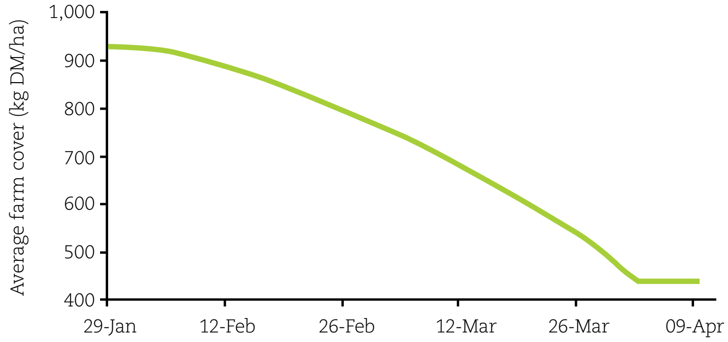

Figure 1. Recommended average farm cover (AFC; kg DM/ha) for a farm stocked at 2.7 to 2.9 LU/ha.

Acknowledgment

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COW index

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The COW index is used for ranking females on expected future profitability.

The Economic Breeding Index (EBI) is now accepted as the optimal tool for identifying superior candidate parents of the next generation. Only the additive genetic merit of an individual is included in the EBI; non-additive effects (e.g., heterosis) are not included because their expression in the resulting progeny is dictated by the genotype of the mate. Thus, non-additive effects, by their very definition, are not directly transmitted across generations.

Permanent environmental effects are non-genetic effects that permanently influence the performance of the individual itself but are not transmissible across generations. Examples of such effects include suboptimal heifer rearing (e.g., overfeeding or underfeeding of the developing heifer) or experiencing a traumatic incident (serious adverse health event or injury). Permanent environmental effects are also not considered in the EBI. Finally, age of the cow and the (expected) calving date of the cow are not considered in the EBI. Therefore, although the EBI is still ideal for making breeding decisions, it may not be optimal for making purchasing or culling decisions based on the expected future profitability of an individual cow.

Framework of the COW index

The COW index is only available for females and is constructed as follows:

COW = Current lactation + Future lactations + Net cull cow value

Current lactation – this component includes the expected profit of a cow until the end of the current lactation based on the cow's expected 305-day milk production (under the prevailing a+b-c milk pricing system) and live-weight (derived from cull cow carcass weight) as a proxy for feed intake. Expected profit is also dictated by the most recent calving month of the cow. Expected milk production is based on both additive and non-additive genetic merit, as well as permanent environmental effects (i.e., historical effects) experienced by the cow.

Future lactations – this component considers the same animal attributes as the current lactation component, but also includes: 1) the parity of the cow, since older cows are less likely to survive for several additional years; and 2) the expected month of calving in the subsequent lactation, which influences future profit but also the likelihood of survival to the next lactation. Also included in the future lactations component is the expected number of female progeny born multiplied by their expected profit (i.e., EBI). Predicted future longevity of the cow is based on the current parity of the animal, its total genetic merit (i.e., additive plus non-additive) for survival, and current month of calving. Figure 1 shows how all three interact to influence the probability of survival to the

Table 1: Least square means (standard errors in parentheses) for milk production traits for each quartile of animals ranked on cow own worth (COW) or economic breeding index (EBI).

Group	Milk (kg)		Fat (g/100g)		Protein (g/100g)		SCC (cells/mL) [SCS]§
	COW	EBI	COW	EBI	COW	EBI	COW
1	6965 (6.17)	6674 (6.32)	4.07 (0.003)	4.11 (0.003)	3.57 (0.001)	3.57 (0.003)	155 [4.55] (0.004)
2	6695 (6.45)	6580 (6.38)	4.03 (0.003)	4.04 (0.003)	3.52 (0.001)	3.52 (0.003)	169 [4.61] (0.005)
3	6512 (6.18)	6530 (6.27)	4.01 (0.003)	4.00 (0.003)	3.49 (0.001)	3.49 (0.003)	199 [4.71] (0.005)
4	6164 (6.08)	6467 (6.24)	3.97 (0.003)	3.93 (0.003)	3.44 (0.001)	3.44 (0.003)	231 [4.80] (0.004)

Group 1 = Highest ranking (top 25%); Group 4 = Lowest ranking (worst 25%);
§SCS is the natural log transformation of SCC; SCS standard errors in parentheses.

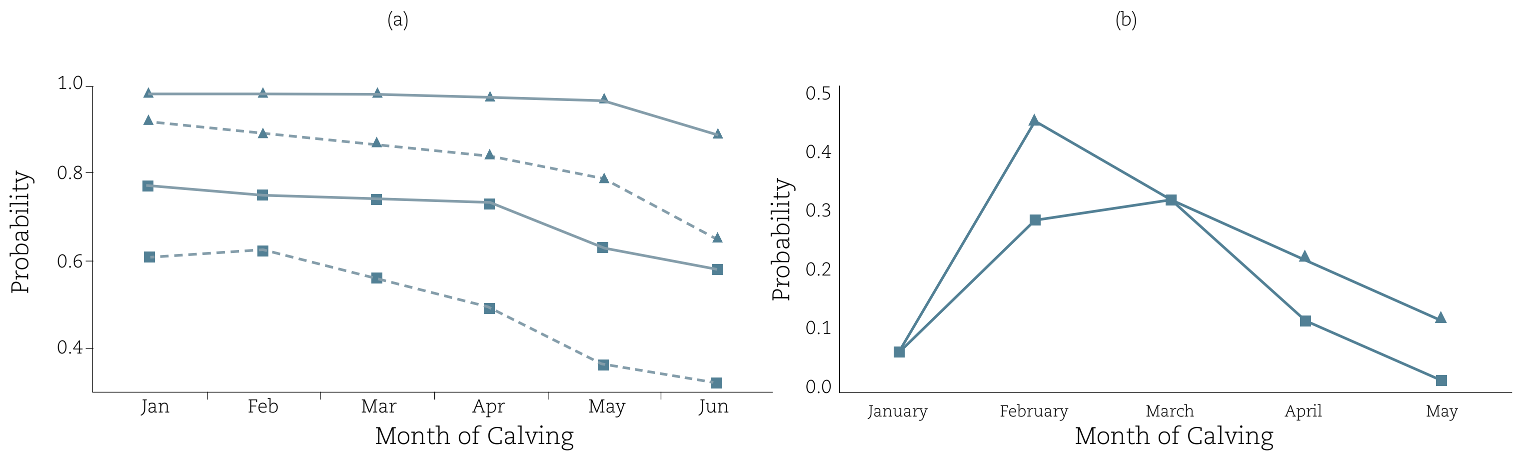


Figure 1. (a) Probability of surviving to the next lactation for a parity 1 cow (triangles) of either high (continuous line) or low (broken line) genetic merit for survival for each month of calving; also included is a fifth parity cow (squares). (b) Probability of calving in each month of the subsequent year for a March-calving cow with high (triangle) or low (square) genetic merit for calving interval.

next lactation. Older cows of inferior genetic merit, that calve later in the year, have a reduced likelihood of surviving to the next lactation than younger cows of superior genetic merit for survival that calve earlier in the year. Expected month of calving in the following lactation is based on a combination of the month of calving in the current lactation and the animal's total (i.e., additive plus non-additive) genetic merit for calving interval. Using data from the national database, a cow with superior genetic merit for reproductive performance is more likely to calve in the same (or an earlier) month the following year than a cow with inferior genetic merit for calving interval (Figure 1).

Net cull cow value – this component of the COW index deducts the cost of a replacement heifer from the expected cull cow value based on genetic merit for carcass weight of the cow times the prevailing cull cow value.

Performance of the COW index

The correlation between the individual animal COW index value and EBI is 0.65. Month of calving of the cow in her current lactation explains 18% of the variability in the COW index with the parity of the cow explaining an additional 3% of the variability in the COW index.

Phenotypic performance records for 162,981 cows in the year 2012 were used to validate the COW index. Genetic and permanent environmental effects for these cows from the 2011 national genetic evaluations were used to calculate the COW index and their EBI. Cows were stratified per quartile within herd, based on their COW index value and EBI. Females ranking higher on the COW index yielded more milk and milk solids and calved earlier in the calving season than their lower-ranking contemporaries (Table 1). The difference in phenotypic performance between the best and worst quartiles was larger for cows ranked on COW index than the same cows ranked on EBI.

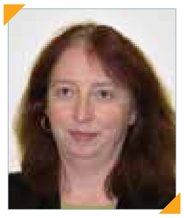
Conclusions

The COW index is envisaged as a supplementary index to the EBI. The EBI remains the most appropriate index for identifying the genetically superior candidate parents of the next generation, whereas the COW index is optimal for identifying animals for culling. The COW index considers both the additive and non-additive genetic merit of a female, its permanent environmental effect, as well as its age and (expected) calving date.

Acknowledgments

Funding from Teagasc core grant is gratefully acknowledged.






Bacillus cereus in bulk tank milk – importance to IMF

Infant milk formula has been earmarked as a category of high potential for Ireland's dairy industry in the new post-quota era. To optimise that potential, the management of *Bacillus cereus* will be essential.

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The global market for infant milk formula (IMF) is estimated to be worth in the region of €5 billion, and Irish-based companies produce approximately 15% of the global export market. The Chinese infant formula market is growing at approximately market is growing at about 10% per annum. Ireland is well positioned to supply this market as it produces a broad product portfolio, has a highly developed specialised ingredient capability, and three of the key multinational players have production facilities in the Republic of Ireland. The IMF market is strategically important to the expansion of the Irish dairy industry. The recent multimillion euro investments in facilities for infant formula manufacture by a number of processors in Ireland instil a sense of optimism in this growing sector. Maintaining a high-quality milk supply is imperative for the successful expansion of this lucrative market. Due to the vulnerability of the consumers of IMF, strict precautions are put in place to minimise bacterial contamination of IMF. The presence of *Bacillus cereus* in IMF is of particular concern to the IMF market. *B. cereus* is a gram-positive, rod-shaped, spore-forming food-borne pathogen that can survive pasteurisation and grow during subsequent processing. Reports of illnesses from contaminated IMF are rare; however, caution to prevent contamination is necessary due to the vulnerability of its target consumers.

Current regulations/specifications and methods of isolation

The European Union (EC, 1771/2007) has set a threshold for B. cereus in dried infant formulae intended for infants below six months of age. The protocol requires five samples from a batch of IMF to be analysed for *B. cereus*. Four of those samples must have readings below 50cfu/g, while the remaining sample can have a reading between 50cfu/g and 500cfu/g. To achieve this standard, individual manufactures require that the number of vegetative *B. cereus* cells in a tanker of milk destined for IMF is no greater than 10cfu/mL. Molecular methods for detection of *B. cereus* are not currently used at industry level; instead, traditional culture methods are extensively used by processors to detect presumptive *B. cereus* (species not confirmed). Mannitol-egg yolk-polymyxin (MYP) agar and Bacara agar are used to identify presumptive *B. cereus* colonies. The colonies are pink (mannitol negative) with a zone of precipitate (lecithinase positive) on MYP agar while the colonies are pink orange and lecithinase positive on Bacara agar plates.

Comparison of *Bacillus cereus* isolation methods at Moorepark

The *B. cereus* group is comprised of six closely related species: *B. cereus*, *B. mycoides*, *B. pseudomycoides, B. thuringiensis, B. weihenstephanensis*, and *B. anthracis*, which are very difficult to distinguish. Consequently most methods of detection based on traditional culture are unable to differentiate between B. cereus group species. Based on colony morphology on MYP agar, presumptive *B. cereus* group colonies were identified from 10 bulk tank milk samples. Molecular

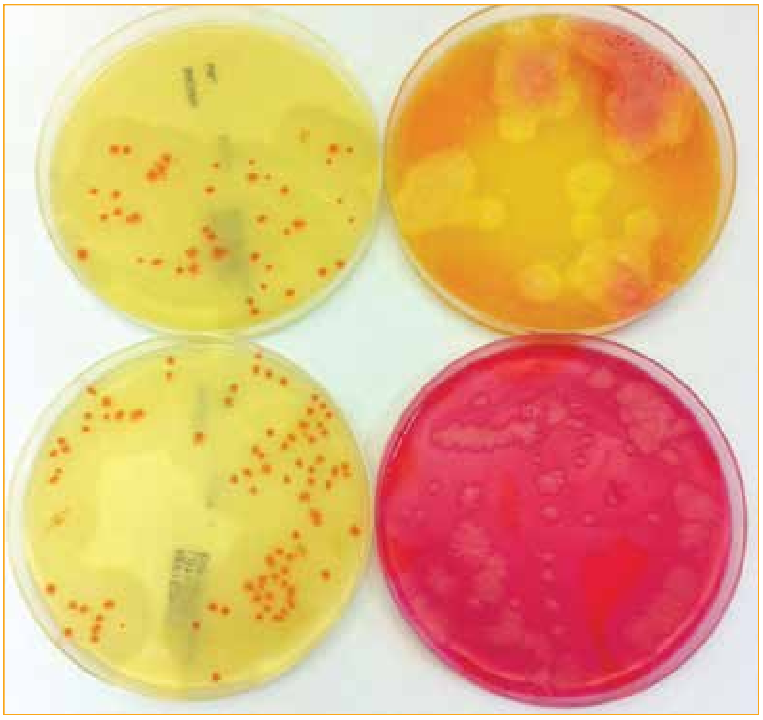

Figure 1. Comparison of Bacara (left) and MYP agar (right) for the identification of *Bacillus cereus* group spp. from raw (top) and pasteurised (bottom) bulk tank milk samples.

analysis (16S-DNA sequencing) of the presumptive *B. cereus* group isolates was carried out to identify each species. The sequence results indicated that the isolates identified as *B. cereus* group were in fact members of the *Enterococcus, Staphylococcus, Lactococcus* and other families. Subsequently, it was decided to compare identical raw bulk tank milk samples on Bacara and MYP agar plates to identify *B. cereus* group colonies. On MYP agar the pink colonies (mannitol negative) that were considered to belong to the B. cereus group were masked by yellow colonies (mannitol positive). Even when milk samples were pasteurised (reduced number of competitive flora) it was difficult to count presumptive colonies on MYP agar since the colonies had coalesced and the precipitation zones overlapped (Figure 1). Conversely, enumeration and detection of B. cereus colonies from both raw and pasteurised milk on Bacara agar was easier, because the colonies were discrete and uniform in colour and size. Molecular analysis of colonies from both agars indicated that colonies grown on Bacara agar belonged to the B. cereus group while only one colony grown on MYP agar belonged to the B. cereus group.

Reducing levels of *Bacillus cereus* in bulk tank milk

The number of *B. cereus* bacteria in pasteurised dairy products is dependent on the initial population in the raw milk. *B. cereus* is ubiquitous in nature and spores of *B. cereus* have been isolated from dairy farm environments including bedding materials, teats contaminated with soil, dirty alleyways, faeces and silage. When cows are housed, spores in used bedding are a major source of *B. cereus* contamination of bulk tank milk via contaminated teat and udder surfaces. When cows are grazing, contamination of teats with soil is the main route of contamination of bulk tank milk. Teat preparation before cluster attachment can reduce the number of spores in bulk tank milk. Since milk in Ireland is selected for IMF manufacture based on its vegetative *B. cereus* cell count, the farm factors that influence the vegetative *B. cereus* count in raw bulk tank milk were investigated between July and August 2012. The level of *B. cereus* in bulk tank milk was monitored on 63 farms at every milk collection for two weeks, and then a farm visit took place at milking time. A questionnaire survey was completed by each farmer and management routines used for milking, washing and grazing were recorded. The average *B. cereus* count was calculated for each farm. The geometric mean *B. cereus* count for all milk samples was 40cfu/mL (CI = 28.4 to 55.1). The temperature of the cleaning solution, feeding cows silage and reusing the cleaning solution more than once were all associated with the *B. cereus* count in bulk tank milk. The *B. cereus* count in milk was four times greater (201cfu/mL) when cows were housed compared to when they were on pasture (50cfu/mL). The allocation of fresh grass every 12 hours (62cfu/mL) resulted in a decrease in *B. cereus* count compared to a 24-hour grass allocation (166cfu/mL).

Conclusions

Findings from current research indicate that Bacara agar is a more suitable agar for the detection of *B. cereus* than MYP. Farm management factors associated with counts of *B. cereus* in bulk tank milk were identified. More frequent allocations of fresh grass reduced the *B. cereus* count in bulk tank milk. Housing cows, feeding silage and reusing the detergent solution more than once increased the *B. cereus* count in bulk tank milk. Management practices aimed at improving the hygienic environment of the cow reduce the levels of *B. cereus* contamination in bulk tank milk, thus making the milk more suitable for IMF manufacture.

Acknowledgements

This work was funded by Teagasc Core funding and the Teagasc Walsh Fellowship Scheme.

Optimum production systems post milk-quota abolition

The removal of milk quotas will create significant opportunities at farm level. The realisation of this potential is dependent on system choice and the technical performance of the farm.

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For the first time in a generation, many dairy farmers have the opportunity to expand their dairy businesses unhindered by the milk quota regime. Dairy farmers no longer have the restriction on farm milk output, but now the restrictions will come in the form of land for grazing cows, environmental legislation or available skilled labour. Each individual farmer must now decide on how much milk they will produce. The effects of that decision on the system of farming operated will have significant implications for the overall profitability of the business and the success of any expansion process. According to the United Nations (UN), the global human population is predicted to increase to over nine billion by 2050, and the UN's Food and Agriculture Organization says that this will undoubtedly lead to a rise in consumption of bovine milk and meat products. The proportion of this market filled by the Irish dairy industry will depend on the relative competitiveness of milk production in Ireland. This will undoubtedly be reflected in the choice of milk production system operated by Irish dairy farmers.

Advantage of grazed grass

When Irish milk production systems are compared to many of our competitors, the key advantage is our ability to produce milk at a lower cost due to the levels of grazed grass in the diet. When grazed grass is compared to other feeds such as grass silage or concentrate on a per unit of energy basis, grazed grass has a relative cost that is approximately 2.5 times lower than grass silage and 3.3 times lower than purchased concentrate. For the expansion process to be sustainable, the system operated must focus on maximising grass growth and converting as much of the grass grown to product, through efficient grazing cows. That requires a cow that calves at the right time of year, calves every 365 days and survives for over 5.5 lactations, while producing high yields of high solids milk. At farm level, there will be a temptation to increase milk production through bought-in supplementary feed, especially at times when milk price is high. However, this will not increase the overall business sustainability. In most situations, excessive use of bought-in feeds will be associated with a reduction in profitability, less grass utilisation, increased costs and reduced environmental sustainability of the business.

New skills and abilities

While the constraints of milk quotas are gone, expansion at farm level will require farmers to use new skills and increase efficiency through the expansion process. With the opportunity to expand comes increased risk: increased milk price volatility, higher debt levels and farms operating at higher stocking rates. In order for dairy farmers to take advantage of expansion, there will be a requirement for cost control. The increased output must come from increased pasture growth and utilisation with a fertile, low maintenance herd. Successful dairy farming businesses in the future will be low-cost, with >90% of the cows diet originating from home-produced grazed

Table 1. Key performance indicators affecting grass utilisation.

Grass utilised / ha					
Grass growth t DM/ha	Concentrate feed (t/cow)	Stocking rate (LU/ha)	Cow weight (kg)	Milk yield (kg MS/cow)	Grazing season (days)
>15	<0.5	2.70	<550	>450	>280

Grass growth			Milk Solids Yield (kg MS)		
Soil pH	Soil P&K Index	Proportion of ryegrass	Milk volume (L)	Milk protein (%)	Milk fat (%)
6.5-7.0	≥3	>80%	>5,250	>3.70	>4.6

Table 2. Key performance indicators affecting six-week calving rate.

Six-week calving rate (target 90%)					
Submission rate (%)	Conception rate (%)	EBI – Fertility sub-index (€)	Mean calving date	Replacement rate (%)	Inseminations per cow in-calf
>90	<60	<120	February 15 to 25	<18	<1.7

grass and grass silage, resilient to price volatility, labour efficient and simple to operate, with a robust type of cow. Investment should be prioritised towards: grazing infrastructure; labour-efficient, functional winter accommodation; milking facilities; and slurry storage facilities. Successful dairy farmers will require grassland and animal management skills and the business management ability to enable them to appraise business opportunities as and when they arise. The key decider when accessing finance for expansion will be the track record of the individual demonstrating their technical ability and their potential to repay debt and manage increased scale.

Key performance indicators

There are a variety of key performance indicators (KPIs) to assess the efficiency of the business as a whole. In a post-quota environment, the financial metrics of importance will change from KPIs linked to margin per litre of quota to margin per unit of the next most limiting resource (land that cows can graze accessible to the milking parlour). All financial and investment decisions should be evaluated based on their effect on the business from the perspective of profitability, available cash, return on investment and return on equity.

The two most important technical KPIs on a pasture-based dairy farm are the amount of grass that is being utilised per hectare on the farm and the percentage of cows calving in the first six weeks of the calving season. Nationally, the average Irish dairy farmer is utilising approximately 7.3t DM/ha even though the achievable industry target is 12t DM/ha. Research has shown that each 1t DM/ha utilised is worth €161/ha. The average six-week calving rate is 58% with an achievable industry target of 90%. Research has shown that each 1% increase in six-week calving rate is worth €8.22/cow. Increasing these two KPIs from their current national position to the target would be worth €1,450/ha per year.

Grass utilised per hectare

The key factors affecting grass utilised are the amount of grass grown, which is primarily influenced by soil fertility, and grass utilisation rate, which is driven by grazing management (Table 1). The level of concentrate feed used, the stocking rate, cow live weight and the milk yield of the animals affects the utilisation of the grass that is grown, while the length of the grazing season affects whether the grass grown is utilised as grazed grass or grass silage. To achieve 12t DM/ha utilised, it is necessary to grow 15t DM/ha, stock the farm at 2.70 LU/ha with a herd that is less than 550kg live weight producing 450kg milk solids (MS) during a 280-day grazing season with less than 0.5t of bought-in feed. Growing 15t DM/ha requires optimum soil pH and fertility, and ryegrass dominant swards. Achieving 450kg milk solids sold per cow on a pasture-based diet requires a long (>280 days) lactation, a mature herd (5.5 lactations/cow) and good grazing management.

Six-week calving rate

The two key factors affecting six-week calving rate are: cow and replacement heifer submission; and conception rates (Table 2). These two factors will drive herd mean calving date, overall herd replacement rate and the number of inseminations required to get a cow in calf. The key factor that will influence these variables are: herd genetics for fertility; and reproductive management.

Conclusion

The removal of milk quotas will create significant opportunities at farm level. The realisation of this potential will be dependent on the system choices. There is potential to increase milk output and efficiency by focusing on the key performance indicators of grass utilised per hectare and six-week calving rate.

Professional diploma in dairy farm management

The first graduates of the Professional Diploma in Dairy Herd Management were presented with their diplomas by the Minister for Agriculture, Food and the Marine, Simon Coveney, TD at an awards ceremony in the Paddy O'Keeffe Innovation Centre at Teagasc Moorepark recently. Pictured with the graduates are: Minister for Agriculture, Food and the Marine Simon Coveney, TD (front row, centre); Frank O'Mara, Head of Research, Teagasc (front row, far left); Alex Evans, UCD (second row, far left); Tony Pettit, Head of Education, Teagasc (front); and Marion Beecher, Course Coordinator (front row, second from left).

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The first graduates were recently awarded their Professional Diploma in Dairy Farm Management. Given the challenges that lie ahead, programme coordinator, Marion Beecher, outlines its importance in the education and training of young dairy farmers

The targeted milk production expansion on Irish dairy farms has been well documented. However, this growth can only be achieved with a supply of well-trained farmers, including owners and managers, who have the experience and skills needed to cope with the many new challenges facing the dairy industry in the future. It is a Teagasc priority to increase the number of enrolments on its dairy education programmes. Teagasc offers two specialised dairy education programmes. These are the level 6 advanced programme in Dairy Herd Management and the Teagasc Professional Diploma in Dairy Farm Management (PDDFM), which is the focus of this article. The Professional Diploma in Dairy Farm Management course will provide the next generation of dairy farmers with the additional skills and knowledge to meet the challenges of an expanding industry in the future.

Changing business environment for dairy farming

The business environment for dairy farming is changing rapidly as global market forces now have a significant impact on Irish producers. Irish dairy farmers are facing an increasingly turbulent business environment caused by several factors including, milk price variability and climate change, leading to farm income volatility. Against this backdrop, herd size will increase on many dairy farms over the coming years, placing added physical and financial pressure on the management capability of dairy farmers. As a consequence, modern dairy farming systems must be sufficiently resilient to provide farming families with a viable income in this changing environment.

Resilient businesses need resilient people

Resilience denotes the ability of a farm to 'bounce back' and recover quickly and effectively from a difficult period or adverse event, while still maintaining essential operational performance. A farm with resilient people, as well as systems and processes, is more agile and proactive in adapting to the changing environment. It is in this context that appropriate training programmes are an essential component to provide farmers with both the skills and experiential learning necessary to become resilient, profitable dairy farmers within this new environment.

Practical learning environment

The ability to adapt in a changing environment is a learned skill in order to develop habits to be more effective in navigating through changing conditions. Such habits are best acquired in a practical learning environment from experience, as well as learning from the experience of other farmers with a proven track record for personal and business resilience. Successful farmers and managers are well educated and their education allows them to use existing information more competently and help find solutions to problems. These farmers have better access to information and are more likely to adopt new technologies or products early, because of their ability to sort the relevant from the irrelevant (Nuthall, 2006). This ensures that educated farmers are more efficient and develop farming systems that are able to absorb and respond to change, resulting in more profit per hectare (Heanue and O'Donoghue, 2014; Kilpatrick *et al.*, 1999). These skills, combined with the resilient farming systems, mean that educated farmers are well equipped to manage the challenges of farm expansion.

Course details

The PDDFM programme was developed by Teagasc, in conjunction with UCD and in consultation with other dairy industry stakeholders, to provide suitably skilled and experienced dairy farm managers for the expanding dairy industry. The programme is centred on experience-based learning from host farmers and also incorporates both formal (lectures) and informal training (discussion groups). The programme aims to equip future dairy farmers with a broad range of skills, experience and practical knowledge to become successful managers (both on home farms and as farm managers).

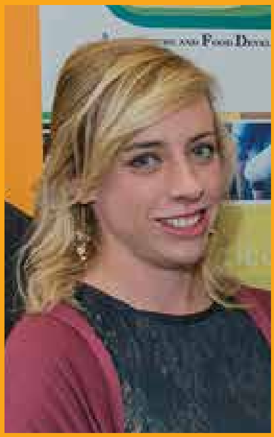
The core elements of PDDFM are a two-year, fully-paid professional work experience based programme on high performance dairy farms. There is an option to travel overseas to New Zealand to experience the calving and breeding seasons on large-scale, grass-based farms. While on work experience, students have the opportunity to implement their technical knowledge in a controlled learning environment. There are approximately 25 days per year of course work at the Teagasc, Animal & Grassland Research and Innovation Centre at Moorepark and Teagasc Kildalton Agricultural College. Students develop skills covering a broad range of topics such as grassland management, animal breeding and reproduction, herd health, business and financial planning and people management skills. The contact element of the programme is delivered by an integrated team of highly specialised Teagasc staff including Moorepark researchers, college lecturers and knowledge-transfer specialists. Guest lectures are invited from key industry stakeholders and highly successful commercial dairy farmers. The programme incorporates discussion groups facilitated by a Teagasc facilitator.

Maximise career prospects

The aim of the programme is to maximise students' career prospects in the dairy industry. This is achieved by supporting them in gaining solid experience and career development. On completion of the PDDFM course, students will be able to manage a farm – either their own farm or as an employed farm manger. The students will have developed the skills required to build a resilient farm system that has the capability to not only adapt to change, but also capitalise on any opportunities created. Additionally, they will have the ability to maintain productive capacity in the face of production, financial and market variability.

The first graduates from the PDDFM graduated in November 2014 and most have been successfully employed in New Zealand, Saudi Arabia and Ireland as dairy farm managers, as share farmers or as managers on their own family farms.

GRADUATE EXPERIENCE



Name: Ruth Kerrigan

Background: From Newcastle, Co Dublin. Non-farming background.

Previous Education: Degree in Animal and Crop Production, University College Dublin.

With the abolition of quotas in April, it was clear to me that there would be many opportunities for young farmers from farming and non-farming backgrounds. I chose this course after completing my degree in Animal and Crop Production because it offered practical, fully-paid professional work experience. This was important, as it gave me access to the best farmers in the industry (both the host farm I worked with and also through attending course discussion groups). This was invaluable as I got to meet and mix with some of the top farmers and managers in the country. Being on a farm for a full year was very satisfying for me. It allowed plenty of time to settle into the role and allowed me to see the fruits of my labour. The course also provided essentially unlimited access to industry experts and first-hand knowledge of the recent research results from Teagasc. This was hugely beneficial; if we had any issues on farm, we had experts to hand to ask about such problems. The host farmer experience was so positive that once I finished the course I stayed on as a full-time employee on that farm.

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There is an urgent requirement for more highly skilled, young and ambitious farmers in the Irish dairy industry.

Land consolidation and career progression

Developing farm business structures that will facilitate land consolidation and encourage new people into farming

Inheritance is the main form of land ownership transfer in Ireland, with less than 1% of the land area in the country coming on the market for sale annually. This creates a situation where some land owners may have inherited land from family, but have little ambition to farm it. The average age of farmers in Ireland is 54, and a recent Macra na Feirme survey found that 48% of farmers over the age of 50 have no identified successor (Bogue, 2013). There is also a shortage of young farmers in the country, with only 6% of farmers under 35. Hence, there is a urgent requirement for more highly skilled, young and ambitious farmers to work with these farm owners and older farmers.

During the EU milk quota regime, there was little chance for somebody from a non-farming background to progress to owning their own dairy farming business. The removal of milk quotas offers a huge opportunity to get new people into farming, but a range of farm business structures are needed to allow them capture this opportunity and work with farm owners.

A variety of collaborative farming options are also needed to cater for the dramatic variation in farmer circumstance (e.g., scale, age profile, presence of a successor, farming preferences and attitude). This research project is aiming to develop a suite of collaborative farming arrangements to cater for different farming situations.

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Essential resources

The goal of any collaborative farming venture is to allow farmers to share or access the essential resources of land, labour, livestock and capital. For example, a farmer may want to enter an arrangement to increase their land base, or share labour to reduce their workload, or potentially both of these. The desired outcomes of successful collaborative farming options are more profitable farms that offer a good quality of life to all the participants in the arrangement.

A range of structures that are operated internationally are being evaluated to identify and adapt the structures most suitable to Ireland. These structures include partnerships, contract farming, contract milking and share farming.

Collaborative options

Since their introduction in 2002, milk production partnerships have been the main collaborative farming option in Ireland. Today, at present, there are over 775 active partnerships registered with the Department of Agriculture, Food, and the Marine and it is expected this number will increase further in the future. Approximately two thirds of these are family partnerships (parent and child) and the remaining are between different families. Partnerships will continue as a viable and popular collaborative arrangement in the future. While a new entrant can enter into a partnership with a farm owner, other options are needed.

Share farming is where two parties operate separate businesses on one farm and share the incomes and expenses. It is very common in New Zealand where over 3,500 dairy farms (one third of total farms) operate through share farming (LIC, 2013). Typically, the farm owner provides the land and infrastructure (milking parlour etc.) needed to milk the cows, while the share farmer provides all the labour, and either party can supply some or all of the livestock. Share farming is practiced on some tillage farms in Ireland where one farmer supplies the land and the other party supplies machinery and labour, while the cost of growing the crop and resulting crop sales are shared.

Many people from non-agricultural backgrounds enter share farming arrangements in New Zealand, as it's seen as an attractive and rewarding career route.

Share farming is a viable option for the Irish dairy industry. It could attract new people to the dairy industry, as well as provide a mechanism for existing non-dairy farms to secure the individuals and skills that will be required to successfully run a dairy farm.

Whether it is the profit share in partnership or or split in income and expenditure in share farming, the share is based broadly on the contribution of resources (land, facilities, labour and livestock) that the different parties bring to the table. This allows people to build their wealth via stock growth over time, and means owning land is not essential to allow someone become a successful farmer.

Essential skills

To better understand the essential skills needed to make collaborative farming options work, a number of case studies were completed in New Zealand in autumn 2014 with people at various stages of their farming careers. An essential component of the case studies was the Biographic Narrative Interview Method (Wengraf, 2001). Analysis of the case studies is in progress. An initial theme emerging from the analysis is the theory of personal resilience (e.g., Ungar, 2008) as an essential characteristic of people who successfully operate collaborative farming arrangements.

Potential returns

Work has been completed on a tool that can be used to devise an equitable split in a share farming arrangement (See Table 1). Once share splits have been devised, they should be tested in a robust farm budget to investigate the potential returns to both parties from the arrangement.

Likely candidates

To better understand the availability of potential candidates for collaborative farming in Ireland, a survey was completed with 140 dairy students (studying for Level 6, 7 and 8 qualifications) to capture data on their farming backgrounds and future intentions. In total, 12% were from non-farming backgrounds and, therefore, do not have farms to return to at home. Subsequently, they are prime candidates for collaborative farming options. A further 8% identified themselves as having a relative that is farming, meaning the potential for within-family collaboration. Eighty per cent of students were from a farm but scale and current enterprise varied widely.

Table 1. Share split from share farming calculator

Asset contribution	Nominal returns for calculation	Total	Percentage
Land	200ac at €200/ac	€40,000	23.5%
Capital	€400,000 (sheds etc.) – 10% return on capital	€40,000	23.5%
Labour	200 cows - €250/cow for labour	€50,000	29.5%
Livestock	200 cows - €200/cow	€40,000	23.5
		€170,000	100%

The essential resources for a profitable dairy farm business: land, labour, cows and infrastructure.

Conclusion

New farm business structures are going to be essential for successful expansion within the dairy industry in Ireland. This research project is analysing the international structures in operation, and will develop optimised structures for Ireland.

Acknowledgments

This project is closely linked to other research projects in Teagasc. Dr Kevin Heanue and Dr Aine Macken Walsh are leading another collaborative farming research programme in Teagasc entitled 'Join to Farm'.

This research project is funded by the Irish Research Council – http://research.ie/

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Lessons from Kilkenny greenfield dairy farm

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The Kilkenny greenfield dairy farm was set up in 2009 to demonstrate the potential and pitfalls associated with expansion.

The Greenfield dairy farm in Kilkenny is a project detailing the conversion of what was once a tillage farm into a grass-based dairy farm managed by Teagasc. The three shareholders in the farm (leased for 15 years) are the Phelan family (land owners), Glanbia and the *Irish Farmers Journal*. The Department of Agriculture, Food and the Marine provided the quota to allow the venture to start. The total conversion costs for the farm was €1.2 million, with €350,000 of that provided by the three shareholders equally and the remainder borrowed from AIB with a 15-year loan (first two years interest-only). Cows were milked on the farm in February 2010 for the first time, with five full lactations now complete. The main objectives of the project are to demonstrate the following: (1) financial viability of a stand-alone dairy farm; (2) the potential of converting a tillage farm to a dairy farm; (3) the issues associated with the setting up of a dairy farm; and (4) the potential of low-cost housing technologies on a large-scale dairy farm.

Farm progress to date

Outputs from the farm have increased over the first five years driven by increasing stocking rate, as well as increased milk yield per cow. Both milk volume and milk solids concentration have increased steadily over the first five years. Herd non-pregnancy rate (see Table 1) is running at approximately 10% following a 12-week breeding season using only artificial insemination. The number of heifers required to enter the herd is declining as the herd size stabilises. The key driver of further increasing output from the farm is the ability to increase grass growth and then match it to an increased stocking rate.

Table 1. Farm physical performance over the first five years.

	Year			
	2010	2011	2012	2013
Cows at start of year (no.)	250	307	306	346
Cow mortality (%)	2.20	1.31	1.91	2.03
Replacement Rate (no)	-	70	116	93
Empty rate (%)	12.3	13.0	11.0	10.0
Milk solids sold (kg)	83,183	108,552	110,881	123,005
Milk volume delivered (L)	1,032,687	1,328,654	1,316,477	1,469,612
Milk protein (%)	3.54	3.52	3.57	3.63
Milk Fat (%)	4.28	4.41	4.61	4.46
Meal fed /cow (kg)	280	330	307	620
Grass grown (t/DM ha)	12.0	11.80	11.80	10

Farm financial performance

The farm receipts have been well ahead of the original budget expectations, primarily driven by a higher-than-projected milk price. The costs, however, have also been greater than the original budgets. The main reasons for the greater costs include: purchased feed requirements; fertilizer price; number of replacement heifers reared; original development overspend; and higher-than-expected ongoing farm maintenance costs. When year one is excluded, the return on equity (ROE) and return on investment (ROI) from the farm are running, on average, at 9% and 20% respectively. These returns are comparable with attractive prospects outside of farming.

Table 2. Farm financial performance over the first five years.

	Year			
	2010	2011	2012	2013
Farm Receipts (€)	397,949	567,323	573,666	725,910
Total Costs (€)	397,831	537,640	527,654	608,626
Net Profit (€)*	118	81,433	45,323	97,483
ROI (%)		9	6	10
ROE (%)		23	13	21
Surplus Cash (€)	47,239	103,334	20,155	97,339

*Net Profit excludes inventory change and capital repayments.

Key lessons learned to date

Staff

- Skilled, motivated staff are vital to the success of the business. While the greenfield project successfully recruited high-calibre staff, the availability of skilled labour will be a huge challenge facing Irish dairy farms in coming years.
- Maximising the use of contractors allows the staff on the farm to concentrate on the important drivers of productivity. These key drivers are grassland performance, conversion of that grass to product and fertility management of the herd.

Grass growth

- It has taken five to six years for the soil organic matter to increase after being converted from long-term tillage into grass. This reduced grass production in the start-up years (2010-2014).
- The farm is situated in the east of Ireland (Kilkenny), where average annual rainfall is low (822mm). This means cows can graze for 330 days. The dry summers in this area can sometimes be a challenge for both grass growth and milk production.
- Fertilizer applied to the farm is within the Nitrate Directive regulations for artificial nitrogen (N) and phosphorus (P). As the farm is low in organic matter, the level of N applied has restricted grass growth. Detailed soil sampling shows P levels are decreasing since 2009. Potash levels are increasing slowly as up to 90kgs/ha of potash is applied annually.

Livestock

- The herd was sourced by purchasing animals from eight different herds. The key objective was to minimise the likelihood of infectious disease problems through a herd-health plan. This involved significant screening and minimising the number of source herds. This strategy has helped ensure that there has been no serious infectious disease outbreak on the farm.

- The herd has progressively become a high EBI Jersey/Friesian crossbred herd.
- The biggest herd-health challenge on the farm has been Somatic Cell Count (SCC). There was not enough emphasis put on SCC history when cows were purchased. This has added significant extra burden to staff who have to manage SCC in the herd. Progressive SCC management is essential in a large herd and targeted management through the use of a second herd has been employed to stop the spread between animals and allow greater time to manage the problem.
- When a herd is put together from different sources through the purchase of full herds, a subsequent high replacement rate can be expected.

Financial performance

- Financial planning is the most important step in the development process. The plan should include a number of financial metrics (profit, cash flow, ROE, ROI). If it does not work on paper, it certainly will not work in practice.
- Investment should be prioritised into areas that will give the highest returns (grassland, grazing infrastructure, livestock) while all other investments should be rigorously questioned.
- A risk-management strategy should identify all the risks that exist for a particular farm, and a management plan should be developed to manage these risks. A key risk for the greenfield farm is price volatility. Strategies developed to mitigate this include the creation of a reserve fund, utilising the fixed pricing schemes and maximising the conversion of grazed grass to milk to minimise the costs of production.

Farm conversion

- The conversion or development process requires a particular set of skills that are different to the key skills for operating a dairy farm. Hiring a project manager to oversee and manage the planning of the farm layout, planning permission application and project management of the development would have added an initial cost, but may have resulted in substantial savings to the original investment as well as the ongoing costs on the greenfield dairy farm.
- Within the budget for the conversion, a contingency budget for both the timeframe required and cost should be built into the overall planning process. A reasonable time and money contingency budget could be six months and 20% of the capital budget.

Rapid detection of BVD

Immunosensor for rapid detection of Bovine Viral Diarrhoea (BVD) antibodies in serum has been developed by Tyndall National Institute in conjunction with Teagasc. This technology has the potential to develop portable devices to detect a range of diseases on-farm.




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Definitive diagnosis of a disease state is often delayed due to unavailability of laboratory test results. This has, and is, being overcome in human medicine by the use of 'point-of-care' diagnostic devices, e.g., glucometer for diabetic patients. Technologies are now being sought to allow rapid testing of domestic livestock on-farm to prevent widespread disease transmission throughout a herd, and for the purposes of continuing disease surveillance. Such technologies will greatly improve the appropriateness of interventions that can take place rapidly on-farm, and will lead to improvements in herd disease management and overall herd health. An immunosensor to rapidly identify BVD antibody-positive individuals is described hereunder. This diagnostic tool can be used for BVD surveillance to monitor successful eradication of the disease at herd level, thereby supporting the Irish national BVD eradication scheme.

BVD testing

BVD, caused by BVD virus (BVDV), is a highly contagious viral disease of cattle. Successful BVDV eradication has been achieved through the use of 'test and cull' protocols involving removal of persistently infected (PI) individuals. In January 2013, a mandatory national eradication programme for BVD, coordinated by Animal Health Ireland (AHI), was introduced in the Republic of Ireland.

Currently, the scheme involves ear-notch BVD virus testing of all newborn calves in order to identify PIs for culling. The scheme is due to move into the surveillance phase of testing based on the progress of the scheme so far in halving the number of PIs being born annually (www.animalhealthireland.ie). Surveillance is most often based on checking for the presence of anti-BVD antibodies in bovine serum or milk (individual or bulk). Bulk milk testing is an inexpensive and practical means of determining herd antibody status but has two significant drawbacks in terms of national surveillance in Ireland. Firstly, bulk milk analysis for BVDV antibodies does not readily distinguish between vaccinated and unvaccinated herds for all vaccines. Secondly, BVD antibody readings may reflect historical, rather than current viral herd status.

To overcome this issue, it is useful to test unvaccinated homeborn youngstock (weanlings) for antibodies against BVDV (i.e., a 'spot test'). Positive antibody readings in this population, once maternal antibodies have dissipated, can be indicative of current or recent viral circulation. It would be hugely beneficial for BVD surveillance if on-farm antibody testing of youngstock could be rapidly completed by veterinarians, and appropriate interventions applied when required.

Electrochemical immunosensor for BVD antibody

An electrochemical immunosensor is a device that converts the highly specific antibody-antigen binding reaction into an electrical output, which can be detected by 'off-the-shelf' electronic devices. The electrical output of the immunosensor is equivalent to the colour change reaction detected in colorimetric enzyme-linked immunosorbent assays (ELISA). The electrochemical immunosensor has a number of distinct advantages over ELISA. ELISA is based on labeling the antibody-antigen complex with a colour-generating substrate. This increases assay time, assay cost, and requires specialised laboratory-based equipment. The electrochemical sensor is label-free, which allows more rapid generation of results. Additionally, as the outputs are electrical, basic handheld equipment is suitable for measurement. Finally, immunosensors are very small and this has benefits, in terms of assay sensitivity.

The immunosensor described in this article consists of a gold nanowire fabricated on wafer-scale silicon substrates. The use of a nanowire increases the level of biological reagent diffusion to the reaction surface which increases assay speed and sensitivity, two important considerations for on-farm testing.

The BVD immunosensor was developed by firstly electrodepositing O-aminobenzoic acid (o-ABA) onto the nanowire, which was necessary to covalently attach BVD virus (at a concentration of 100µg/mL) to the sensor. Following this immobilisation, the sensor was washed to remove unbound proteins and unreacted active sites were blocked by immersing in ethanolamine for 30 minutes. Finally, the antigen-modified electrodes were exposed to known concentrations of BVD antibody solution in phosphate-buffered saline. BVD antibody detection was also completed in serum samples of known BVD status. Figure 1 shows a schematic of the layer-by-layer build up on a nanowire surface. As the thickness of the layering on the gold nanowire increases, changes in current intensity and impedance occur. These electrical changes are proportional to the thickness of the layer on the nanowire, which in turn is proportional to the amount of BVD antibody present in the sample. The electrical output, therefore, can be used to determine BVD antibody levels in serum.

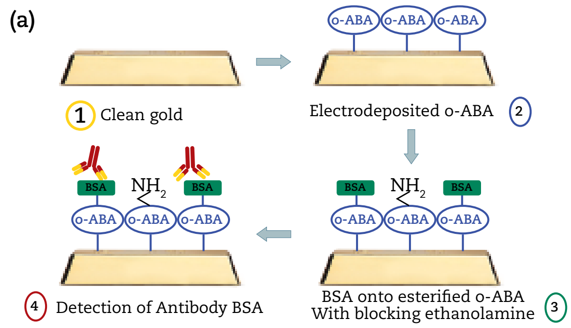

Figure 1.

BVD antibody detection in serum

Figure 2 outlines the typical electrical output (nyquist spectra) with increasing layer thickness on the nanowire, as virus and antibody specifically bind to each other. As mentioned previously, the shift in signal is proportional to the degree of layering on the gold nanowire allowing quantification of BVD antibody present in a sample. The total assay time to generate the results presented here was 20 minutes following initial chip preparation. It is envisaged that this assay time will be reduced to five minutes to allow the sensor to be used at a practical level on-farm.

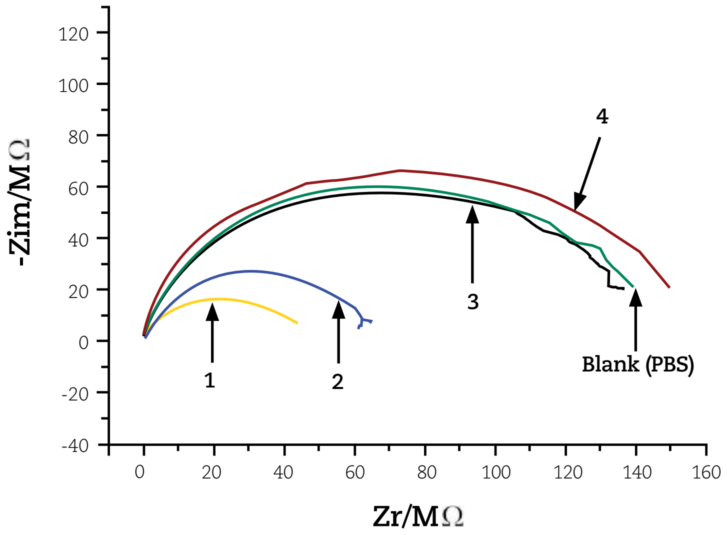

Figure 2.

Conclusion

The chip nanowire-based electrochemical sensor described here was found to clearly discriminate between BVD antibody positive and negative bovine sera. The potential now exists, therefore, to develop portable devices to detect a range of diseases on-farm.

Acknowledgements

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A dairy farm in the Timoleague catchment, west Cork, where enterprises are comparable to the top 10% economic performing specialist dairy farmers nationally.

Dairy farm soils and water quality

The Agricultural Catchments Programme is investigating the balance between the needs of intensive dairy farm soils and water quality.

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Sustainable intensification

Food production, including milk production, for a growing global population is a primary justification for intensive agriculture. However, maximising agricultural productivity while minimising environmental impact is the central principle of sustainable intensification objectives.

The Nitrates Directive and soil phosphorus

The European Union (EU) Nitrates Directive deals with the risk of agricultural nutrient pollution, and to minimise diffuse nutrient losses from agricultural soils during rainfall, agronomic thresholds are used. For example, fertilizer nutrient use is limited to the requirements of crop types and, for phosphorus (P), the nutrient status of the soil.

Plant available soil P is monitored using the Morgan P method and assessed in an index system where indices 1 and 2 require P build-up and index 3 is considered optimum, where P is added as replacement. Index 4 is considered excessive, indicative of no further crop response if further P is added, and at higher risk of being washed into rivers during rainfall. This principle is used in the Irish Nitrates Directive regulations where index 4 fields have to be managed to decline to index 3.

Teagasc's Agricultural Catchment Programme (ACP) is a long-term monitoring and evaluation project that monitors the consequences of the Nitrates Directive regulations on water quality in six intensively farmed river catchments. This includes monitoring the decline of excessive P index 4 soils.

The nutrient cascade

Decreases in soil P status could mean a number of things. Decreased soil P may indeed mean a decrease in P in runoff to rivers during rainfall – although this is extremely difficult to measure as these 'runoff events' are short lived. Decreases in soil P might also have knock-on consequences for soil fertility and farm profitability. This trail from P use, soil P status, losses from soil during rainfall and subsequent ecological impacts in water bodies (and with the added economic dimension) is termed the nutrient 'cascade' and can be measured to assess if there is an environmental, agronomic or economic risk – or if there has been a recovery.

Part of the ACP experimental design to monitor this 'cascade' relies on nutrient management and production records from catchment farmers, field-by-field soil P measurements, continuous measurements of P in rivers and ecological measurements in catchment rivers. This kind of intensive monitoring programme requires a close farm-advisory relationship and also a range of agricultural, soil, hydrological and economic scientists.

From risk to recovery?

The most intensive dairy catchment (34% in derogation in a 7.6km^2 catchment area) in the ACP study is near Timoleague in west Cork. The nutrient cascade trends for this catchment over a 3-4 year period have recently been published (Murphy *et al.*, 2015). Soils were sampled at an intensive 2ha field resolution in late 2009 and early 2010, and the survey was repeated again in late 2013. Other surveys during this time included water quality in the river and farm nutrient efficiency and production records. This catchment was noted, in 2009-2010, as having the highest occurrence of soil P index 4 fields in the ACP catchments with 32% of fields at this excessive status. In the years following the Nitrates Directive regulations, and with a strong advisory presence, the 2013 repeat survey indicated that this occurrence had reduced to 24% and the occurrence of the optimum index 3 had increased from 27% to 36%. There was a small movement in the index 1 and 2 fields from the first survey, but the main movement appeared to be from excessive to optimum (Figure 1). These changes were made with a low average surplus of 2.4kg/ha per year of P applied over P removed in produce and an increasing P use efficiency of 89%.

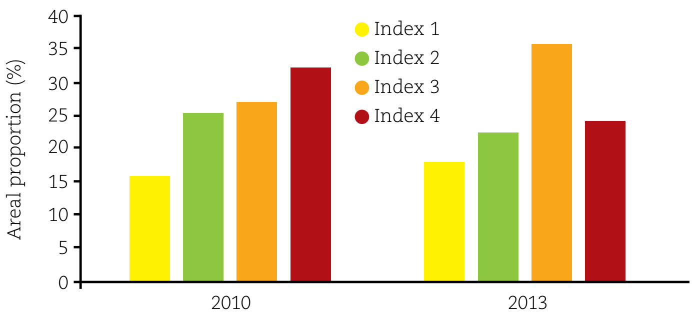

Figure 1. Soil P changes by index in the Timoleague catchment showing a decrease in index 4 fields (32% to 24%) between 2009-2010 and 2013.

In other parts of the cascade, despite wetter years providing more opportunities for P loss in water runoff pathways, a closer analysis of high resolution water quality data during winter periods indicated that the concentrations of P decreased between 2010 and 2013 in soil surface (quickflow) and shallow underground (interflow) water pathways, where contact with soil P would be greatest (Figure 2). Ecological trends were less clear in the catchment river over the 2010-2013 period and the main pattern appeared to be seasonal showing better ecological quality in the spring rather than summer period.

Remaining profitable

Production records showed that expansion occurred on the catchment dairy farms between 2010 and 2012 with more land and an increased number of dairy cows in milk production. Within the study period, dairy farmers remained comparable to the top 10% economic performing specialist dairy farmers nationally. The stocking rate was 2.48 LU/ha (2.47 LU/ha for top 10% nationally), and yields were 1,125kg milk solids/ha (1,045kg milk solids/ha

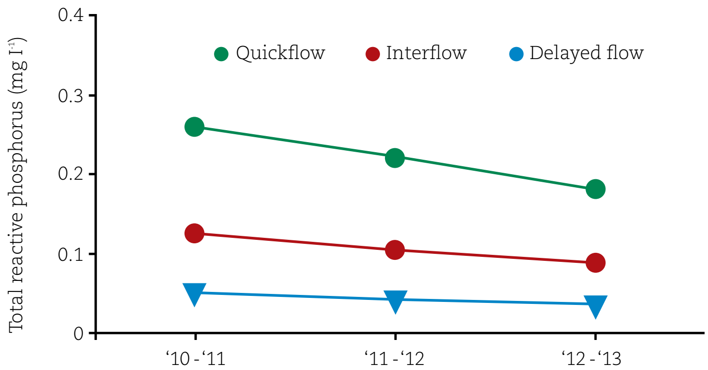

Figure 2. Decreasing flow-weighted mean concentrations of total reactive P (TRP) in the Timoleague catchment flow pathways over three years during the winter period (closed period for slurry spreading). The data-points are summaries of tens of thousands of individual TRP concentration and river discharge measurements.

for top 10% nationally) and 450kg milk solids per cow (428kg milk solids per cow for top 10% nationally).

Advice and data

As Irish dairy farmers adapt to post-quota management, the messages emerging from this study are clear. Declines in the excessive P index 4 soils are achievable with the right motivation, specialist advice and especially through soil testing. In this intensive dairy catchment, the movement towards the agronomic optimum soil P index 3 was achieved without changing the economic performance of the farms and, notwithstanding the vagaries of the Irish weather, there was a decrease in the P lost from the catchment soils in terms of polluting runoff. These findings are possible through targeted monitoring by the ACP, a focus towards high-resolution data gathering across the nutrient cascade and a farmer-advisory-science partnership.

Acknowledgements

This study was conducted by current and past researchers, technologists, technicians and specialist advisers from the ACP. This article includes summaries of data analysis by Paul Murphy (soil P status and use), Per-Erik Mellander (hydrochemistry), Mairead Shore (ecology) and Cathal Buckley (economics). Particular thanks are given to catchment farmers for participation in the ACP. The ACP is funded by the Department of Agriculture, Food and the Marine.

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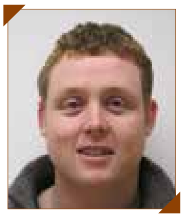
Sub-optimal soil fertility costing dairy farmers dearly

Low levels of soil fertility pose a significant threat to achieving increased productivity and profitability on dairy farms.



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Grass-based dairy systems hold certain advantages over confined and high-concentrate feeding systems in terms of: lower cost structure; increased farmer control over feed supply; the high quality of the milk produced; and increased levels of environmental sustainability. As many Irish dairy farms strive to increase their milk output per ha post milk quota, it is critical that Irish dairy maintains its 'green' image in order to compete in a fiercely competitive world dairy market. Good productive soils are the foundation of any successful farm system and key to growing enough high-quality grass to feed the herd. Post quota, Irish dairy farmers are in a position to maximise the potential milk output from their farms and to achieve this, high grass growth rates are needed over an extended season. This places an increasing demand on soil nutrient supply. The ability of soils to supply nutrients at a time and in appropriate quantities for grass growth is a key determining factor of how productive a field or farm can be. Therefore, the management of soil fertility levels should be a primary objective of every dairy farm.

Nutrient requirements for grass swards

Grass requires a continuous and balanced supply of nutrients from the soil to achieve its production potential. Some well managed and fertile farms are capable of growing in excess of 16t/ha of grass dry matter (DM) annually. This level of grass production requires large quantities of nutrients, such as nitrogen (N), phosphorus (P), potassium (K), and sulphur (S), which are shown in Table 1. However, only a fraction of these nutrients are required as fertilizer inputs due to the continuous recycling that occurs within the soil and nutrients returned by animals during grazing or through slurry. For example, Irish soils are capable of supplying large quantities of N (50kg to >200kg N/ha) in the absence of N fertilizer (McDonald *et al.*, 2014). Annual fertilisation rates are usually calculated based on replacement of nutrients removed in product (i.e., milk or meat) including an efficiency factor, which accounts for soil nutrient lockup and loss. The high rates of nutrient uptake required by high-yielding grass swards indicate the importance of soil fertility.

Table 1. Typical concentrations of N, P, K and S in a tonne of grass DM, and the total uptake of each nutrient required in a full year by swards growing 16t/ha of grass DM.

Nutrient	Typical concentration (kg/t of DM)*	Total uptake required in 16t of grass DM
N	34.9	558
P	4.1	67
K	29.7	475
S	2.9	46

*Source: Kavanagh *et al.*, 2014.

Trends in fertilizer use

There has been a sharp decrease in total fertilizer N, P and K use on farms in recent years (Figure 1) mainly due to the combined effects of increasing fertilizer prices, and the regulation of N and P fertilizer use. This decrease has been most severe on grazed grassland, and in 2009 national P and K fertilizer use was at its lowest level for more than two decades. Regular applications of lime are also required to counteract soil acidification processes, especially in our high-rainfall environment. The average total lime use in Ireland is currently less than half that used annually in the 10-year period 1975-1984 (average annual usage 1,671,000t) (Source: Department of Agriculture, Food and the Marine [DAFM] statistics). In total, Irish farmers currently spend approximately €613 million on fertilizers, and this represents one of the biggest single input costs (15-20% of total variable costs) on dairy farms. When used efficiently, fertilizer inputs help to attain target crop yields and represent good value for money. With fertilizers becoming more expensive, it is vital that each kg of fertilizer is managed as efficiently as possible with maximum return in grass growth and milk production. Two steps are required in order to achieve this:

1. Taking soil samples; and
2. Using the results to plan fertilizer and lime applications.

Both of these steps are equally important.

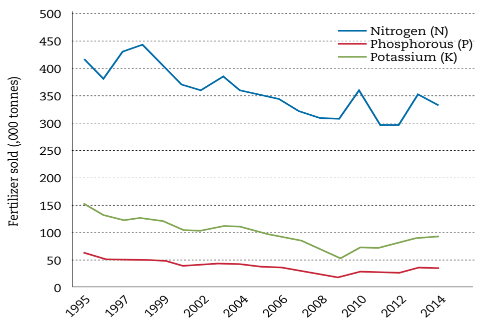

Figure 1. Annual N, P & K fertilizer sales in Ireland between 1995 and 2014 (Source: DAFM).

Soil fertility levels on dairy farms

Soil testing is a critical tool available to farmers for assessing the fertility (soil P, K, Mg, pH and trace elements) status of the soil. It is also a compulsory requirement for our most intensive nitrates derogation farms. However, it is important to remember that the primary function of soil testing should be to inform a farmer of the soil fertility status and to plan fertilizer applications. Soil tests submitted to Teagasc indicate that soil fertility levels have declined dramatically in recent years and, currently, 90% of grassland soils have less than optimum balance of pH, P and K status (Figure 2). In particular, with the low levels of lime being applied, it is no surprise that over 60% of soils sampled on dairy farms have soil pH that is sub-optimal (<6.2; Figure 2). These very low levels of soil fertility pose a significant threat to achieving increased productivity and profitability on dairy farms.

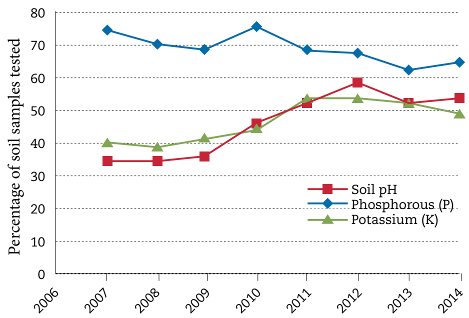

Figure 2. The percentage of soil samples from dairy farms analysed through Teagasc with sub-optimal pH, P and K fertility levels (Source: Teagasc).

Return on investment for increasing soil fertility

Soils low in soil pH, P or K result in grass yield reductions and poor N fertilizer utilisation. Investing in soil fertility will pay dividends in terms of increasing the carrying capacity of the farm through increased grass production and off-setting more expensive imported feedstuffs. At current fertilizer prices, building a soil of low fertility status (i.e., Index 1 for P and K) to target fertility status (Index 3) will cost approximately €100 per year where no slurry or farmyard manure is available to offset fertilizer requirements. This level of additional costs raises the valid question of whether there will be a return on this investment.

Research shows that low soil P levels (Index 1) can cost the farm in excess of 1.5t/ha per year of grass DM production. This is worth a minimum of €300/ha per year and, for a highly stocked 50ha dairy farm, this equates to an increase in annual feed costs of €15,000 assuming that concentrate feed is used to fill the resulting feed gap. However, in reality these costs could be higher as loss in grass production has serious knock-on effects for the whole farm in terms of livestock carrying capacity, provision of winter feed (silage), animal health and, ultimately, profitability.

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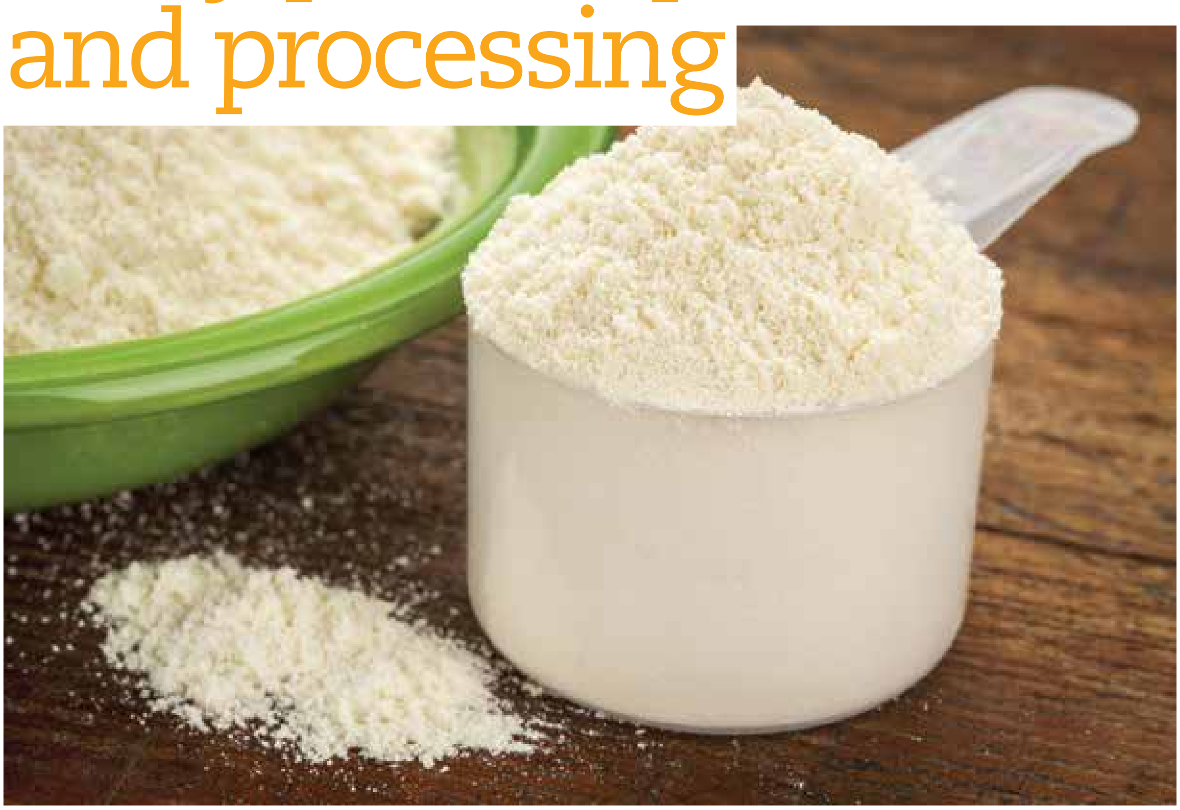
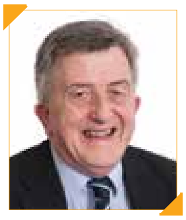
Dairy protein production and processing



The production of high value whey protein concentrates and total milk protein for sports and medical applications relies totally on UF-based processes.



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Researchers are looking at means of aligning Irish dairy protein production and processing with long-term global nutritional needs.

Projected growth in the world's population is raising concerns among international organisations, such as the World Health Organization, which has questions about the adequacy of protein supply to meet future nutritional needs. This is further exacerbated by current consumer demand for the deployment of extra protein ingredients to formulate higher protein variants of familiar consumer dairy products. As milk processors currently develop adequate manufacturing capacity to deal with the increasing volume of milk supply, this overview looks below the surface to reveal the technological innovations of current protein research in Moorepark's Food Chemistry and Technology Department to underpin Ireland's capacity to respond to this market opportunity and challenge. Two examples are used: significant developments in membrane separations for protein ingredient production; and the unintended consequence of higher protein content mozzarella-style cheese, resulting from co-development of reduced fat and salt variants.

New added value products

In less than half a century, membrane separation technologies have gained widespread application with milk processors throughout the dairy industry. Membrane separation technologies provide cost-effective opportunities for the complete deconstruction of milk, and the subsequent recombination of selected milk components, thus creating novel, added-value products to complement existing dairy commodity portfolios.

Crossflow microfiltration

The launch of ceramic-based crossflow microfiltration (MF) in the dairy industry was heralded for its capability to separate microorganisms (about 1.4µm pore size) from skim milk. Further MF applications quickly followed, e.g., defatting (about 0.2µm pore size) of whey and whey retentates as a means of upgrading whey protein concentrates (WPC) to isolates (WPI). Recent developments in spiral-wound, organic MF elements in the size range 0.1-0.5µm are enabling cost-effective and robust separation processes to be developed for the production of new generation ingredients. These include micellar casein isolates and native whey protein isolates for applications in infant, sports and medical nutritional products.

Ultrafiltration

Ultrafiltration (UF) is regarded as the workhorse of dairy industry separations with a global installed membrane separation surface area of 350,000m^2. UF is a low pressure (1-10 bar), molecular sieving system that allows small molecules and water to permeate, while retaining proteins and fat. The production of high-value whey-protein concentrates and total milk-protein for sports and medical applications relies totally on UF-based processes. The fractionation of bioactive peptides from dairy-protein hydrolysates is guided by the selection of membranes according to molecular weight cut-off (MWCO). Novel applications rely on the extent to which the UF membrane performance can be fine-tuned to improve selectivity for particular target molecules.

Reverse osmosis

Reverse osmosis (RO) evolved, as its name implies, as a reversal of the natural osmotic propensity that exists between two liquids separated by a permeable membrane. The reversal of osmosis across membranes with permeability restricted to <100 Dalton is pressure-dependent (about 30 bar). However, there is an economic payback when it comes to RO-based dewatering of relatively dilute dairy streams (including white water recovery from process flushings, evaporator condensate polishing, and salt recovery from brines). In the case of skim milk and whey, preconcentration to approximately 30% dry matter is becoming increasingly attractive economically in an overall process that includes final concentration in a falling-film evaporator. While still in its infancy, the concept of forward osmosis (FO) reverts to the original osmosis idea involving a membrane separating two liquids – this time the liquid on one side is used as a draw solution for the other. The attraction of this approach is that much lower pressures (typically those of UF) are required to make the process work. The final challenge, however, is to achieve effective recovery of the permeated target molecules from the draw solution.

Nanofiltration

When nanofiltration (NF) was first introduced as a 'leaky' version of RO because of the unique features of its novel, thin-film composite membrane, the opportunity was quickly seized for simultaneous accomplishment of dewatering (concentration) and partial demineralisation in whey (up to 40%) and milk permeates. Recent developments in NF membranes extend the MWCO range from 100 to 1,000 Da i.e. converging at the interface with 'fine' UF. Current Moorepark research is addressing the role of new generation NF for enrichment of milk oligosaccharides and further enhancement of its demineralisation capability.

Reduced-fat, reduced-salt cheese

Pizza consumption continues to expand globally, especially in the US where sales value was estimated at US$38 billion in 2014. Nevertheless, pizza at high consumption rates can contribute significantly to dietary fat and sodium, especially among the young. As a result, there is an increasing demand for cheeses with reduced levels of salt and fat. An EU-funded FP7 project 'Novel processing approaches for the development of food products low in fat, salt and sugar reduced' (known as PLEASURE) has recently been completed. This project addressed the twin research objectives of reducing fat and salt simultaneously, from 22% to 11% and from 1.7% to 1.0%, respectively, on the quality of mozzarella-style cheese. An innovative aspect of the investigation included reducing the degree of calcium-mediated cross-linking of para-casein as a means of normalising the characteristics of the reduced-fat, reduced-salt (RFRS) cheese.

Performance during cooking of mozzarella-style cheese is a key attribute when selecting for pizza toppings.

Performance during cooking of mozzarella-style cheese is a key attribute when selecting for pizza toppings. Compared to standard mozzarella, RFRS performed differently under simulated cooking conditions. For example, there was less displacement on heating due to a denser casein matrix and less available free-fat and moisture to lubricate molten cheese flow. Higher levels of protein and moisture, lower contents of moisture-in-non-fat substances, fat-in-dry matter and salt-in-moisture were the dominant compositional differences that distinguished RFRS cheese. These changes coincided with lower water binding capacity, lower proteolysis and increased hardness and chewiness in the unheated RFRS cheese, along with a lower meltability of the heated cheese. Moreover, the heated RFRS mozzarella required a comparatively high degree of work (energy) to stretch. Hence, the overall reduction of fat and salt significantly impaired the quality of mozzarella cheese.

Microstructural attenuation of the casein network in RFRS mozzarella through lowering of the calcium phosphate content significantly enhanced quality by altering the step sequence during pilot-scale cheese manufacture. The unheated, reduced-calcium RFRS cheese had higher water binding capacity, reduced hardness and chewiness, while the heated cheese had higher flowability and required less work to stretch, compared to the RFRS cheese. Further work is needed to improve flavour by modifying the manufacturing process to incorporate tailored enzyme modified cheeses.

Conclusion

Recent infrastructural investments by Irish dairy processors are well positioned to take advantage of future market opportunities for milk-protein based products by competitively producing innovative ingredients and products for export in preserved form. Separation in its various forms is at the core of protein technology research at Moorepark. Traditional curd separation used in cheese making is being adapted to generate protein-enhanced consumer products, while developments in new crossflow membrane filtration systems are opening the way for sustainable processing of novel functional ingredients.

Acknowledgements

FIRM (2011)-funded Dehydration/rehydration dynamics for development of 'SMART' dairy ingredients.

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FIRM (2006)-funded Strategic equipment investment in the Biofunctional Engineering facility at Moorepark.

Ultrasonication in dairy powder hydration

Ultrasonication – a novel technological approach for improved solubilisation and hydration of dairy powders.

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Ultrasonication is a technology that may have innovative applications in dairy and ingredient manufacturing processes. Novel technologies that have less detrimental impact on foods compared to traditional thermal-based processes, are appealing because of the potential to retain nutrients and maintain better sensory properties. Ultrasonication with a frequency range between 20kHz and 100kHz, and 10W/cm^2 and 1,000W/cm^2 of power is generally non-thermal, although it can contribute a temperature rise due to energy-transformation effects.

Principles of operation

Ultrasound refers to sound pitched above human detection (i.e., >16kHz). It is primarily divided into three frequency ranges: power ultrasound (16-100kHz), high frequency ultrasound (100kHz-1MHz) and diagnostic ultrasound (1-10MHz). Ultrasonication of liquids at high intensity causes sound waves to propagate into the liquid media resulting in alternating high-pressure (compression) and low-pressure (rarefaction) cycles, with rates depending on the frequency. During the low-pressure cycle, high-intensity ultrasonic waves create small, vacuum bubbles or voids in the liquid. Compression cycles exert a positive pressure and push the liquid molecules together, while expansion cycles exert a negative pressure and pull molecules apart. When these bubbles attain a volume at which they can no longer absorb energy, they collapse violently during the high-pressure cycle. The collapse of these bubbles leads to a rapid localised rise in temperature (approximately 5,000K) and pressure (101MPa), a process known as cavitation.

Cavitation consists of three recurring steps: formation (nucleation), rapid growth (expansion) to a critical size and collapse. This causes high shear forces and powerful collisions among particles. The turbulence produced by ultrasound can also enhance the physical mass transfer between solid particles and a solvent. Hence, these sonophysical effects can facilitate various mixing and dissolution of powder particles. The particular technical features that make ultrasonication effective relate to factors such as acoustic power density, frequency, sample volume, vessel geometry, viscosity, solids concentration, solution temperature and other experimental conditions. Ultrasound has a wide range of applications in food processing, such as drying, dehydration, thawing, freezing, inactivating pathogens in food products and emulsification.

Dissolution of dried dairy ingredients

Generally, non-agglomerated spray-dried milk powders reconstitute readily with the aid of mechanical stirring. However, new generation dairy ingredients such as milk-protein concentrates (MPCs) with very high-protein concentrations (>80%) are proving to be much more difficult to reconstitute, compared with commodity dairy powders (see panel 'Instant Milk Powders'). Hence, the process of rehydrating MPC powders during formulation is time consuming and also further affected by background-process adaptation such as skim-milk preheat treatment, protein and mineral content and spray-drying temperatures. Furthermore, prolongation of powder-storage time, particularly at elevated temperature post-drying increases rehydration time, particularly in high-protein MPC powders. Detailed studies at Moorepark are providing some insights into the mechanism of MPC rehydration. Initial dissolution of powder particles involves de-agglomeration (initial dissolution) and release of the primary particles into solution. This is followed by sub-component release into the aqueous phase (equilibrium dissolution), leading to an increase in the number of smaller particles and a bimodal size distribution. At a physico-chemical level, it is believed that casein-micelle fusion, due to hydrophobic interactions, also opposes rehydration. Traditionally, increasing mechanical agitation (e.g., by use of high-speed mixers) during powder dissolution, helps to decrease rehydration time by promoting turbulence and facilitating the solubilisation of powder particles in the liquid media.

Recent studies at Moorepark have made considerable strides in the use of ultrasonication to rapidly dissolve commercially-produced MPC powders (McCarthy *et al.*, 2014). At laboratory level, ultrasonication was carried out at an operating frequency of 20kHz and amplitude of 100% (i.e., 266W) for set time periods. Ultrasonication for 1min at <50°C, resulted in a process that significantly improved the dissolution rate of MPC powders, compared to conventional stirring at 50°C for 300min. Hence, high-intensity ultrasound (20kHz) exceeded conventional mixing methods by achieving complete dissolution and solubilisation of MPC powder in a fraction of the time.

On a chemical basis, it was possible to see that, while intermolecular hydrophobic interactions were cleaved, disulphide bond linkages between κ-casein, β-lactoglobulin and α-lactalbumin were not promoted, thereby resulting in the absence of large protein aggregates. While the above studies at laboratory level would appear to simulate batch processing, the ultrasonicator readily lends itself to scale-up as a continuous in-line process (with/without recirculation). Arising from this research, a combination mixing technology concept is currently under development whereby a sono-probe may be integrated into the design of classical high-shear mixers. Such innovation is very timely considering the increasing use of MPC as an ingredient in the formulation of products such as infant milk formula, dairy-based beverages, sports and nutritional foods. In addition, this technology will contribute significantly to the push towards high solids processing in the interests of greater energy efficiency and sustainability.

Conclusions

Dramatic improvements in the rehydration of high protein MPC powders make a compelling case for early adoption of ultrasonication as a supporting technological tool during powder reconstitution and formulation. Already, a considerable momentum is building up in terms of additional fields of application within dairy processes. Research in recent years (Ashokkumar *et al.*, 2010) revealed a range of further possibilities including homogenisation of milk-fat globules, disaggregation of denatured proteins, reducing product viscosity and promotion of whey-protein gelation. Ultrasound may also be employed to reduce fouling of heat transfer surfaces, as well as that of polymeric membranes used during whey ultrafiltration. Spray atomisation by ultrasonication offers the possibility of better and more uniform droplet formation. While it may not be applicable in large-scale, commodity milk spray drying, it does offer potential for the dehydration of more challenging functional ingredient feedstocks. Meanwhile, ongoing research at Moorepark is examining the potential use of ultrasonication to influence the outcomes of enzymatic hydrolysis and other applications.

'Instant' Milk Powders

The classical method of assessing the rehydration and solubility of 'instant' milk powders was based around the concept of 'wettability', dispersibility and sinkability. The instantisation process during spray drying was aimed at mediating the ability of powder particles to:

- absorb water on its surface (wettability);
- penetrate through a surface layer of water (penetrability);
- sink through water, after being moistened (sinkability);
- disperse without formation of agglomerates (dispersibility); and
- dissolve quickly (rate of dissolving).

The analytical method for the determination of the dispersibility and wettability of instant dried milk is enshrined in the international standard ISO/TC 34/SC 5, FIL/IDF 87:1979

Acknowledgements

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Quantifying the carbon footprint of Irish Milk

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The goals of improving economic performance and reducing the carbon footprint of milk are complementary. Grass-based dairy farmers can implement simple 'win-win' strategies to mitigate the carbon footprint of milk and increase profitability.

Anthropogenic greenhouse gas (GHG) emissions are the main driver of climate change, which, as reported by the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC) (2014), rose to their highest level between 2000 and 2010. Without action, GHG emissions from dairy production are unlikely to decrease. In fact, emissions are expected to increase, given that the demand for milk is forecast to grow at a rate of 1.1% per annum until 2050 (Opio *et al*., 2013). Ireland has agreed ambitious binding targets to reduce emissions from the non-emissions trading sector (includes dairy production) by 20% relative to 2005 levels by 2020 (European Council, 2009). Over the same period, national milk output in Ireland is expected to grow by over 50% following the removal of the milk quota system, further exacerbating the GHG situation. Thus, improving GHG emissions per unit of milk, or the carbon footprint of milk has become an important sustainability measure for the dairy sector.

Relating economic performance to carbon footprint

Several strategies are available to mitigate GHG emissions (e.g., improving total genetic merit of livestock (EBI), increasing the grazing season length, increasing the amount of milk produced from grazed grass and increasing soil carbon). Producing milk with a low carbon footprint, however, does not necessarily imply that this is economically viable. Thus, the goal of this research was to develop a footprint methodology that could be deployed within a nationally representative database to quantify the carbon footprint of the Irish national milk pool and to evaluate the relationship between the carbon footprint of milk production and economic performance at an individual farm level.

The Teagasc National Farm Survey (NFS) database (Hennessy *et al*., 2013) was used to assess the economic performance and the carbon footprint of Irish milk. The NFS primarily collects financial data from a nationally representative sample of dairy farms and was used in this study to estimate pre-tax profit margin and labour income on a gross and net basis. To estimate GHG emissions, the NFS was expanded in a number of areas to collect technical farm data (e.g., farm feeding practices). The survey was then carried out on 256 dairy farms in 2012. In total, sufficient data was collected on 221 farms to estimate GHG emissions.

The GHG model of O'Brien *et al.* (2014), which was independently certified to comply with the British standard (BSI, 2011) for life cycle assessment (LCA), was applied to the NFS nationally representative sample. The model calculated annual on-farm and off-farm GHG emissions from imported inputs (e.g., electricity) up to the point that milk was sold from the farm in CO_2-equivalent (CO_2-eq). Annual GHG emissions computed using LCA was allocated to milk based on the economic value of dairy farm products and expressed per kg of fat and protein corrected milk (FPCM).

Higher economic performance is associated with a lower carbon footprint

The results indicate that for 2012, the average carbon footprint of Irish milk was 1.19kg of CO_2-eq/kg of FPCM (95% confidence interval ranging from 0.75-1.63 CO_2-eq/kg of FPCM).

In general, the carbon footprint of milk on Irish dairy farms decreased as economic performance improved. For instance, the carbon footprint of milk for the top one-third of farms, ranked in terms of gross margin/ha, was 7% lower than the mean and 15% lower than the bottom one-third (Figure 1). In addition, there was less variability in the carbon footprint of milk for the top group. For instance, Figure 2 shows that the variability in the carbon footprint of milk as measured using the 90% confidence interval was lowest for the top group (0.84-1.43kg of CO_2-eq/kg of FPCM) followed by the mean (0.84-1.62kg of CO_2-eq/kg of FPCM) and bottom (0.94-1.84kg of CO_2-eq/kg of FPCM) groups.

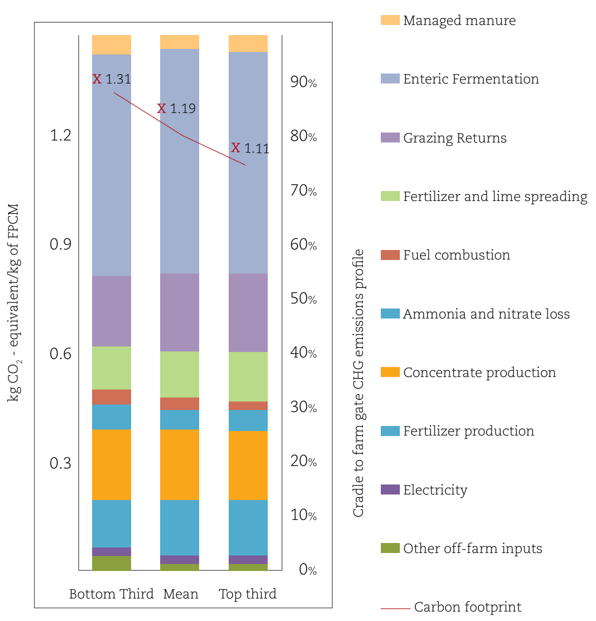

Figure 1. Cradle to farm-gate carbon footprint of Irish milk and greenhouse gas (GHG) emissions profiles for the bottom third, mean and top third of farms ranked in terms of gross margin/ha. FPCM = fat and protein corrected milk.

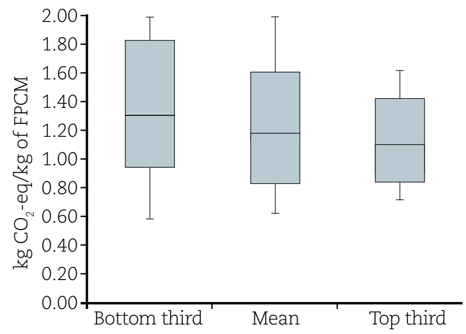

Figure 2 Box plots of the carbon footprint of milk (kg CO_2-equivalent/kg of fat and protein corrected milk (FPCM)) for the bottom third, mean and top third of Irish dairy farms in terms of gross margin/ha. The grey shaded area represents 90% of the distribution of the carbon footprint of milk for each farm group.

The carbon footprint of milk and economic performance were strongly influenced by farm management practices. The main management practices that were associated with improved farm profitability and reduced carbon footprints were extending the length of the grazing season and increasing milk yield/ha. Increasing milk production through greater concentrate feeding, however, had a negative effect on profit and income and tended to increase the carbon footprint of milk. Therefore, this implies that to reduce the carbon footprint of milk and increase economic performance, grass-based dairy farms should aim to increase milk output from grazed grass.

Overall, this study indicates that the goals of improving economic performance and reducing the carbon footprint of milk are complementary and that grass-based dairy farmers can implement simple 'win-win' strategies to mitigate the carbon footprint of milk and increase profitability.

Acknowledgements

This research was conducted with the financial support of the Department of Agriculture, Food and the Marine.

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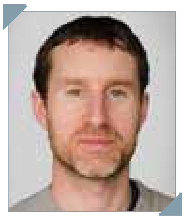
Expanding milk production while achieving water quality targets

Improving nutrient management efficiency is key to sustainable intensification.



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Producing sufficient food for a growing global population while complying with environmental legislation is a significant challenge. Post milk-quota abolition, ambitious growth targets for milk production have been set under Food Harvest 2020. Concurrently, strict environmental targets for water quality must be achieved under Water Framework Directives (WFD) legislation.

Nitrogen (N) is a key input on Irish dairy farms and inefficient use can reduce farm profits and increase the risk to water quality. The EU Nitrates Directive (ND), now under the umbrella of the WFD, was introduced to minimise surplus N applications on farms, with the aim of reducing associated N losses from agriculture to water bodies. Under the ND, the Good Agricultural Practices (GAP) regulations (enacted in 2005/06) are the framework for the agricultural sector to minimise nutrient transfers to watercourses. The Republic of Ireland was one of seven EU member states to receive a derogation from the standard stocking rate cap of 170kg organic N/ha (two cows/ha) to farm more intensively up to a maximum stocking rate of 250kg organic N/ha (2.94 cows/ha). Failure to achieve WFD targets of 'good' status across all surface waters threatens this derogation and, hence, the ability of more intensive dairy farms to reach their production targets. Over 5,500 of our most commercial dairy farms currently avail of this derogation.

This article reports the trends in N use across specialist dairy farms since the introduction of the GAP regulations in 2006 up to 2012, and discusses results in the context of sustainable intensification of milk production post milk-quota abolition.

Study of dairy farms

Two sustainability indicators are developed in this study:

- Farm-gate balance – calculated by subtracting the total quantity of N (kg/ha) exported from that imported.
- Nitrogen use efficiency (NUE) – calculated by dividing total N exported (kg) by total N imported (kg), expressed as a percentage.

Farm-gate balance and NUE have been proposed as methods of assessing nutrient-management efficiency at farm level, while also providing an indicator of environmental pressure on water quality. These accounting systems measure nutrients imported onto a farm (feedstuffs, fertilizers, etc.) and subtract quantities exported from the farm through outputs (e.g., milk, meat, cereals) using relevant coefficients. The underlying assumption is that lower N surpluses and higher NUE will result in a lower burden of environmental risk.

The data used in this analysis was from 150 specialist dairy farms in the Teagasc National Farm Survey (NFS) over seven years (2006-2012). Average population weights for the period were used; consequently the sample is representative of 8,668 Irish dairy farms. The sample profile is outline in Table 1.

Table 1: Sample production profile 2006-2012 (mean values).

Production profile	Mean (standard deviation)	Range
Farm size (ha)	47.7 (25.6)	8 – 161
Total livestock units	87.8 (48.0)	13.2 – 313.8
Dairy cow livestock units	56.2 (29.3)	7.7 – 184.2
Milk (L/ha of land in milk production)	9,814 (3,490)	2,371 – 32,976
Milk (L/cow)	5,026 (1,021)	1,878 – 8,701

Decline of N surpluses

Total N imports declined by 23.7kg N/ha on average between 2006 and 2012. This decline was driven by reduced chemical N fertiliser use, which accounted for over 80% of total N imports over the period (Table 2). The main N export was in the form of milk, which accounted for over 70% of total N exports. Farm gate N surplus declined by 17% from 169.0kg N/ha in 2006 to 144.1kg N/ha in 2012. This decline (24.9kg N/ha) was largely due to reduced N imports driven by less chemical fertilizer use as N exports in milk remained static during these quota years. Average NUE also improved from 21.2% in 2006 to 23.6% in 2012, peaking at 24.3% in 2011.

Table 2: Nitrogen balance and use efficiency results (2006-2012).

	Year						
Imports (kg/ha)	2006	2007	2008	2009	2010	2011	2012
N Fertilizer	177.0	163.0	147.7	159.2	163.7	157.4	153.9
N Concentrates	26.7	23.8	28.7	23.4	25.0	21.7	25.6
N Other imports	6.2	6.1	5.0	6.2	6.3	6.1	6.7
Total N Imports	**209.9**	**192.9**	**181.4**	**188.8**	**195.0**	**185.2**	**186.2**
Exports (kg/ha)							
N Milk	29.9	30.5	29.8	28.6	32.8	33.7	32.6
N Livestock	9.8	9.4	8.7	8.2	8.3	8.2	8.4
N Other exports	1.2	1.2	1.5	0.9	1.1	1.2	1.1
Total N Imports	**40.9**	**41.1**	**40.0**	**37.7**	**42.2**	**43.1**	**42.1**
N Balance (kg/ha)	169.0	151.8	141.4	151.1	152.8	142.1	144.1
N use efficiency (%)	21.2	22.8	23.3	21.3	22.4	24.3	23.6

Nutrient-management efficiency

Results indicate that N surplus declined by 24.9kg/ha and NUE improved by 2.4% across specialist dairy farms over the study period. The reduction in N surpluses was predominantly due to declining chemical N fertilizer use as other N imports and exports remained relatively stable. This decrease is equivalent to 1,188kg less N across the average farm and equates to a cost saving of €1,283 per annum.

While N surpluses across specialist dairy systems declined between 2006-2012, the nitrate concentrations in Irish rivers has also declined over the same period. In 2007, 55% of sites monitored by the Environmental Protection Agency had average nitrate concentrations of less than 10mg/L (i.e., one fifth of the drinking water standard). This figure increased to 71.5% in 2012. The challenge is to maintain this positive trend in improved water quality in the face of increased milk production post milk quota abolition. Increases in cow numbers and greater demand for grazed grass will require additional nutrient inputs. Policy makers have stipulated that the targeted 50% increase in milk output by 2020 (Department of Agriculture, Fisheries and Food, 2010) must be produced in an environmentally sustainable manner. This places further emphasis on nutrient management efficiency. Hence, it's critical that dairy farmers further build on gains already achieved in nutrient management efficiency. Potential strategies to further improve NUE include optimising N fertilizer and organic manure applications (i.e. choice of N fertilizer type, improvements in timing, rate and method of application), incorporation of N fixing forage legumes, such as white clover into grass swards, improved grazing management and grass utilisation, optimal soiled water management and increased genetic merit of the dairy herd. Additionally, critical source areas, where the risk of nutrient transfers from agricultural production to the aquatic environment is greatest, could be identified and management strategies implemented in these areas to minimise losses and associated ecological impacts.

Good status is a requirement under the Water Framework Directive.

Acknowledgements

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Environmental Protection Agency. (2013) 'EPA report under Article 29(1)(b) of the European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2010'. Available online: http://www.environ.ie/en/Publications/Environment/Water/FileDownLoad,35231,en.pdf

Events

JUNE

June 29-30 *RDS, Dublin*

NutraMara Conference and Expo: Harnessing marine bioresources for innovations in the food industry

This major forum will allow the exchange of new ideas and business opportunities from marine bioresources for industry exploitation by the food sector. The main theme of the event is: Harnessing marine bioresources for innovations in the food industry. The conference will focus on science-based innovations and major technological challenges for market up-take. An exhibition will also take place which will showcase innovative technologies and opportunities in marine bioresources for the food industry.

Contact: nutramara@teagasc.ie www.nutramara.ie

JULY

July 1 *Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co Cork*

Sustainable Expansion – Teagasc Dairy Open Day at Moorepark

This national open day will be held at the Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark. It is set against the backdrop of milk quota abolition, volatility in milk price and a positive market outlook for dairy products due to significant growth in world demand. Attending this event is a necessity for all dairy farmers and stakeholders in the Irish dairy industry.

Contact: Margie.Egan@teagasc.ie

http://www.teagasc.ie/events/2015/20150701.asp

July 8 *Castletroy Park Hotel, Co Limerick*

Teagasc Rural Development Conference

The theme for this year is Innovation to Enterprise and will focus on the enterprise supports necessary for rural businesses to develop or expand an enterprise. The conference will draw on the experiences of past participants in the Rural Innovation Awards in addition to insights from successful entrepreneurs.

Contact: Edel.Burke@teagasc.ie

SEPTEMBER

September 7-10 *University of Stuttgart, Hohenheim, Germany*

Perennial Biomass Crops for a Resource Constrained World

Perennial crops offer a sustainable and efficient way of producing biomass. Because of their specific features, such as low nutrient demand and stress tolerance, they can also be grown under marginal site conditions. The GrassMargins project, coordinated by Teagasc, is organising this meeting, which will present advances in the agronomy, physiology, breeding, plant biotechnology, genetic resources, farm scale production, processing and life-cycle analysis, of perennial biomass and fibre crops, mainly with regard to their potential to be grown on marginal lands. Deadline for full papers is September 10, 2015.

Contact: iris.lewandowski@uni-hohenheim.de

September 28-30 *Co Wexford, Ireland*

Catchment Science 2015

An international conference exploring the latest developments in catchment science and its application to the challenges facing farmers, policy makers and regulators. The conference is hosted by the Agricultural Catchments Programme in Wexford with two days of indoor sessions and a choice of field trips on day three.

Contact: CatchmentScience2015@teagasc.ie

OCTOBER

October 13 *Kilbrin, Co Cork*

Research on 1st & 2nd Thinning of Conifers

Teagasc, as part of its forestry research programme, has established a new thinning trial in Kilbrin, Co Cork.

The research is aimed at providing growers information about the effect of thinning on the growth and development of the forest crop and the optimum treatment to produce a commercial crop. It is possible that rotation ages could be significantly lowered on highly productive sites. Financial analysis indicates that a robust first thinning, close to marginal thinning intensity, yields the best return on investment, and if thinning is to be considered stands should be thinned early to offset the risks of windblow.

Contact: john.casey@teagasc.ie http://www.teagasc.ie/forestry/events/

October 20 *Cavan Crystal Hotel*

October 21 *Horse and Jockey Hotel, Thurles*

Pig Farmers' Conference

This conference features a number of presentations covering a broad array of topics relating to nutrition, performance and animal health. It also features a research update on current projects and a poster session by students involved in the research programme at Teagasc, Moorepark. This provides attendees with the opportunity to meet with our researchers and students to find out more about the projects ongoing in the Pig Development Department.

Contact: Ciaran.Carroll@teagasc.ie

October 21-22 *Killeshin Hotel, Portlaoise, Co Laois*

Teagasc Biodiversity Conference

Teagasc is pleased to announce a conference titled 'Farmland Conservation with 2020 vision' and encourages submission of papers on relevant topics. This conference follows on from the successful conference: 'Conserving Farmland Biodiversity' organised by Teagasc in May 2011.

The EU Biodiversity Strategy to 2020 aims to halt the decline of biodiversity and the degradation of ecosystem services by 2020. The Food Harvest 2020 strategy highlights the need to develop effective methods for biodiversity conservation, as part of the development of sustainable production systems. A key aim of this conference is to address how the agriculture sector has responded to these and other policy objectives, and how prepared the sector is for similar policy objectives post 2020.

Contact: Daire.ohuallachain@teagasc.ie www.teagasc.ie/events

NOVEMBER

November 8-15 *Teagasc locations*

Science Week

Teagasc proudly supports this initiative, which is coordinated by Science Foundation Ireland (SFI) Discover, the education outreach programme of SFI, by holding events at its research and education centres.

The aim of Science Week is to promote the relevance of science, technology, engineering and maths (STEM) in our everyday lives and to demonstrate their importance to the future development of Irish society and to the economy.

Contact: Catriona.Boyle@teagasc.ie www.scienceweek.ie

For a list of Teagasc's food industry training schedule (food safety, food law, animal welfare, quality assurance, microbiology, cheese making, calculating meat content, laboratory auditing) please see: http://www.teagasc.ie/food/research/training/schedule.asp
For presentations from previous Teagasc events see: http://www.teagasc.ie/publications/