Animal & Grassland
Research and Innovation
Programme

Moorepark

Irish Dairying

Securing a Sustainable Future

Tuesday 4th July, 2023

Teagasc
Agriculture and Food Development Authority

MOOREPARK '23
IRISH DAIRYING – SECURING A SUSTAINABLE FUTURE

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Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

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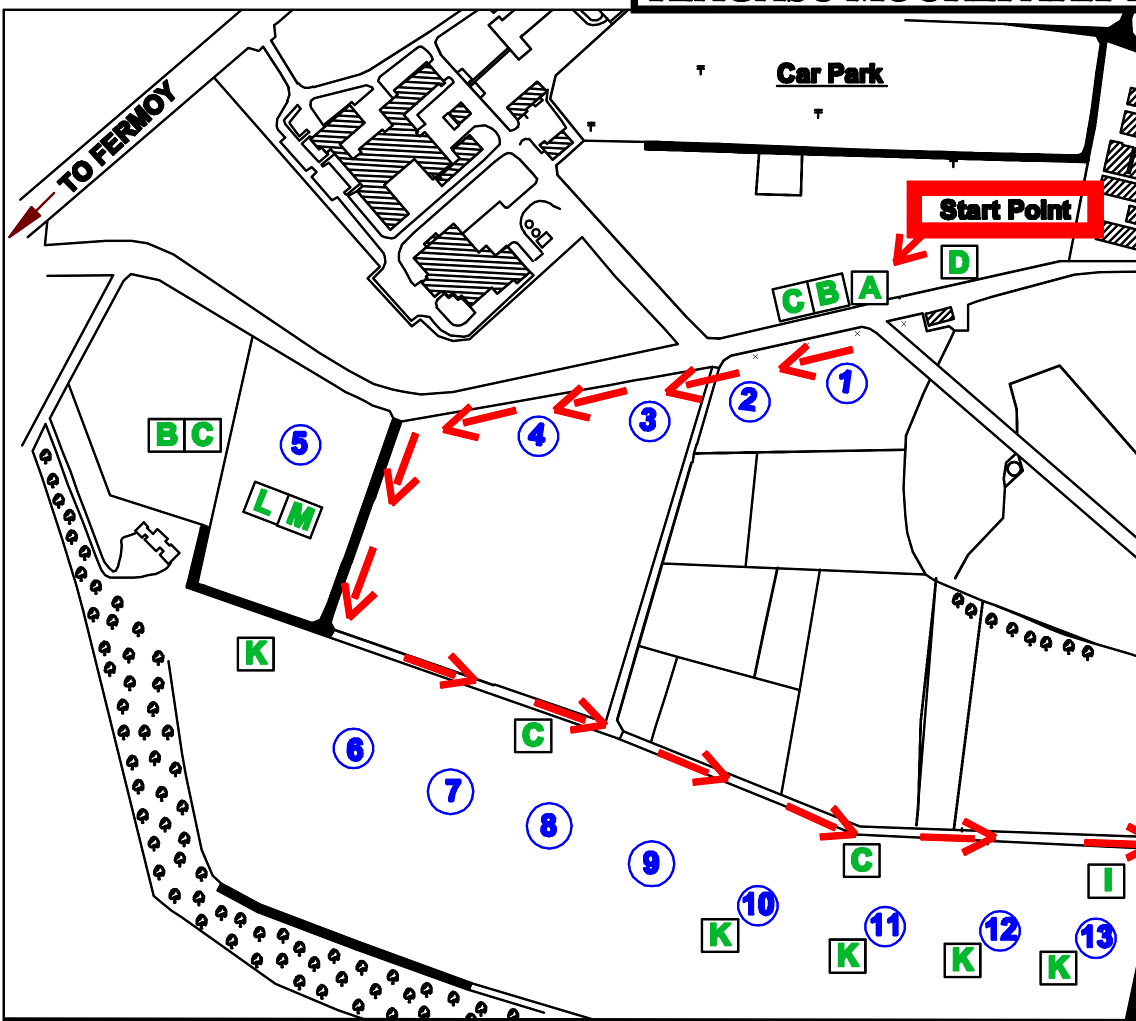


Stands

1 Sustainability Challenges

2 Profitable Systems

3 Breeding and Reproduction

4 Sustainable Grassland

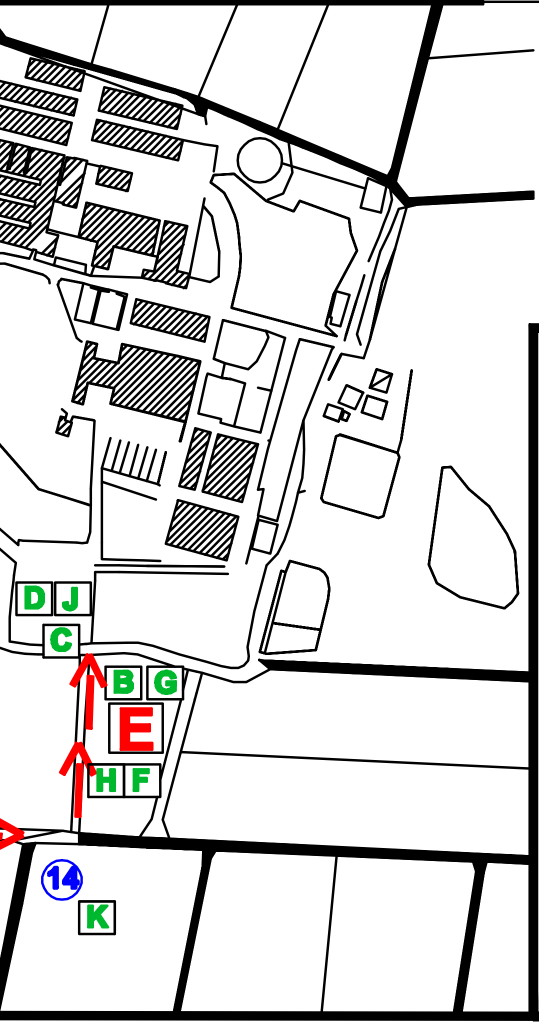
5 Grass10 - Grazing Demo

6 Grassland Village

7 Signpost Village

8 Breeding and Reproduction Villa

...23 OPEN DAY SITE MAP



ROUTE

MOOREPARK '23
IRISH DAIRYING – SECURING A SUSTAINABLE FUTURE

Services

- A INFORMATION
- B REFRESHMENTS
- C TOILETS
- D FIRST AID
- E ORNUA FORUM TENT
- F VISTAMILK
- G FOOD SCIENCE
- H FBD
- I AIB
- J EVENT CONTROL CENTRE
- K HEALTH & SAFETY
- L ARENA
- M INTERNATIONAL VILLAGE

Villages

...age

- 9 One Health, One Welfare Village
- 10 Working Effectively Village
- 11 Skills Village
- 12 Infrastructure Village
- 13 Industry Representatives
- 14 Agtech Ireland

MOOREPARK '23

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Teagasc,
Animal & Grassland Research and Innovation Centre,
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Introduction

Securing a Sustainable Future

Grassland Village

Signpost Village

Breeding and Reproduction Village

One Health, One Welfare Village

Working Effectively Village

Infrastructure Village

Introduction

Irish Dairying – securing a sustainable future

Laurence Shalloo

Head of Animal & Grassland Research and Innovation Programme, Teagasc, Moorepark, Fermoy, Co. Cork

The Irish dairy industry has undergone a transformational change since the removal of the EU milk quota in 2015. Since the Irish dairy industry began to prepare for EU milk quota removal in 2007-2009, milk solids output has increased by over 96%. This increased output has been achieved through increased cow numbers, increased milk yield per cow, increased fat and protein percentages, increased grass growth, increased stocking rate and additional land entering the dairy industry. Looking ahead, it is clear that the phase of rapid expansion that occurred after 31 years of milk quotas has now passed, and the industry is in a different phase of development. When the removal of milk quotas was first signalled, there were many questions and challenges facing the dairy industry including the level of expansion expected, the most appropriate milk production systems, developing and funding processing capacity, and identifying and securing markets for increased milk production. These challenges were addressed by farmers, industry and stakeholders working together. The collective investments made at farm and processor levels have transformed the dairy industry, and were achieved with little increase in overall debt levels across the industry, even though the industry has doubled in size. As we look forward, there are immediate and future challenges to be addressed. A similar positive attitude towards these new challenges is now required to allow the dairy sector move forward in a sustainable manner. These challenges include competitiveness, greenhouse gas emissions, water quality, biodiversity, people, food security and dairy-beef.

Competiveness

Although there has been significant investment at both farm and industry levels, overall debt levels have remained relatively static at farm level, while debt levels per kg of milk solids produced have reduced significantly. The largely grass-based systems of milk production have resulted in a low cost production system that has provided a comparative advantage for the Irish dairy industry within a seasonal profile of milk deliveries. Recently, published research studies indicate that Ireland's competitive advantage has increased since milk quotas were removed. This was achieved through a constant focus on grazed grass in the diet, which will continue to be the key factor driving the competitiveness of milk production system, especially in the face of severe input price inflation as seen in 2022. The benefits of the system have been further enhanced through the developments within the Economic Breeding Index, which have focussed on selecting a dairy cow with suitable attributes for the system (robust, high levels of fertility and survivability, ability to convert forage to milk, ability to withstand changes in feed supply). The changes in the cost base observed at farm level in 2022 need an urgent focus at both farm and industry levels to ensure the cost increases can be reversed. Recent geo-political events have exposed the need for increased feed, fertiliser and energy security. Systems of milk production that rely less on purchased feed, fertiliser and energy are more resilient in these challenging times. The industry must refocus, optimise pasture inclusion in the dairy cows' diet and closely control costs at farm level. At industry level, efficiencies that facilitate cost control must be reviewed, and the additional processing capacity in the industry used to maximise industry returns and milk price. It may be time to review the A+B-C calculations (the C portion in particular) and evaluate whether the volume related processing costs should be increased to reflect increases in energy and other costs.

Greenhouse gases

The biggest and most serious challenge of our time is Climate Change. The Irish government declared a climate and biodiversity emergency in June 2019. Since then policy initiatives regarding climate have been developed, culminating in the Climate and Low Carbon Bill. In July 2021, the Climate Action and Low Carbon Development (Amendment) Act 2021 was signed into law. The Act commits the Government to moving to a climate-resilient and climate-neutral economy by 2050. The required reduction in emissions from Ireland is 51% by 2030 relative to 2018 across society, with an emissions reduction target for agriculture of 25%. These requirements are onerous, and only time will tell if they can be achieved and the implications that will arise if they cannot be achieved. Clearly, the industry must now focus on the technologies that are currently available for implementation to reduce emissions. These include using EBI, reducing chemical nitrogen fertiliser use through the adoption of clover and better soil fertility, movement away from CAN based fertilisers to protected urea, drainage of mineral soils, etc. These technologies will be published in a new Marginal Abatement Cost Curve (MACC) for agriculture in the second half of 2023. These currently available technologies can bring the industry on a significant part of the journey to achieve the sectoral targets, but there is also a requirement to develop new farm level technologies, which is a significant focus of current research investment. Investment in research to develop country specific emission factors will ensure that the national inventory emission factors are accurate and robust. These include agriculture-based emissions (such as enteric methane across livestock classes) as well as land use and land use change based emissions. Designing policy where these emissions and emission factors are not robust could result in that policy becoming outdated very quickly. After 2030, when we move to a climate/temperature neutrality goal, there will be a different set of metrics required that reflect the additional warming impacts of the various gases. This will be particularly important when it comes to short-lived gases like biogenic methane, where current metrics do not appropriately reflect the additional warming impact.

Water quality

The competitive advantage of pasture-based systems are based on maximising grass utilisation. Where stocking rate is not high enough to utilize the pasture grown on a farm, pasture utilisation and quality will be reduced, resulting in reduced animal performance. Reducing the maximum stocking rate from 250 kg organic nitrogen per ha to 220 kg organic nitrogen per ha may tempt some farmers to move away from a pasture-based system in Ireland towards a European model of forage maize/high concentrate feeding system to increase output per cow when stocking rate is restricted. International evidence indicates that these high input systems are more detrimental to the environment than pasture-based systems. It is anticipated that nitrogen losses from Irish grassland farmers will reduce significantly over the coming years. This will be achieved through significant reductions in chemical nitrogen fertiliser application (the Food Vision Dairy Group target to reduce chemical N by 27-30% by 2030), precision nitrogen fertiliser application, changes to slurry management and soiled water storage, higher livestock nitrogen excretion rates plus banding, and the extended closed period for chemical nitrogen fertiliser, as outlined in the 5th Nitrate Action Programme. Better soil fertility, increased use of white clover, better grassland management practises and improved nitrogen management will minimise the impact of reduced nitrogen fertiliser application. It is estimated that these new regulations will result in a reduction of between 5.9 and 9.0 kg/ha of nitrate-N leached to one metre level on a grass-only based system. While this reduced loss at one metre level is not the same as reduced loss to rivers (the lag time can be from months to decades), it can be anticipated that the reduced loss will have a significant impact and will contribute to reduced N loads at the catchment levels over time.

Biodiversity

The Nature Restoration Law aims to restore ecosystems, habitats and species across the EU's land and sea areas. The Law will enable long-term and sustained recovery of biodiversity and promote resilient nature. It will also contribute to climate mitigation and climate adaptation, as well as helping Ireland and the EU to meet international commitments. Restoring the agricultural ecosystems will include positively managing existing farm habitats and landscape features such as buffer strips, hedgerows, stone walls, field margins, woodland, trees, archaeological features, drains/ditches and ponds. Existing schemes such as ACRES and EIP can help to contribute to restoring ecosystems. A large amount of research is required to identify the most appropriate solutions and their implementation on farms to enhance the quantity and quality of biodiversity.

People

The availability of people to work in the dairy industry is probably the biggest challenge on dairy farms today. Greater efforts are required to demonstrate the types and opportunities of jobs/careers that are available on dairy farms. This is particularly important given the current scenario where there is full employment within a buoyant economy. The People in Dairy Initiative was launched in 2017 and identified a number of key focus areas that are still relevant today. It is necessary to develop long-term strategies around training, creating career pathways at all levels, providing appropriate farm facilities for staff, investing in farmer HR skills and implementing appropriate practices at farm level. Developing seasonal business models that allow people to move between industries and creating a culture of awareness that dairy farms are rewarding and positive work places is required. Investing in technologies and practices that reduce the demand for labour will help address the supply/demand balance from both sides.

Food Security

When milk quotas were introduced in the EU in 1984, the global population was 4.8 billion; in November 2022, the global population exceeded eight billion for the first time. As the global population grows, there is a corresponding requirement for more food. As population wealth increases, there has generally been a historic trend for increased demand for animal sourced proteins. In recent years, there has been a significant scientific debate regarding the benefits of animal-based proteins in the human diet. A recent report by the FAO identifies the important contribution of animal source food (milk, meat, eggs) to healthy diets for improved nutrition and health outcomes. How that animal sourced protein is produced, and in particular, the overall impact on net human edible protein production, is an important consideration. Several metrics have been developed to measure the net contribution of livestock to the supply of human digestible protein (HDP). The edible protein conversion ratio compares the amount of HDP in animal feed with the amount of HDP in the animal product. The land-use ratio (LUR) compares the potential HDP from a crop grown on the land used to produce the livestock feed versus the quantity of HDP that livestock produce. For both metrics, Irish dairy performs well. Irish dairy is providing a positive contribution to global HDP production, even where the opportunity costs of the land used for dairy are taken into account (LUR). In the context of global food production, two key questions arise: (1) does it make sense to feed animals food that humans could eat? (2) should land be used to grow crops to provide food for humans rather than animals? There is also a related question as to whether or not more of the ruminant products consumed globally should originate from regions and countries where ruminants do not compete for land use (land not suitable for growing crops, climate that better supports grass growth) for human edible crop production, such as in Ireland.

Dairy-beef

There is a significant opportunity associated with dairy-beef in Ireland. There has been substantial growth in dairy calf-to-beef production since milk quotas were removed. Financial returns from the DairyBeef500 programme suggest that there is potential to generate a net profit of greater than €1,000 per hectare (excluding a land and labour charge). In this context, the dairy industry must embrace technologies like sexed semen and the Dairy Beef Index to deliver profitable genetics for both the dairy and beef farmer. There is an urgent need for joined-up strategies between the beef and dairy industries to develop profitable beef systems based on early maturing animals (lower emissions) and can provide a reward to both the dairy and beef farmers, while helping to decarbonise agriculture. The live export of calves is extremely important to satisfy a market demand, as well as alleviating a supply/demand imbalance within the Irish calf market associated with the seasonal nature of the dairy industry. A key component of calf transport centres on achieving satisfactory animal welfare, which must be underpinned by scientifically proven strategies that minimise animal discomfort and stress. Policies introduced at a national and EU level must be underpinned by science.

Finally, after three very challenging years associated with Covid19, it is our pleasure to welcome you here today to see the research being conducted in Moorepark and to meet the Teagasc teams and industry stakeholders present. It is important to stop and take a step back and recognise the achievements that you have made on your farm. The industry has many current and future challenges, but farmers who are informed and embrace new technologies will be in a better position to deal with those challenges as they arise.

Securing a sustainable future – sustainability challenges

Dairy systems – farming today with tomorrow in mind

Sustainable and responsible breeding and reproductive programs

Grassland - the source of a sustainable future

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Securing a Sustainable Future

Securing a sustainable future – sustainability challenges

Laurence Shalloo[1], Siobhan Kavanagh[2] and Deirdre Hennessy[3]

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Summary

- Policy changes at both national and EU levels will require greater focus on a wide range of sustainability metrics at farm level.
- Irish pasture-based systems perform at a high standard across a whole range of impact categories and metrics.
- There are many currently available technologies that can be immediately implemented by farmers today with favourable impacts on sustainability.
- Future technologies currently being developed/researched will further increase the sustainability of the dairy industry once proved and deployed.

Introduction

The Irish dairy industry has undergone a transformational change since the removal of the EU milk quota in 2015. Since the Irish dairy industry began to prepare for EU milk quota removal in the 2007-2009 period, milk solids output has increased by over 96%. This increased output has been achieved through increased cow numbers, increased milk yield per cow, increased fat and protein percentages, increased grass growth, increased stocking rate, and additional land entering the dairy industry. The largely grass-based systems of milk production have resulted in a low-cost production system that has provided a comparative advantage for the Irish dairy industry within a seasonal profile of milk deliveries. The benefits of the system have been further enhanced through the development of the Economic Breeding Index, which has focussed on selecting a dairy cow with suitable attributes for the system (robust, excellent fertility and survivability, efficient conversion of (mostly grazed) forage to milk, and ability to withstand changes in feed supply).

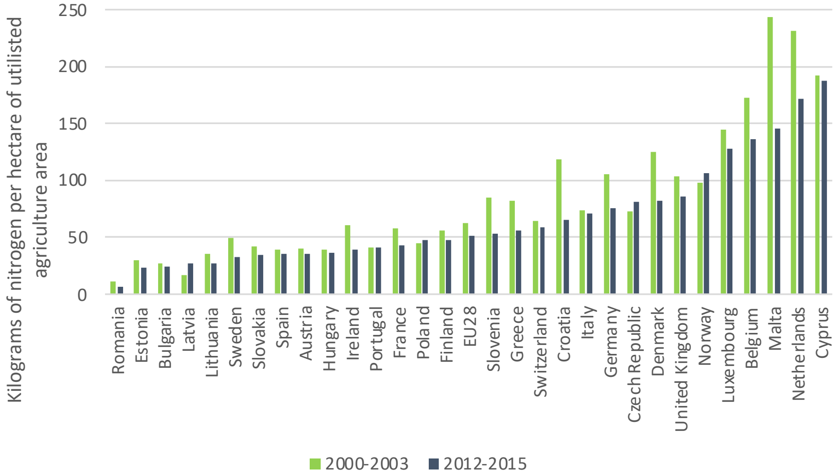
Looking ahead, there are new challenges that the dairy industry has to address as it matures in the current, and indeed future, economic and policy environments. Recent geo-political events have exposed the need for increased feed, fertiliser and energy security. Systems of milk production that rely less on purchased feed, fertiliser and energy are more resilient. Additionally, environmental pressures (greenhouse gas emissions, water quality and biodiversity) require the industry to have a cohesive plan to maintain profitability while addressing these challenges. Widespread and immediate deployment of the currently available solutions at farm level is necessary, coupled with further investment in research to develop new solutions in the medium to long-term, providing options for the industry to meet its overall commitments. The availability of skilled and motivated people to work and lead within the industry is, and will continue to be, a central challenge. Therefore, there is a requirement to ensure that education and training are delivered based on industry requirements and across different career roles, and this will be central to delivering a more vibrant industry in the future. In addition, greater integration between the beef and dairy industries will benefit both sectors. The generation of healthier dairy-beef progeny with better genetic merit for beef traits and reduced age at slaughter will be an essential requirement to develop profitable, simple and sustainable grass based dairy-beef systems.

In order to evaluate the overall performance of the dairy industry, it is important to look at its overall sustainability. There are three sustainability pillars that must be included in any system evaluation: economic, social and environmental. Economic sustainability deals with the financial performance of the business including debt levels, profitability, cost of production, etc. The social element deals with both animal and people related topics. For example, does the farm have good welfare outcomes and standards for the farmer themselves, their employees and their animals? Finally, and equally as important, the environmental impact and use of resources must be considered for the farm (e.g. GHG emissions, nutrient use efficiency, biodiversity etc.). For this paper, key aspects related to social and environmental sustainability will be discussed. Economic sustainability is discussed in the first paper in this Open Day proceedings.

What are the main policy challenges?

Nitrates Directive

Ireland is one year into the 5th Nitrates Derogation. The Nitrates Derogation is the means by which some Irish farmers can surpass a 170 kg per ha limit of organic nitrogen on their grassland area, as set out in the Nitrates Directive. The Nitrates Action Plan outlines the specific measures to protect surface and ground waters from nitrates loss. The current Nitrates Action Plan will be reviewed in 2023. It is extremely important to note that Ireland, relative to the rest of the EU, operates a low surplus nitrogen (Figure 1). The derogation is an important tool for some farmers to farm to their pasture production potential. In non-pasture based systems, as operated in many parts of Europe, slurry exports are used as a tool to manage stocking rates. This is less possible in pasture-based systems, where most of the animal manure is deposited on the pasture by the grazing animal.



Data source: *Eurostate Gross Nutrient Balance, b. EEA_Indicator SEB1019*

Figure 1. *Gross nitrogen balance by country*

The Department of Agriculture, Food and the Marine introduced three new livestock excretion banding rates related to milk yield per cow for dairy cows from 1st January 2023 as part of the Nitrates Action Programme. These are 80 kg nitrogen per cow for cows producing less than 4,500 kg milk per cow per year (Band 1); 92 kg nitrogen per cow for cows producing between 4,501 to 6,500 kg milk per cow per year (Band 2); and 106 kg nitrogen per cow for cows producing more than 6,501 kg milk per cow per year (Band 3). For farms that are above the maximum 250 kg organic nitrogen per ha as a consequence of the introduction of banding, the least negative financial options at farm level to reduce organic nitrogen would be to contract rear all replacement heifers, rear fewer replacement heifers or rent additional land. Exporting slurry is not practical given the quantities to be exported, and also the subsequent negative impact on the soil fertility of the exporting farm as most grassland farms are close to farm phosphorous balance and exporting will create a phosphorous deficit across the whole farm. Reducing cow numbers from optimal will have a significant negative impact on farm profitability. It is therefore likely that farmers will attempt to exhaust other available options before a reduction in herd size is considered.

While some dairy farms will find it very difficult to adjust their farming system to the new organic nitrogen excretion banding at a maximum 250 kg organic nitrogen per ha, reducing the maximum organic nitrogen per ha to 220 kg would cause significantly greater difficulties for these farms. Teagasc research has reported that the combined effect of banding and reducing the maximum organic nitrogen stocking rate from 250-220 kg organic nitrogen per ha could reduce profitability by 29% in the most extreme scenarios.

Biodiversity

There has been a significant decline in biodiversity and ecosystem services during recent decades. Historic Strategies and Directives have failed to halt this decline. More recently, a Nature Restoration Law has been proposed, which aims to restore ecosystems, habitats and species across the EU's land and sea areas. If ratified, the Law will enable long-term and sustained recovery of biodiversity and promote resilient ecosystems. It will also contribute to climate mitigation and climate adaptation, as well as helping Ireland and the EU meet international commitments.

The Nature Restoration Law sets legally (and consequently enforceable) binding targets for the EU and its Member States, with the intention that it will be transposed into law by late 2023/early 2024.

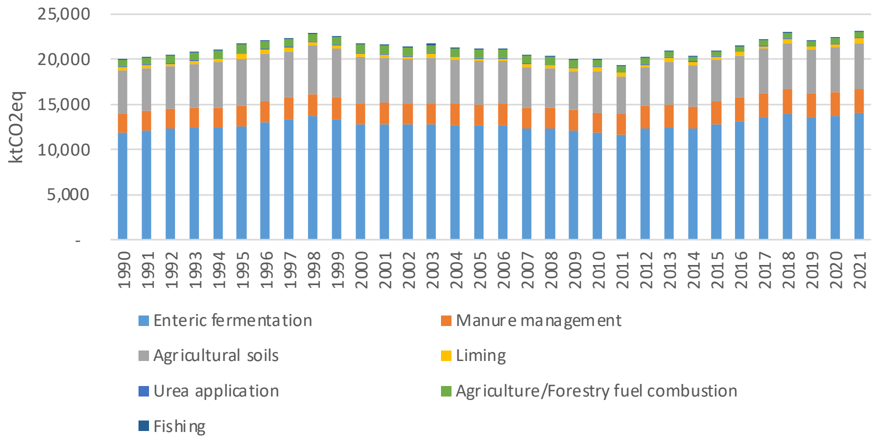
Agriculture must demonstrate improving trends across many metrics including, but not limited to, high diversity landscapes, pollinator index, butterfly index, farmland birds and soil organic carbon from the date of Regulation introduction to December 2030, and continuing thereafter until satisfactory metrics have been achieved. The percentage of agricultural land area required to achieve satisfactory scores has not been defined, but is likely (based on recommendations within the EU Biodiversity Strategy for 2030) to be in the region of 10%.

Restoring agricultural ecosystems (and the services that they deliver) will include retaining and managing landscape features such as buffer strips, hedgerows, stonewalls, field margins, woodland, trees, archaeological features, drains/ditches and ponds. Existing schemes such as ACRES and EIPs can contribute to restoring ecosystems.

Restoring and rewetting drained organic peatlands will also contribute to restoring agricultural ecosystems. In Ireland, however, there is considerable research needed to accurately determine the area of drained peats currently in existence before rewetting plans can be put in place. Further research is required to reverse the decline in biodiversity loss across all land types, and to determine the most appropriate solutions that can be incorporated into the farming systems to enhance the quantity and quality of biodiversity (and associated ecosystems services) on farms.

Greenhouse gas emissions

The Climate Action and Low Carbon Development (Amendment) Bill 2021 set a 'national climate objective' to achieve a climate neutral economy no later than 2050 and a total reduction in GHG emissions of 51% over the period to 2030, with the agricultural sectors target to reduce emissions by 25% by 2030. This poses a significant challenge for Irish agriculture, as methane is the single greatest GHG emitted from livestock production systems and is difficult to reduce. Ireland's GHG emissions from agriculture in 2021 was similar to 1998 (Figure 2). Agricultural emissions declined between 1998 and 2011, followed by an increase as dairy cow numbers increased following EU milk quota removal. It is important to note that current policy reduction targets are more difficult due to the timing of milk quota removal relative to the target reduction baseline of 2018.



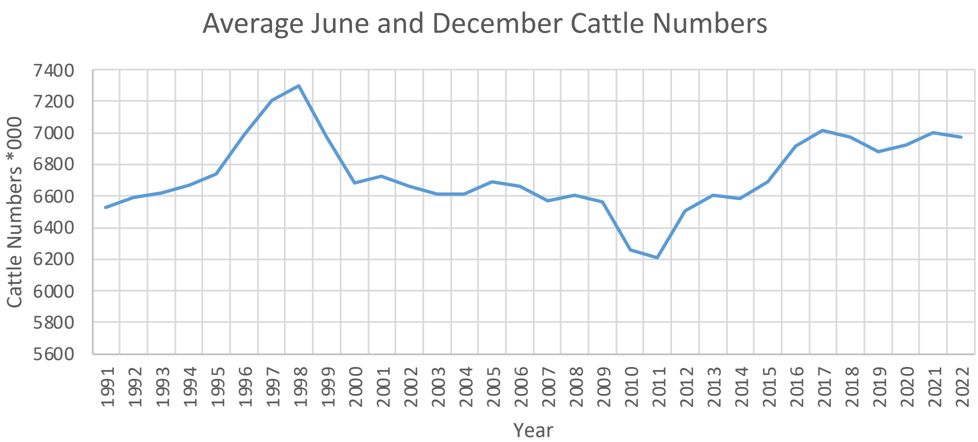
Source: *EPA (2023)*

Figure 2. *Agricultural GHG emissions between 1990 and 2021 using GWP100*

Current situation

Livestock numbers

The total number of cattle in Ireland peaked in 1998 at 7.3 million (Figure 3). Between 1998 and 2011, the total number of cattle was reduced to 6.2 million as the number of dairy cows declined. Between 2011 and 2022, the total number of cattle increased from 6.2 million to 7.0 million. The current total number of cattle is well below (circa 5%) the national peak recorded in 1998.



Source: *CSO (2023)*

Figure 3. *The average number of cattle between June and December over the period 1991-2022*

Cow welfare

Dairy cows in Ireland have access to grazed grass, on average, for 71% of the year and are free to roam within an assigned paddock. Irish pasture-based systems, with average milk yields of just over 450 kg milk solids (MS) per cow, have one of the lowest milk yields per cow in the EU. In general, profitability in Ireland is maximised when grass utilisation per hectare is maximised but not when milk yield per cow is maximised (Hanrahan *et al.*, 2018). In Ireland, the key animal welfare indicators are lameness and somatic cell count (SCC). Somatic cell count is a good indicator of mastitis. Data from the Animal Health Ireland (AHI) *CellCheck* program highlighted that average SCC levels in dairy herds has declined during the last decade, and the average SCC is now close to 180,000 cells per ml (AHI, 2023). In terms of lameness, a recent analysis reported that 6% of cows on a sample of commercial farms had moderate suboptimal mobility, and less than 1% of cows had severe suboptimal mobility. Finally, in relation to dairy cow welfare, herd age profile continues to increase, with the average number of calvings per cow increasing from 3.3 in 2014 to 3.6 in 2022 (ICBF, 2023). The target is for the average parity within the herd to increase to 4.5.

Calf welfare

There are approximately 48% more dairy cows in Ireland now compared with the period from 2007-2009. Incidentally, dairy cow numbers are approximately the same now as they were in 1984 when EU milk quotas were first introduced. These additional cows are resulting in increased numbers of dairy origin calves entering the beef industry.

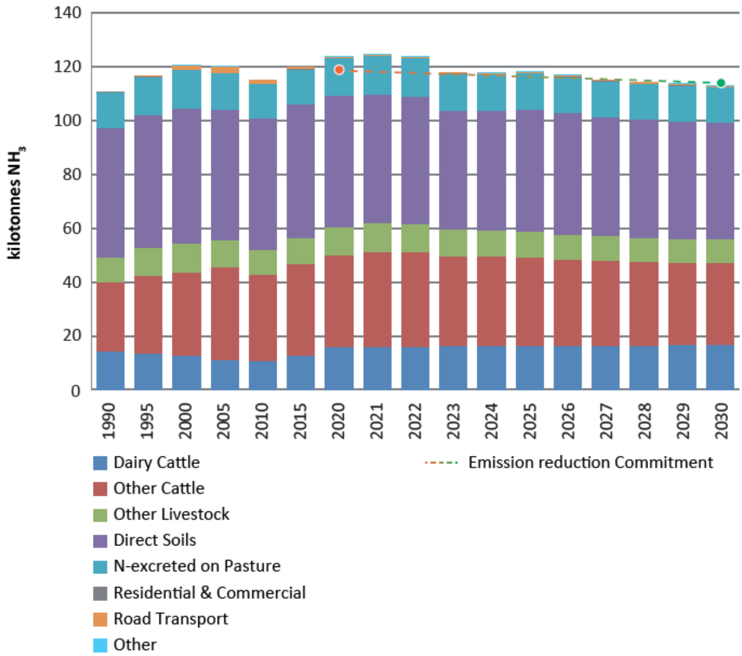
In Ireland, the additional calves provide a significant opportunity for the beef industry to reduce GHG emissions per unit of product and production costs associated with beef production. The dairy industry is now embracing the use of sexed semen to generate replacement heifers and selecting bulls from the Dairy Beef Index (DBI) to generate non-replacement calves. The number of sexed semen straws available in 2023 (driven by demand) was approximately 300,000, which will result in over 100,000 less male dairy calves and provides a significant opportunity to increase the use of high DBI beef straws. Recent research from Teagasc Grange and from the DairyBeef500 programme reported that there is potential to achieve significant profits in dairy calf-to-beef systems. The continuation of the live export of calves is extremely important to satisfy a market demand while helping Ireland meet its policy targets. Maintaining calf welfare during transport is crucial to the integrity of the calf transport process and requires robust monitoring as well as the development of solutions to increase welfare during transport.

Carbon footprint

The carbon footprint of Irish milk is one of the lowest in the world. Based on national activity data from 2017-2019, the average dairy carbon footprint was 0.97 kg CO_2e per kg fat and protein corrected milk yield (FPCM), and when the carbon (C) sequestration is included in the calculation this figure is closer to 0.86 kg CO_2e per kg FPCM (Herron *et al.*, 2022). Analysis based on 2022 data, suggests the footprint has reduced to 0.93kg CO_2 per kg FPCM and with more representative Irish emission factors is 0.86 kg CO_2 e per kg FPCM. While all published studies use different approaches, and some are more robust than others, there are very few comprehensive studies that show a footprint as low as these figures. The New Zealand C footprint, using a similar approach to Ireland, is 0.88 kg CO_2e per kg FPCM, while similar approaches in the US generate C footprints of just over 1.01 kg CO_2e per kg FPCM. While Ireland's C footprint for milk is in a strong position at present, the published strategy for the dairy industry will bring that footprint from 0.97 kg CO_2e per kg FPCM today to 0.73 kg CO_2e per kg FPCM under the future systems identified in the Teagasc Dairy Roadmap. When sequestration is included, this figure will be closer to 0.61 kg CO_2e per kg FPCM. The global average C footprint before 2010 was 2.4 kg CO_2e per kg FPCM (FAO, 2010) with no newer data available. Displacing milk production with an average C footprint (2.4 kg CO_2e per kg FPCM) through expansion of dairy production in Ireland (0.97 kg CO_2e per kg FPCM) can have a substantial effect on reducing global emissions, assuming that the global demand for dairy continues to increase. This analysis does not include the fact that biogenic methane is described as a flow gas, whereas GHG emissions like nitrous oxide (N_2O) and carbon dioxide (CO_2) are known as stock gases. The difference relates to the permanence in the atmosphere. When biogenic methane is stabilised and reduced, the effect on atmospheric concentrations is almost immediate. There is a general scientific agreement that relatively small reductions in biogenic methane across a prolonged period of time will prevent any additional warming from methane and further reductions in methane will result in a reduced warming effect.

Ammonia emissions

Ammonia (NH_3) emissions are associated with the acidic deposition onto ecosystems and the formation of secondary particulate matter. Agriculture accounts for 99.4% of the NH_3 emissions in Ireland. Total NH_3 emissions are above the national ceiling target since 2016, with a substantial increase in NH_3 emissions in 2018 to 135,200 tonnes. Ireland's national NH_3 emissions ceiling is 116,000 tonnes, set as part of the NEC (National Emissions Reduction Directive). Emissions in 2019 declined by 9,800 tonnes relative to 2018, driven by decreases in livestock numbers, reductions in fertiliser N use, as well as increased use of low emissions slurry spreading technologies (Figure 4). This was followed by another decline in emissions in 2020, and subsequently a slight increase in 2021.

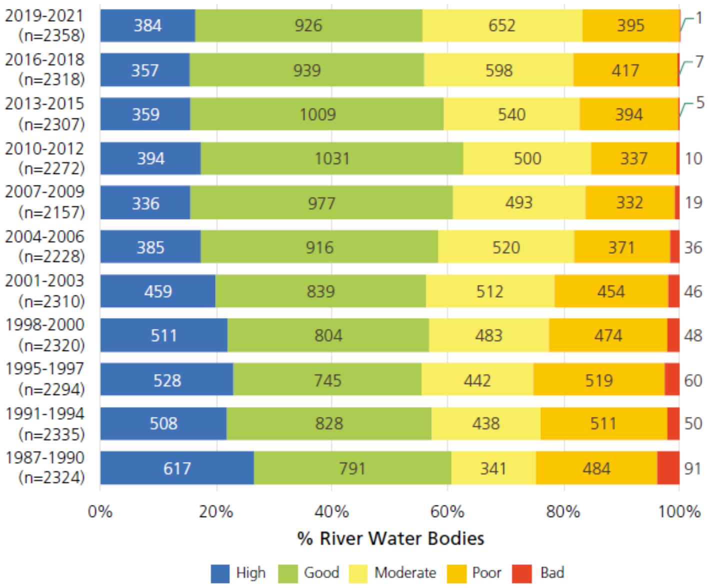


Source: *EPA (2023)*

Figure 4. *Trends in ammonia emissions between 1990 and 2021 with projections to 2030*

Water quality

The EPA publish detailed reports describing the changes in biological quality and nutrient concentrations in water on an ongoing basis. The most recent report on water quality was published in 2022. This report, entitled 'Water quality in Ireland 2016-2021', covers the periods from 1987-1990 through to 2018-2021. The report indicated a consistent and steady reduction in river water bodies described as 'bad' (3.92% in 1987-1990 period and 0.04% in the 2019-2021 period). Just over 60% of rivers were described as having high or good biological status in the 1987-1990 period with the corresponding figures for the 2019-2021 period being 56% (the same as the period 2016-2018). Over the period 2019-2021, the number of rivers classified as moderate increased from 26% to 28% while at the same time the number of rivers classified as poor declined from 18%-17% (Figure 5).



Source: *EPA (2022)*

Figure 5. *Biological river water quality in Ireland over the period 1987-1990 to 2019-2021*

In the same report, when the periods 2013-2018 and 2016-2021 were compared, the number of high and good status rivers declined by 1%, while more rivers increased in quality than declined in quality over the same periods. It must be noted, however, that 2018 has been identified as a very problematic year in the context of nitrate loss, primarily due to drought conditions across the summer period and a slow growth period in the spring. This was compounded by increased use of chemical nitrogen fertiliser at farm level coupled with lengthening of the period when fertiliser could be spread, as well as greater purchased feed use.

The Agricultural Catchments Programme (ACP) has carried out extensive research in six river catchments ranging in size from 4-30 km^2. The catchments have been continuously monitored for a range of biophysical parameters since 2010. The catchments were selected to represent intensively managed agricultural land on different physical settings, and therefore, represent a range of differents types of riskiness for nitrogen (and phosphorus) loss in terms of vertical drainage or lateral runoff risk.

The high frequency monitoring of nitrogen concentration in catchment outlets indicated that both the absolute N concentrations and the dynamics of N loss varied across the catchments. The link between the percentage of land in derogation and the stream water concentration of nitrate-N was not clear, reflecting differences in soil type, land-use and meteorological factors that were evident at the catchment scale of the ACP. For example, Castledockerell (Co. Wexford) has the highest nitrate-N concentration in stream water, despite having the lowest stocking rate organic nitrogen (with only 5% of the catchment in derogation). The ACP research reported that, in general, physical settings tend to override source pressure in terms of nutrient export risk. This highlights the overriding importance of soil type, subsoil geology and groundwater hydrochemistry in controlling nitrogen (and phosphorus) losses to water.

To assess the temporal trends in nitrogen export rates within ACP catchments, an analysis was carried out over 4-year rolling periods (the minimum number of years required for this method), as well as over the whole 12-year period (Table 1). During the last 4-year rolling period (2019-2022), there was a trend for declining nitrate-N concentrations in the Timoleague catchment, stable in the Dunleer and Corduff catchements, and no consistent trend in the Ballycanew, Castledockerell and Cregduff catchments. This in the context of the organic nitrogen stocking rates in the Timoleague catchment increasing from approximately 130 kg organic nitrogen per hectare to greater than 180 kg of organic nitrogen per hectare.

Table 1. *Annual average nitrate-N concentration (mg/l) and the four-year inter-annual trends are indicated with symbols: = no trend, = stable (no change), = ↑ increasing and ↓ = decreasing*

Land –use:	Grass	Grass	Arable	Grass	Grass	Grass
Drainage:	Poor	Well	Well	Moderate	Poor	Well
YEAR	Ballycanew	Timoleague	Castledockerell	Dunleer	Corduff	Cregduff
2010	2.29	5.00	6.22	4.95	1.15	1.36
2011	2.34	5.39	6.48	4.48	1.17	1.65
2012	2.98	6.30	7.13	5.82	1.13	1.19
2013	2.56	5.64	7.21 ↑	4.57 →	1.20	1.14 →
2014	2.50 →	5.45 →	7.15	5.33	1.11 →	1.46 →
2015	2.53 →	7.07 →	7.37	5.22 →	1.25	1.61
2016	2.50 →	5.57 →	7.02 →	3.93 →	0.92 →	0.93 →
2017	2.91	6.49 →	7.42	4.40 →	1.35	1.34 →
2018	2.91	6.64 →	7.41	6.37	2.13	1.21 →
2019	2.73 →	7.15 ↑	7.22 →	8.44 ↑	2.30 ↑	1.39
2020	2.27 ↓	6.30 →	6.96 ↓	5.93	1.43	1.01 →
2021	2.48 →	5.43 →	6.66 ↓	5.51 →	2.20 →	1.05 →
2022	2.85	4.95 ↓	-	6.06 →	2.28 →	1.80 →

Source: *ACP*

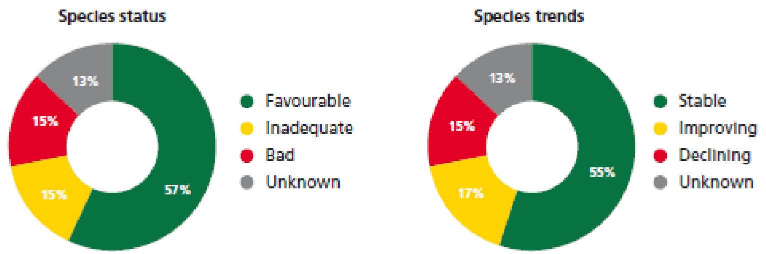
Water footprint

Relatively high rainfall and extremely low water scarcity values means that Ireland has a very low water footprint for milk production. A water footprint measures the amount of water used to produce a good or product, in this case milk. In general, the water footprint can be broken into three figures: green, blue and grey. The green water footprint measures water from precipitation that is stored in the root zone and used to grow the feed consumed by the animals. Blue water is sourced from surface or groundwater and is used in the production process, e.g. animal drinking water or irrigation. Grey water is the soiled water that leaves the system from washings, etc. A recent analysis across 24 intensively monitored dairy farms reported that blue water consumption was 6 L water per kg FPCM yield in Ireland. This compares with 108 L per kg FPCM in Australia and 125 L per kg FPCM yield in the US. The differences in blue water use are mainly driven by differences in irrigation. Even though Ireland's blue water use is very low, it can still be further reduced through prompt repair of leaks, recycling plate cooler water and integration of high pressure washers in the washing process.

Biodiversity

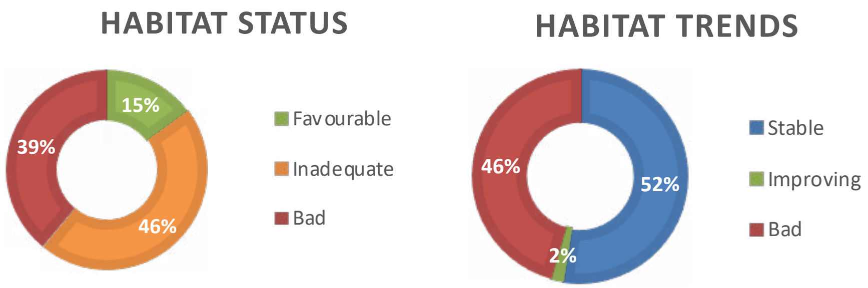
There is increasing emphasis on biodiversity as highlighted by the recent Citizens' Assembly on Biodiversity Loss. Biodiversity (the variety of plant and animal life, and the habitats in which they live) is declining globally. As agriculture is the dominant land use in Ireland, it has an important role to play in helping to reverse the decline in biodiversity. Understanding the actions that can be implemented to reverse the decline is extremely important. The key actions revolve around retaining, enhancing and creating habitats. On the average dairy farm in Ireland, it is estimated that approximately 7% of the farm area can be described as semi natural; these areas include hedgerows, streams, field margins, etc.

Figure 6 illustrates the current status and trends for species protected under the Habitats Directive in Ireland. Presently, the status of 57% of designated species is defined as favourable, while the trend for 72% of designated species is defined as stable or improving. Figure 7 illustrates the current data for habitat status and habitat trends across Ireland; both of these measures currently have poor metrics.



Source: *NPWS article 17 Data (2019)*

Figure 6. *Overall assessment results for the status and trends in species protected under the EU habitats directive in Ireland*



Source: *NPWS article 17 Data (2019)*

Figure 7. *Percentage of habitats in favourable, unfavourable-inadequate or unfavourable-bad condition and percentage of habitats with stable, improving or bad trends*

Current technologies to improve social and environmental sustainability

There are many currently available technologies that can be immediately implemented by farmers that will have positive impacts on sustainability. These technologies are discussed across the impact categories. In most cases, they will not increase costs at farm level and in some cases these measures would help reduce costs and increase profitability.

Cow welfare

Achieving continued improvements in cow welfare requires a focus on farm management, infrastructure and breeding:

- Roadways should be well maintained and upgraded where required. Locomotion scoring of dairy cows should be conducted regularly to pick out cows with suboptimum mobility, which will aid early detection of lameness problems.
- Ensure winter accommodation is suitable with appropriate space allowances.
- It is essential that every dairy herd has a 'herd health and welfare programme' as an essential part of the management system. The EBI, including the emphasis on the health and fertility sub-indices, should be used to identify bulls that are suitable for a pasture-based system.

Calf welfare

Adopting correct calf management practices are critical to ensuring healthy, well-grown calves. Management during the pre-weaning period has implications for subsequent animal health and welfare, and also for subsequent productivity and longevity. When the calf is born, attention needs to be paid to colostrum management and ensuring the calf receives a sufficient volume (3 litres) of high quality colostrum (>50 mg per ml IgG) within the first two hours of life is critical to achieve passive transfer of immunity. At least four feeds of transition milk should follow the initial colostrum feed before the calf moves to high quality whole milk or milk replacer. Calves should be fed three litres of milk twice daily for at least four weeks of life. Fresh water and concentrate should be made available from birth with the aim of encouraging rumen development. Milk volume can be reduced to four litres and fed once daily from four weeks of age, to promote increased concentrate intake and ensure a smooth transition between the pre- and post-weaning periods. When weaning, calves should be weaned gradually to minimise post-weaning reductions in growth rate and to maintain good health and welfare. In addition, the housing environment should allow calves perform to their maximum ability with minimum disease risk, and positively influence the health, growth, development and general welfare of the calf.

Greenhouse gas emissions

The Marginal Abatement Cost Curve (MACC) (Version 3 to be published in July 2023) has identified the most cost-effective pathway to reduce sectoral emissions. The adoption of measures such as reducing our reliance on chemical nitrogen fertiliser, a change of nitrogen fertiliser type to protected urea, using high EBI and high DBI genetics, use of sexed semen, improved animal health, extending the grazing season, and use of white clover are critical to reducing sectoral emissions. Initially, our focus must be on reducing our reliance on chemical nitrogen fertiliser.

- There are a range of proven technologies to reduce reliance on chemical nitrogen fertiliser:
  - » Correct soil fertility. Moving from pH 5.5-6.3 can increase soil nitrogen availability for grass growth by between 50-70 kg nitrogen per ha per year, as well as reducing nitrous oxide emissions per kg nitrogen applied. Target soil Index 3 for phosphorus and potassium for optimum sward nutrition.
  - » Apply slurry using low emission slurry systems (LESS; e.g. trailing shoe, band spreading) between February and May. The nitrogen fertiliser replacement value of slurry can be increased (25%-50%) by using LESS instead of splash plate and ammonia emissions are reduced.
  - » Incorporate white clover on farm. White clover can fix between 80–120 kg nitrogen per ha per year depending on underlying soil fertility and sward management.
  - » Use red clover for silage to significantly reduce the requirement for chemical nitrogen fertiliser on silage swards.
- Where chemical nitrogen fertiliser is used, switching from CAN and straight urea to protected urea will directly reduce both GHG and ammonia emissions, while also being cheaper per kg nitrogen applied.

Ammonia emissions

There are a range of options to reduce ammonia emissions on dairy farms. These include reduced crude protein in concentrate feed, use of protected urea instead of ordinary urea or CAN, as well as the use of LESS technology for the application of animal manures. At dairy farm level, the two measures responsible for the vast majority (circa 80%) of the ammonia emission reductions are using protected urea and LESS:

- Protected urea will reduce greenhouse gas and ammonia emissions compared with CAN and straight urea.
- LESS technologies such as trailing shoe and band spreading results in greater retention of the nitrogen in the slurry within the system.

Water quality

The Teagasc ASSAP programme is designed to enable landowners to engage positively in seeking solutions to local problems in relation to water quality through the support of a confidential sustainability advisory service focused on water quality improvement. Contact your local ASSAP advisor and book a consultation. Three key actions have been identified:

- Reduce phosphorus and sediment losses. Use 'break the pathway' measures to prevent run-off overland into the drainage networks. For example, targeted riparian margins and buffer margins, use of low earthen mounds, planting of trees and hedgerows, prevention of livestock access to water, wetland ponds, careful management of critical source areas and sediment traps.
- Reduce nitrogen losses. Ensure soil fertility is optimum for P, K and pH, take soil samples and follow a nutrient management plan. Apply fertiliser/slurry when soil temperature, soil moisture content, growth rates and weather forecast are suitable particularly in the early and late growing season. Quantify the nitrogen surplus on your farm and take measures to reduce the surplus that is available to be lost to water.
- Ensure that your slurry, soiled water, dairy washings, silage effluent and farmyard manure collection and storage facilities meet requirements. Make your contractor aware of the locations of critical source areas, watercourses, drains, etc. on your farm. Ensure appropriate buffers zones are kept when spreading organic manures.

Biodiversity

Biodiversity management on-farm involves retaining, enhancing and creating habitats. It is important to optimise the biodiversity value of existing farmland habitats before new biodiversity measures are established.

- Do not top escaped hedges, side trim only. The biodiversity value is in the canopy and in bank and ground vegetation.
- Side trim topped hedges from a wide base to a triangular profile. Cut the growing point to prevent escaping, leaving the peak as high as possible. Retain occasional thorn saplings and allow them to mature into flowering and fruiting trees.
- Maintain riparian buffer strips. These are strips of permanent vegetation adjacent to rivers and streams that are typically excluded from intensive farming practices. Appropriately managed buffer strips play an important role in maintaining water quality, ensuring bank stability and providing a habitat for biodiversity.
- Quantify the biodiversity enriched area across the overall farm, and develop a plan to increase biodiversity across the rest of the farm.

Future technologies to increase sustainability

New technologies are currently being developed/researched. In time, these will further increase the sustainability of the dairy industry.

Cow health and welfare

Recently published Moorepark research highlighted links between reduced lameness and reduced SCC associated with genetic selection (i.e. better EBI). In the future, it is anticipated that there will be greater emphasis on health traits in the EBI as other issues become less of an issue. For example, a recent study indicated that animals with greater genetic merit for TB resistance are less likely to test positive for TB even though their herd mates may test positive. Data from ICBF indicates that herd replacement rate has declined from 23% in 2013 to 19% in 2022. At the same time, the number of recycled cows in the system has reduced from 16% to 11%, while difficult calvings has declined from 1.8% in 2013 to 1.2%

in 2022. The focus will continue to remain on a pasture-based system with a long grazing season with grazed grass constituting the majority of the dairy cow diet and not on milk yield per cow.

It is anticipated that there will be a substantial growth in the beef-cross offspring coming from the dairy herd, facilitated by increased use of sexed semen. Teagasc Grange research has reported that when Angus calves are compared with Holstein Friesian calves, the Angus calves finish at an earlier age and have a higher carcass value, resulting in both reduced costs of production and higher output. Every spring, there is a period when there is greater calf supply to the market than demand for calves. There are a number of strategies that affect both the supply of calves to the market and the demand for calves. These include increasing the profit potential of the calf, developing profitable production systems for early maturing dairy calf-to-beef, developing and maintaining high welfare animal transport systems that allow calves to move to mainland Europe, investing in labour efficient calf-rearing systems that will facilitate calves remaining on farm, if required, for longer periods, as well as dairy and beef farmers developing relationships that facilitates a model that is beneficial to both parties. The newly developed Commercial Calf Value (CBV) tool will provide the communication mechanism around dairy-beef calf potential profitability.

Greenhouse gas emissions

There is a significant programme of work underway in GHG emissions research that has the potential to markedly reduce the emissions profile from agriculture, as well as providing solutions to reduce emissions at farm level. Enteric methane is estimated based on models that were developed based on international emission factors for methane. Research conducted in recent years across several research groups in Ireland indicated that the emission factor for enteric methane for Ireland is over-estimated. Table 2 summarizes a number of published studies quantifying enteric methane using different techniques between 2010 and 2023. The studies indicated enteric methane emission factors as a percentage of gross energy intake ranging from 4.9%-6.78%. The most recent study, which lasted for more than seven months of the lactation: found that enteric methane emissions were extremely low in the spring, <4.8% of gross energy intake, and then increased as the grazing season progressed. The seasonal pattern of enteric methane emissions within pasture-based systems requires further investigation to increase the understanding of enteric methane emission profiles. A number of studies recently completed suggest that the emission factor used when animals are indoors on grass silage also over-estimates the enteric methane emissions.

Table 2. *Enteric methane measurements across a range of studies carried out with grass in Ireland*

Study	Enteric methane measurement method	Ym* (%)
Wims *et al.*, 2010	SF6	5.9
Ferris *et al.*, 2020	SF6	4.9
Hynes *et al.*, 2016	Respiration chamber	5.6
Lahart *et al.*, 2023	Greenfeed measurement	5.3
Jiao *et al.*, 2014	SF6	5.6
Foley *et al.*, 2008	SF6	6.3
Lovett *et al.*, 2005	SF6	5.64
Hidalgo *et al.*, 2014	SF6	6.78
Mean		5.75

**Ym is the methane conversion rate expressed as a fraction (i.e. the fractional loss of GEI as combustible CH4)*

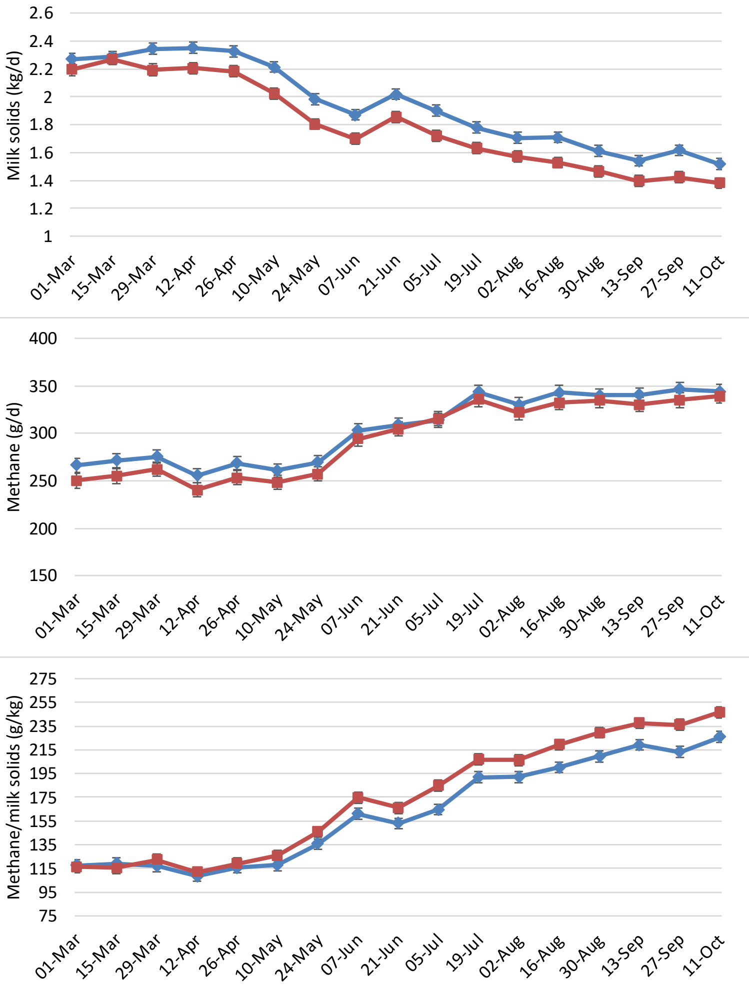


Figure 8. *Graphs showing a) milk solids yield, b) methane emissions and c) the proportion of methane emitted per unit of milk solids for the high economic breeding index (EBI) (blue lines) and national average EBI (orange lines) dairy cows across the experimental period*

Previous studies have reported that increasing EBI results in a reduced carbon footprint but does not result in reduced total emissions. This analysis was completed using models that simulated herd performance. The modelling simulated that enteric methane increased when milk yield increased. When enteric methane emissions were measured in individual cows, however, high EBI cows had similar daily enteric methane emissions to lower EBI cows even though they produced higher milk yield (Figure 8). This means that as EBI increases, the emissions factor should decline to reflect the actual methane output by the animal.

Grass quality and seasonal profile

The results presented in Figure 8 show that there are significant seasonal effects associated with enteric methane emissions from dairy cows. Increasing our understanding of these factors will potentially allow manipulation of grassland management and grass breeding to facilitate the development of strategies to reduce enteric methane emissions from cows consuming pasture-based forages.

Feed additives

There is considerable research being conducted nationally and internationally on the use of feed additives to reduce enteric methane. Significant progress has been made internationally in recent years with products like Bovaer produced by DSM achieving reductions of up to 30% in enteric methane emissions in a TMR feeding system. This product is less effective when pulse fed through the milking parlour and therefore requires further work for effective use in pasture-based systems. Other products such as the red seaweed, Asparagopsis, has shown great promise in studies completed to date. Other products like Halides are also showing significant promise in terms of reductions in enteric methane emissions. An important consideration for widespread use of any supplement to reduce enteric methane will be the ability to produce the material in large volumes with consistent amounts of the active material. Other important features include the absence of residues, a mechanism to feed the product to the animal, a mechanism for counting the emission reductions through the national inventory, and that the products do not have a negative effect on performance. It would also be desirable that the supplements are low cost, of natural origin, and can be combined with other solutions.

Carbon sequestration

Carbon emissions from grassland are part of the land use and land use change sector. Current estimates of carbon sequestration in grassland are based on Tier 1 emission factors, which are international default values. There is currently a significant research programme being undertaken to develop country specific emission factors for Irish soils. Further research is being developed to enhance the activity data around land use and land status. This will be enriched with emissions data from hedgerows to generate national emission removals. It is anticipated that when this research is complete, the combined effects of more accurate country specific emission factors and activity data will present a very different picture regarding emissions removals.

Warming effect associated with GHG emissions

The scientific discussions in the area of additional warming effects associated with biogenic methane and its lifespan is now very clear. Research findings indicate that when biogenic methane is first stabilised and then reduced that all additional warming effects can be removed. Further and faster reductions in methane would result in a reduced warming effect (reduction from the historic warming effects). It is possible, however, that agriculture and the land use sector could be in a position to not be contributing to increased warming before 2040. This would require that biogenic methane is first stabilised and then reduced, changes to the land use land use change emissions associated with updated metrics, activity data, technical changes at farm level, and the development and deployment of new solutions at farm level around N_2O.

Water quality

Analysis carried out of the 5th Nitrate Action Programme coupled with increased ambition in fertiliser nitrogen reductions in the Food Vision strategy, would result in a reduction in nitrate-N leaching of between 5.9 kg per ha (circa 10%) and circa 9 kg per ha (circa 18%), depending on modelling approach used. Reducing organic nitrogen per ha from 250-220 kg nitrogen per ha will only reduce nitrate-N leaching by between an additional 2.2 kg nitrogen per ha or 3.5 kg nitrogen per ha depending on modelling approach used, but it will have a significant financial impact at farm level. Consequently, in order to ensure that the overall approach is robust, a sequential approach to firstly allow the impact of the 5th Nitrate Action Programme and the additional fertiliser reductions in the Food Vision Dairy Group Report to be assessed before introducing any reduction in organic nitrogen limits would be desirable.

Conclusion

Irish dairy farming has undergone a transformation during the last 10 years. Up until 2015, there had been 31 years of the EU milk quota regime, which stifled innovation. Since then, there has been significant expansion due to the pent up capacity in the industry. The next phase of development will have to be based on the principle of decoupling GHG and NO_3 emissions and N loss from production, while advancing the quality and quantity of enriched areas on-farm. All of this is possible and will be the focus of technologies that are introduced onto farms in the coming years. This will all occur at a time when there is increasing investment in research for new solutions and will provide the platform for even greater ambition around sustainability at farm level. It is also clear, however, that grass-based systems of milk production have an important role in sustainable ruminant production globally, and could play an even greater role in the provision of ruminant products in the future. It is necessary to improve the metrics used to evaluate the sustainability of the farms, and to ensure that a robust and balanced assessment of farm sustainability is completed during the process. Additional metrics for water use, feed/food competition, and international emissions comparisons are required.

Dairy systems – farming today with tomorrow in mind

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Summary

- Increased economic value in tandem with improved environmental sustainability have been achieved within the Irish dairy sector by focusing on core grazing principles to maintain low production costs and high levels of pasture utilisation.
- Against the backdrop of two consecutive years of agricultural input cost inflation coupled with declining milk prices during the last 6 months, dairy farmers must urgently revisit farm financial budgets to secure an adequate household income for 2023.
- Our grazing systems can be further improved by reducing reliance on supplementary feed and chemical fertilisers, maintaining appropriate grazing stocking rates and further refining day-to-day operations to reduce workloads, simplify systems and improve work-life balance on family run dairy farms.

Introduction

Ireland's dairy exports are the largest single element of total food and drink exports, with over 1.7 million tonnes of product shipped to over 130 markets worldwide (Bord Bia, 2023). By any measure, the performance of the sector during 2022 has been extraordinary. With a total estimated value of €6.8 billion in 2022, the year-on-year increase in value alone was worth €1.7 billion to the Irish economy (equivalent to approximately 30% of the total national budget surplus at year-end; CSO, 2023). The sustained recent performance of the sector has been achieved through a 33% increase in product value, together with a 20% increase in total milk output since 2017. Although herd expansion has been one feature of this change (average herd size increased from 75 to 93 cows per farm during the same period), the success of the dairy sector has come primarily from increased productivity via improved animal breeding, grassland management and animal husbandry. Remarkably, the increase in total sector value has been achieved while reducing reliance on both chemical nitrogen (N) fertiliser and chemical herbicide usage on Irish farms. Average N fertiliser usage on Irish farms reduced by 14% in 2022; in part, this was due to a marked increase in fertiliser prices, but also reflects the accelerated adoption of climate-smart farming practices to achieve the target 25% reduction in carbon emissions by 2030. The stellar performance of the sector has been achieved against the backdrop of tumultuous international economic circumstances, most notably in terms of the impact of the war in Ukraine, hyperinflationary cost pressures, tightening financial markets and the ongoing legacy of trade disruptions from the Covid-19 pandemic. Indeed, the sustained recent performance of the sector is in stark contrast to global trends with flat or weakening milk production in all key exporting regions during 2022 and further modest reductions predicted for 2023; as rising input costs, reduced availability of skilled labour and increased environmental regulation have diminished confidence in key exporting nations.

Farming today with tomorrow in mind – first principles of grazing

The next decade is likely to see further pressure on all forms of global food production systems. Increasing population and greater per capita consumption will continue to increase demand. At the same time, greater competition for inputs and land use, the impacts of climate change and the requirement for climate change mitigation are expected to restrict supply. The good news for Irish dairy farms is that despite recent turmoil, profitable and sustainable dairy systems will continue to be based on executing a relatively small number of key management practices accurately. The key performance indicators for Irish grazing systems of milk production are summarised in Table 1. As evidenced by the data below, significant further progress can be achieved within Irish grazing systems. Indeed, a continued focus on improved grazing practices, supported by further genetic improvement, can yield additional pasture utilisation and increased farm profitability on Irish dairy farms. This can be achieved while delivering world-leading dairy products with improved environmental sustainability, increased animal welfare and superior product quality to international consumers.

Table 1. *Target performance indicators for Irish pasture-based dairy systems compared to average and top performing farms*

	Average[1]	Top 10%[2]	Target
Dairy Economic Breeding Index (€)[3]	164	200	>225
Herd maturity (No. calvings/cow)[3]	3.6	4.1	> 4.5
Optimum soil fertility (% farm area)	20	75	100
Fertiliser N (kg chemical N/ha)	180	200	<150
Calving rate (% calved in six weeks)[3]	67	85	90
Grazed pasture in the diet (%)	57	65	>70
Pasture utilised (t DM/ha)[2]	8.0	9.6	13.0

[1]National Farm Survey (NFS, 2021), [2]Ramsbottom et al. (2020), [3]ICBF (2023)

So what are the key management practices that Irish dairy farmers need to revisit to future-proof Irish dairy systems for the next decade? In the next section, we focus on three key components: (1) refocusing on prudent financial management; (2) achieving appropriate stocking rates (SR); and (3) simplifying workloads to achieve a sustainable work-life balance on-farm.

Refocusing on financials – protecting the margin for 2023

The high rate of general inflation in Ireland over the last 18 months has eroded the real value of incomes on all farms and in the wider economy at large. The greatest immediate challenge for Irish dairy farms is to secure an adequate household income for farm families against the backdrop of two consecutive years of agricultural input price hyperinflation (9% and 32% in 2021 and 2022, respectively). Figure 1 illustrates the fluctuations in average gross margin, production costs and net profit margin (excluding family labour) during the last decade on Irish farms. Teagasc estimated that net margins on Irish dairy farms increased by 70% to €3.20 per kg fat plus protein (23.9 cent per litre) in 2022, and resulted in an average family farm income of €151,000 per farm (Teagasc, 2023). However, the strong performance of the sector in 2022 will not be repeated this year as milk prices have already reduced to 2021 levels.

Feed costs in particular, have remained at stubbornly high levels during 2023 (+75% of 2020 levels) and, together with rising interest rates, will likely contribute to a continuation of inflationary pressures and tightening cash flows on dairy farms for much of 2023. On that basis, the average net margin per litre of milk is expected to fall to €1.50 per kg fat plus protein (12-14 cent per litre) in 2023. Hence, 2023 will be more typical of medium term norms, but it is essential for farmers to now create a financial budget to reappraise capital expenditure plans and maintain family farm income in this high cost environment.

To maintain profit margins, Irish dairy farmers must refocus on cost control during 2023. At a general level, multiple prices should be sought when sourcing farm materials during the remaining months of 2023 to take advantage of any market price reductions. More specifically, reduces feed costs as well as costs related to pasture and forage are an essential objective to constrain total production costs in 2023 as fertiliser prices reduce and increased use of clover in swards reduces total N fertiliser requirements.

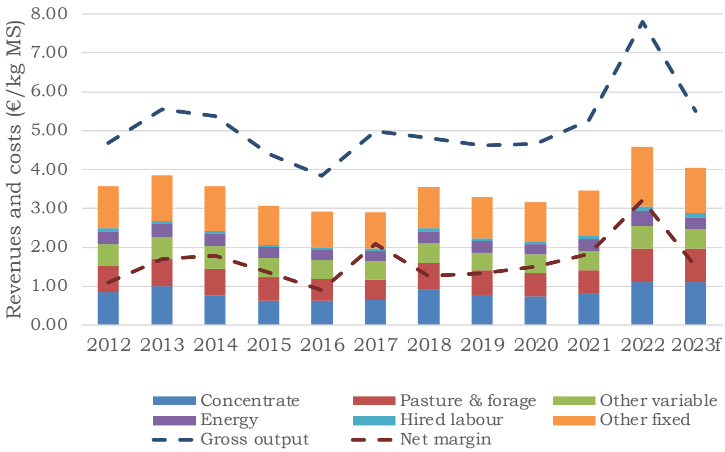

Figure 1. *Trends in gross output, costs and net profit margins on Irish dairy farms during the last decade (National Farm Survey) and forecasts for 2023*

As purchased feed costs have markedly increased during the last decade through a combination of increased land costs, rising fertiliser prices and increased energy costs; the relative cost competitiveness of grazed pasture has been enhanced. Figure 2 outlines how absolute and relative feed costs have increased during the last decade. Grazed pasture and grass white clover have increased in cost by €30/t DM between 2013 and 2023, pit and bale silage have increased by €55 and €75/t DM during the same period and purchased concentrates have increased by €213/t DM. On a relative energy corrected basis, pit and bale silage are currently 2.5 times the cost of grazed pasture and purchased concentrate is five times the relative cost of grazed pasture.

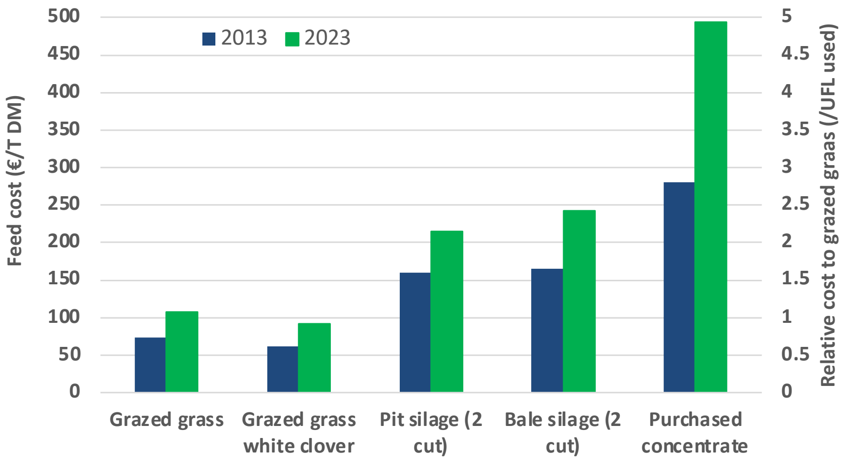

Figure 2. *Actual feed costs (€/tonne) during 2013 and 2023. [Adapted from Finneran et al., 2011, Doyle et al., 2023]*

The central importance of increased pasture utilisation (t DM/ha) to increase economic performance in grazing systems is well recognised. Efficient pasture-based systems must therefore maintain a high proportion of grazed pasture in the animal diet to achieve a low production cost-base, and to insulate the dairy farm business from both climate and imported feed price shocks. An overall target of 70% grazed pasture in the dairy herd diet is appropriate in Irish grazing systems to achieve high levels of performance within a low cost grazing system. This equates to approximately 265 days of grazing and 0.5 tonnes of concentrate fed per lactating cow per annum.

Stocking rate – the happy medium and the 'TMR' cow

Whether the objective is minimising external feed and capital costs, reducing workload or minimising environmental impacts, having the correct stocking rate (SR) has always been a cornerstone of efficient and profitable grazing systems. Recent trends for SR on Irish dairy farms reveals that overall SR has increased only modestly during the last decade from 1.9 to 2.1 livestock units per hectare (LU/ha; NFS, various years), but there has been a significant increase in SR on the milking platform area (i.e. lands adjacent to the milking parlour). Based on available national statistics (National Farm Survey), milking platform SR has increased from 2.0 to 2.7 LU/ha during the last decade; farms have become increasingly specialised in dairy cows and other stock have been moved to outside land parcels or in some cases to contract rearing. Similar to the NFS, Figure 3 illustrates the change in both overall and milking platform SR for a matched sample of dairy farms that completed Teagasc eProfit monitor during the period from 2013 to 2017 and recorded overall pasture utilisation (tonnes DM/ha) during the same period. Similar to the national picture, only a very modest change in overall SR (2.2 to 2.3 LU/ha) occurred during the period, whereas milking platform SR increased substantially (from 2.4 to 2.8 LU/ha). At the same time, and despite a consistent increase in milking platform SR, there was no significant increase in pasture utilisation on these farms between 2015 and 2017. This analysis reveals that, on many farms, milking platform SR has increased to levels beyond that required to maximise pasture utilisation. Consequently, there are additional cows on these platforms that are effectively increasing total purchased feed requirements, labour and capital costs and reducing the duration of the grazing season for the entire dairy herd. In addition, where SR on the available area exceeds the pasture production capability of that area, this results in an increase in total costs that correspond to approximately 1.6 times the increase in feed costs alone.

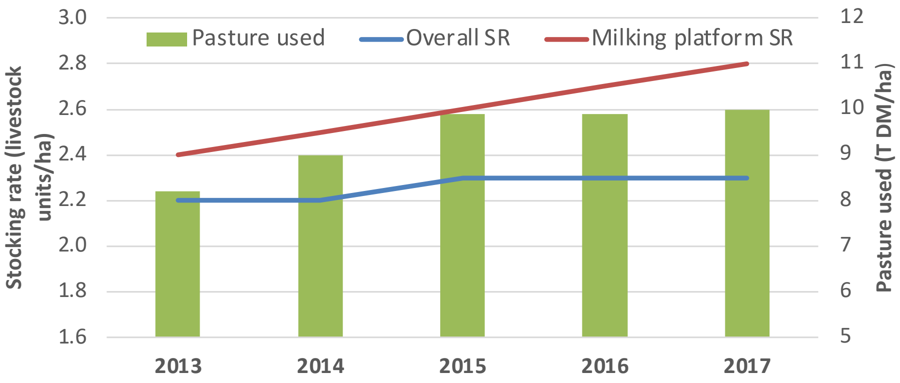

Figure 3. *Trends in overall and milking platform stocking rate and pasture utilisation (t DM/ha, green bars) on Irish dairy farms (2013-2017; Ramsbottom et al., 2020)*

So what should be the optimum overall and milking platform SR for efficient dairy farms in 2023? In defining the optimum SR, it must first be acknowledged that farms differ in terms of land quality and usability, cow type/size, milking platform area, availability of outside land blocks, etc. Nonetheless, pasture production, pasture utilisation and concentrate supplementation levels are the primary considerations that define the optimum SR to allow both high animal performance and high pasture utilisation to be achieved. In Table 2, the optimum whole farm SR for farms that produce different amounts of grass and feed different amounts of supplement are defined within self-sufficient forage systems.

Table 2. *Optimum overall stocking rate* for grazing dairy farms growing different amounts of pasture and feeding various levels of supplement/cow*

	Grass grown, t DM/ha			
Tonnes supplement DM/cow	10	12	14	16
0.00	1.5	2.0	2.3	2.6
0.50	1.8	2.2	2.5	3.0
1.00	2.0	2.4	2.9	3.1

**All of these stocking rates equate to 80 kg live weight/t feed DM available*

For the milking platform, the specific SR can be increased to improve grazed pasture utilisation, while the additional winter feed requirements can be provided on an area away from the platform. In this situation, the additional cows on the milking platform are considered 'marginal cows' as the system is no longer forage self-sufficient and part of the diet is supplied by feeds (both concentrate and silages) from outside the milking platform. The marginal cow milking platform SR to maximise pasture utilisation for farms growing various levels of pasture is outlined in Figure 4.

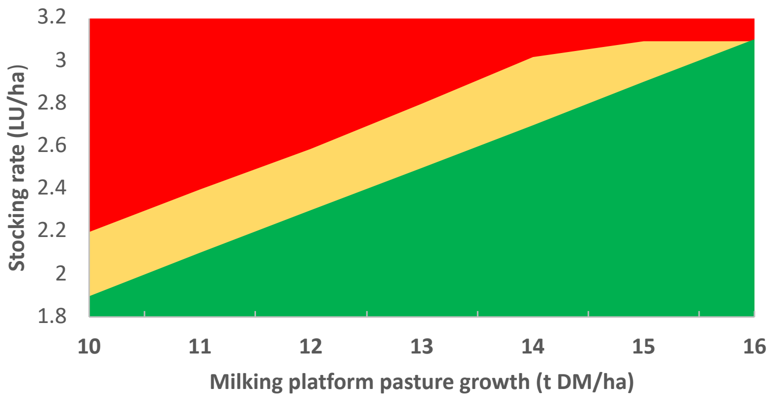

Figure 4. *Overall (green area) and milking platform (yellow area) stocking rate (SR) for farms growing various levels of pasture on the milking platform (t DM/ha). The red area reflects SR in excess of marginal levels where no additional pasture is utilised and the entire requirements of the additional animals are supplied from outside the system*

So what are the milking platform SR guidelines? As evidenced by Figure 4, milking platform SR can be higher than the overall SR to yield a finite additional pasture utilisation on the milking platform, but should never exceed the shaded yellow area as this corresponds to a complete supplementary feed (equivalent to a total mixed ration (TMR)) diet for these additional animals. Farmers should exercise caution with marginal SR increases as additional pasture utilisation is not guaranteed (depending on growing conditions) and the overall economic benefit is heavily dependent on favourable economic conditions (milk price and input costs, capital and labour requirements). For these reasons, previous studies in pasture-based systems in Ireland and New Zealand have reported a linear decline in profitability with increasing feed importation. In addition, many studies also indicate that where increased SR is associated with increased chemical fertiliser and supplementary feed importation, nutrient-use efficiency is reduced, resulting in increased nutrient losses to the general environment.

Becoming the 50 hour farmer - reducing workload on dairy farms

In addition to farm financial and biological performance, dairy farmers are now placing greater emphasis on quality of life, time off and time with family away from the farm as critical measures of family farm business success. While long working hours increase the risk of ill-health and injury in agriculture and the wider economy, it is also a deterrent to young people entering careers in dairy farming. With this in mind, a recent large-scale study was conducted across 76 spring calving Irish dairy herds from February 1st to June 30th 2019. The aim of this study was to examine workload, time-use and labour efficiency, and the effect of labour saving strategies on labour demand. The studied farmers worked on average 60.0 hr/week during the 150-day study period and 63.5 hr/week during February and March. Although the top and bottom 25% of studied farms had a similar herd size (112 cows), the more labour efficient group worked 51.2 hr/wk compared with 70 hr/wk for the least efficient 25%. The working day had a similar start time (06:47 vs 07:00) but the more labour efficient group finished the working day earlier (18:25 vs. 19:58). Maintaining the 16:8 milking interval is a fundamental component of the shorter working day on efficient farms with no negative impact on milk production. Within this system, we believe an 18:00 hr finish time should be an achievable KPI on farms from February to June.

Table 3. *Work organisation effectiveness indices for top 25% and bottom 25% of farms from 1st February to 30th June*

	Top 25%	Bottom 25%
Average herd size (No. cows)	112	113
Labour input (hr/cow, February – June)	17.4	20.9
Farmer work (hr/week)	51.2	70.0
Farmer workday length (hr)	11.4	13.2
Start time (hr:min)	06:47	07:00
Finish time (hr:min)	18.25	19:58

Unsurprisingly, milking was identified as the most time-consuming task on dairy farms, accounting for 31% of time input. Five practices were identified to improve milking labour efficiency that should be relatively easy to implement on most dairy farms:

- one person milking during mid-lactation
- the milker not leaving the pit to feed calves during milking
- using a quad/jeep to herd cows to and from milking
- being able to operate cow exit/entry gates from anywhere in milking pit
- automatic cluster removers

Calf care accounted for 20% of time in the peak months of February and March. Contract rearing calves pre-weaning and selling male calves were two activities that can significantly reduce time input. Contractors have more efficient equipment than farmers to complete tasks such as slurry and fertiliser spreading, and can reduce or replace the need for additional farm staff and farm machinery. Although there is an economic cost to the farmer for contract rearing, additional use of contractors and investments in calf rearing equipment, studies have indicated that these additional costs do not significantly reduce farm profitability.

As part of the study, farm profitability was assessed for those farmers that had data available (n=34). The top 25% of farms for work organisation effectiveness had greater profit (€/ha), which agrees with previous studies. The greater profitability achieved on the most labour efficient farms indicates that the extra workload on less efficient farms does not contribute to farm profitability. More generally, improved labour efficiency can also enhance many other key aspects of dairy farming, including improved health and safety for farm operators and creating more attractive workplaces. In many cases, the work practices required may not need large investments on-farm and should be relatively easy to implement. For others, larger financial investments may be required (e.g. automatic cluster removers and automatic calf feeders); grant funding is currently available under DAFM schemes and should be investigated on a farm by farm basis in terms of cost/benefit.

Conclusions

The financial landscape for dairy production has been substantially altered during the last 24 months with unprecedented fluctuations in dairy product prices and hyperinflation of costs at farm level. In addition to the ongoing requirement to improve efficiency to meet climate action commitments, dairy farmers must also refocus on prudent financial budgeting to reduce costs and maintain financial margins during 2023. To that end, the core components of pasture-based milk production systems will continue to be high productivity pasture management, appropriate overall stocking rates, and highly efficient dairy cattle managed in a seasonal compact-calving system. Such systems can be further improved by reducing reliance on increasingly uncompetitive supplementary feed imports, incorporation of clovers within diverse grazing swards to reduce dependence on chemical N inputs and the further refinement of day-to-day operations to reduce workload, simplify systems and improve work-life balance for family run dairy farms.

Sustainable and responsible breeding and reproductive programs

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Summary

- Optimal breeding and reproductive programs contribute approximately half of the gains in performance for most herds.
- Increased availability of sexed semen facilitates accelerated genetic gain in dairy replacements, and a marked increase in the number of beef-cross calves generated, improving the sustainability of dairy farming.
- Farmers should target usage of sexed semen on the best Economic Breeding Index (EBI) females.
- The Economic Breeding Index (EBI) has been updated to include a carbon sub-index, which will reduce the carbon footprint of Irish dairying.
- The recently launched commercial beef value (CBV) of calves links well with the dairy-beef index incentivising dairy farmers to generate valuable calves for the downstream beef industry.
- In vitro produced embryos will enable elite breeders and animal breeding companies to increase the number of elite offspring derived from planned matings, facilitating genetic gain in dairy breeds to continue despite usage of sexed dairy semen causing a marked reduction in the number of male dairy calves.

Introduction

Animal breeding is a technology that has proven itself time and time again to deliver change. Irrespective of species, breeding programs internationally contribute approximately half the gains in observed performance; dairy cattle breeding in Ireland is no exception. Animal breeding as a vehicle to deliver change enjoys several advantages over non-breeding techniques. The benefits of breeding accumulate with each advancing generation and introduced genes remain within the herd for generations. Importantly though, using bulls or cows of superior genetic merit is no more costly than using their genetically inferior contemporaries, and hence does not incur any additional cost; the same is not necessarily true of many non-breeding technologies (e.g. dietary supplementation). Furthermore, breeding programs do not require a change in day-to-day farm management, as cows must be bred irrespective of the type of genetics or technology used to do that. Additionally, breeding can deliver desirable changes to multiple animal features simultaneously, even if unfavourably correlated – a good example of this is concurrent improvements in fertility and milk production traits, despite being unfavourably correlated. Most importantly though, the benefits from breeding stack on top of advancements achieved through management. Therefore, given the importance of breeding to sustainable productivity, effort must be directed into the careful selection of the parents of the next generation.

The Economic Breeding Index (EBI)

Breeding indexes globally, including the Irish EBI, are regularly reviewed in light of future anticipated changes in costs of production, revenue streams and other external forces like regulatory obligations. Changes to breeding indexes could be implemented for one or more of the following reasons:

- a revision of the genetic evaluation of the trait(s);
- a re-evaluation of the weighting placed on each trait in the index; and/or
- the introduction of new traits into the index.

The genetic evaluation procedures for milk production and calving performance traits were recently updated, with the latter update resulting in separate genetic evaluations now being published for calving difficulty in heifers and cows. Therefore, all bulls now have a separate genetic value for calving difficulty in heifers and cows, since calving difficulty in heifers and cows is not genetically the same trait. The focus is now turning to the reassessment of the national fertility evaluations. Evidence has clearly shown that the current fertility evaluations, which have been in place since 2011, have delivered substantial gains in reproductive performance; however, delivering further gains in already high fertility herds requires a reassessment of the approach to genetic evaluations. Particular emphasis is being placed on accounting for the voluntary waiting period between calving and the herd's mating start date more appropriately; consideration is also being given to pregnancy traits. The existing health and management evaluations are also under revision to ensure the evaluations are appropriate for the data currently being recorded.

The EBI in 2023 was also revised to better reflect the beef merit of dairy animals; this was achieved through both a revision of the economic weight on the traits but also the inclusion of age at slaughter to promote bulls whose progeny are fit for slaughter younger. Reducing the age at slaughter of prime beef cattle is a well-recognised strategy to help achieve the carbon reduction targets of Irish agriculture. With more beef cattle now originating from dairy herds, there is an onus on dairy breeding programs to help deliver this target. A new health trait, susceptibility to tuberculosis (TB), is 12% genetic and was also added to the EBI for 2023. The published genetic merit for TB is expressed as the predicted prevalence of TB in that animal's progeny. Therefore, a lower value is more desirable. For example, a bull with a genetic proof of 10% for resistance to TB is predicted to produce progeny where, on average, one in every 10 of his progeny will be diagnosed as a TB reactor, either during a whole-herd test or at slaughter.

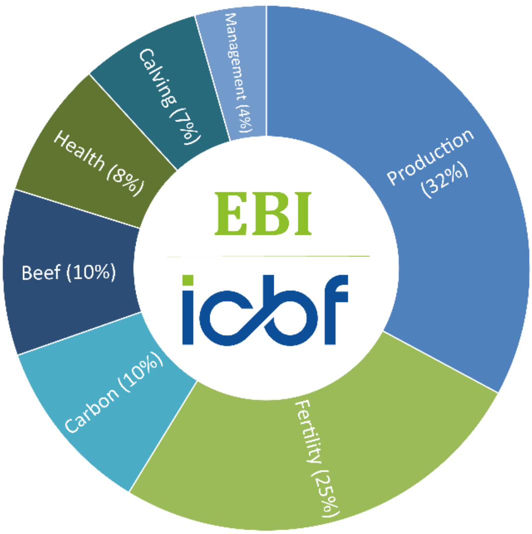

Figure 1. *Relative emphasis of each sub-index within the current EBI*

The pressure to reduce the environmental footprint of Irish agriculture, including dairying, prompted the incorporation of a global first carbon breeding sub-index into the EBI for 2023. Research at Moorepark has clearly shown that high EBI cows are 14% more carbon efficient than cows born in 2000 just before the introduction of the EBI. Nonetheless, more can be done, which instigated the construction of the carbon sub-index. The weighting on each of the 20 traits within the EBI was heretofore simply the expected change in profit per unit change in that trait (holding all other traits constant). The carbon sub-index borrows this approach but instead of the weight being the expected change in profit per unit change in the trait, the weight on each trait within the carbon sub-index is the expected change in carbon output per unit change in that trait. All contributing carbon costs and benefits are included using an approach called complete life-cycle analyses. Hence, the total carbon cost of having to import additional feed should the feed requirements of the herd increase are considered. The carbon weights on the traits included in the EBI are listed in Table 1 along with the respective economic weights of just those traits; the carbon weights are translated to economic weights assuming a carbon cost of €80/t. The carbon weight of 5.52 kg on protein yield, for example, means that each extra kg of protein produced per lactation is expected to be associated with a 5.52 kg greater carbon output (i.e. through greater energy requirements). Multiplied by a carbon cost of €80/t CO_2e, this equates to an economic cost per kg protein due to carbon of €0.44 per kg (this will be a negative value); the economic value on protein owing to the greater profit is €5.88 meaning that the EBI is still strongly selecting for greater protein yield. The emphasis on the individual sub-indexes of the EBI in 2023 is in Figure 1. Milk production and fertility/survival still remain, by far, the greatest contributors to overall EBI representing almost two-thirds of the EBI. Carbon represents 10% of the emphasis within the EBI.

Table 1. *Carbon and economic values for a selection of traits in the EBI*

Trait	Carbon	Economic value	Combined weight	
	Output (kg/unit)	Economic (€/unit)	(€)	(€)
Milk yield (kg)	0.18	-0.01	-0.09	-0.10
Fat yield (kg)	4.68	-0.37	2.08	1.71
Protein yield (kg)	5.52	-0.44	5.88	5.44
Calving interval (d)	18.24	-1.46	-12.59	-14.05
Survival (%)	-13.97	1.12	12.43	13.55
Gestation (d)	11.49	-0.92	7.93	7.01
Age at slaughter (d)	5.40	-0.43	-1.35	-1.78
Carcass weight (kg)	3.24	-0.26	1.38	1.12
Cow maintenance (kg)	5.34	-0.43	-0.74	-1.17

Beef-on-dairy breeding strategies

Many factors have contributed to an intensifying interest in beef-on-dairy matings:

- Improving reproductive performance in dairy herds, reducing the need for dairy heifer replacements
- Herd expansion stagnating on most dairy farms, translating to reduced heifer requirements
- Growing use of dairy sexed semen, meaning that fewer dairy females are required as parents of the next generation, and thus more are available for beef-on-dairy matings
- Greater market opportunities for dairy x beef cattle relative to dairy x dairy.

The dairy beef index (DBI) was launched in 2019 as a tool to help dairy producers identify beef bulls suitable for crossing with dairy females. The construction of the dairy beef index is in Figure 2; one-third of the emphasis is on traits experienced by dairy producers (i.e. calving difficulty, gestation length, calf mortality) while the majority relates to traits associated with beef performance.

The dairy-beef index was updated in 2023 to include age at slaughter as well as a carbon sub-index. The calving and beef components of the DBI are correlated in the opposite direction; this correlation is -0.35 in proven Angus AI bulls. This implies that within-breed selection solely for better calving performance will, on average, reduce the subsequent beef performance of the progeny; the opposite is also true. Such unfavourable correlations can be negated through selection on an index like the DBI where both suites of traits can be simultaneously improved. Evidence of being able to select opposing traits concurrently in favourable directions has clearly been fruitful with the EBI. The unfavourable correlation between milk solids and calving interval in Holstein bulls born before the introduction of the EBI is 0.31; that is, selection for higher yield alone will result in poorer fertility (i.e., longer calving intervals). However, both are improving within the framework of the EBI so the same is possible with the DBI.

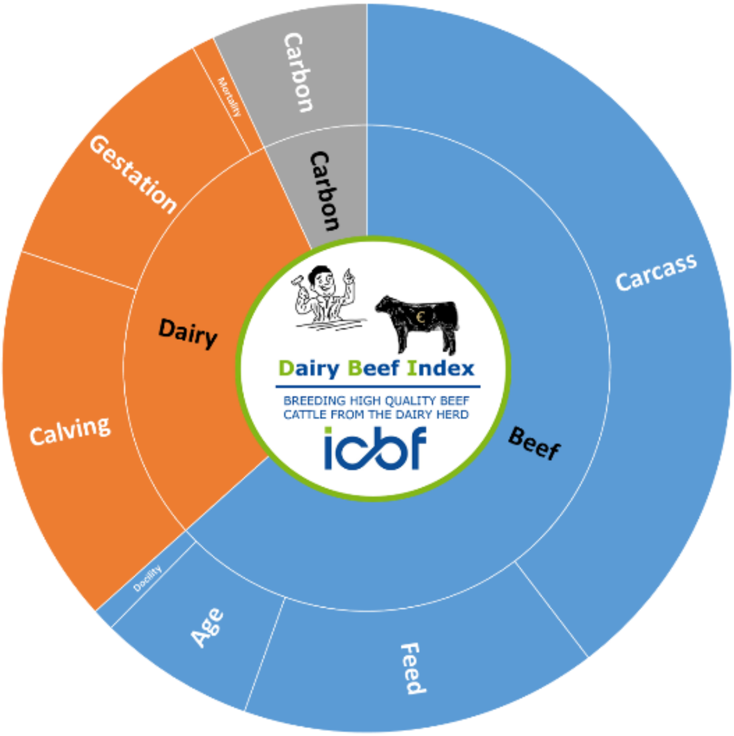

Figure 2. *Relative emphasis of the current DBI*

Like the EBI, the DBI is a guide to bull selection, so consideration must also be given to the individual traits within the DBI in light of the dairy females in the herd, the production system (e.g. when surplus animals are sold), and the personal preferences of the dairy farmer (i.e. willingness to accept slightly more calving difficulty for a more valuable calf). Of immediate interest to dairy producers is gestation length and calving difficulty. A bull with a genetic merit of +1 day for gestation length is expected to translate to an actual gestation length of 282 days when mated to a dairy cow. Each beef bull also has a prediction of its genetic predisposition to cause a difficult calving for heifers and cows separately. The interpretation of the calving difficulty values are the same, however; a bull with a proof (called his PTA) of 3% is expected to require considerable assistance (i.e. calving jack likely required) in three out of every 100 calving events. A bull with a genetic merit for carcass weight of +10 kg is expected to generate heifers and steers with a carcass weight of 293 kg and 347 kg, respectively. A bull with a carcass conformation genetic proof of +1.00 is expected to produce progeny with an O+ to R- grade carcass when mated to a dairy cow.

Once the beef bull team has been selected, they can be inputted into the dairy-beef sire advice to recommend which bull to mate to which female (i.e. heifers and cows). The overriding mathematics underpinning the sire advice is to minimise the risk of a difficult calving. There are two sets of genes that influence calving difficulty in females: 1) those related to the size of the calf (called the direct effects) and 2) those related to the pelvic opening of the cow (called the maternal effects). These are both indirectly estimated when sufficient data exists, such as when the same bull is mated to many different cows enabling the effects to be disentangled. The sire advice algorithm suggests to mate the easiest calving bulls to the females that are more predisposed to a difficult calving (heifers, first parity cows, and cows with a history of calving difficulty), as well as those prone to post-calving disorders (e.g. older cows). The next step is to suggest matings to maximise the probability of the resulting carcass value achieving the desired carcass specifications.

Once the calf is born and genotyped, it will receive a commercial beef value (CBV). The CBV is an indication of expected profit of that animal at the point of slaughter relative to others of the same animal-type. The CBV works on an across-breed basis, whereby there are three animal types: 1) dairy bred, 2) dairy-beef, and 3) suckler beef. The CBV is akin to the dairy-beef index of the sire and dam but without the calving component (since the calf is already born); hence, there is a direct link between the use of high DBI bulls (specifically a high beef sub-index component of the DBI) and producing high CBV calves. Breeding policies to maximise the likelihood of generating high CBV calves is discussed on page 168.

Sexed semen

The use of sexed semen in dairy production allows predetermination of calf sex with ~90% confidence. The recent developments regarding the availability and uptake of sex-sorted semen in Ireland have been remarkable. There was no sex-sorted semen produced in Ireland for the 2021 breeding season with availability limited to only a few Irish bulls that were relocated to a sex-sorting lab in another country or imported foreign bulls from other countries. In November 2021, Sexing Technologies established a sexing laboratory at Teagasc Moorepark, with the primary objective of stimulating the greater availability of sex-sorted semen from more high EBI bulls. The sex-sorting service was available to all AI companies operating in Ireland. For the 2022 breeding season, the lab at Moorepark produced 85,000 straws during a 5-month period. For the 2023 breeding season, Sexing Technologies started sorting at Moorepark in September 2022, and opened a second sexing laboratory at NCBC in November 2022. The combined output of the two labs for the 2023 breeding season was approximately 230,000 straws. There continues to be additional imports of sex-sorted semen from other countries (mainly UK and NZ), meaning that approximately 300,000 straws of sex-sorted semen were available for use in the 2023 breeding season (Figure 3). The enthusiasm for using sex-sorted semen has arisen for several reasons:

- Large teams of high EBI bulls are now available sexed;
- Acceptable pregnancy rates are being achieved across thousands of herds;
- Using high EBI sexed semen on the best EBI dams accelerates herd genetic gain;
- Using sex-sorted semen to generate replacement heifers at the start of the breeding season ensures that all replacements are born at the start of the calving season the following year;
- Sexed-semen programs facilitates a marked increase in the use of high dairy-beef index (DBI) beef semen to generate all non-replacement calves, which could account for over 70% of the total calf crop. These beef-cross calves are more saleable compared with male dairy calves.

Strategies for using sex-sorted semen

The usage of sex-sorted semen must be carefully considered, as overall pregnancy per AI (P/AI) is less for inseminations with sex-sorted semen compared with conventional semen. For example, controlled studies using both sexed semen and conventional semen to inseminate lactating dairy cows in seasonal-calving herds after detected oestrus or Timed AI both reported that, on average, P/AI was ~10 percentage points less for sexed semen. The reasons for a deterioration in P/AI following AI with sex-sorted semen include fewer sperm per straw (4 million in sexed semen straws vs. 15 million in conventional straws), damage to sperm during the sorting process and shorter fertile lifespan in the female reproductive tract. On a positive note, our recent studies have also reported that a subset of herds achieved P/AI with sex-sorted semen that was equivalent to P/AI with conventional semen, highlighting that it is possible to achieve excellent reproductive performance using sexed semen. On the other hand, some herds had poor P/AI with sexed semen, highlighting that attention to detail is critical when using sexed semen. As the sperm cells within the straw have already been exposed to potentially damaging steps during the sorting process, it is likely that sexed semen straws are more susceptible to any errors during the insemination procedure (e.g. thawing temperature, thawing time, cold shock, time from thaw to completion of insemination). When sexed semen was used fresh (i.e. without cryopreservation), field data generated in New Zealand indicated non-return rates that were comparable with conventional semen. Hence, freeze-thawing is potentially a large source of fertility loss, and needs to be implemented with strict adherence to protocols. It is likely that the difference in P/AI between conventional semen and sex-sorted semen will continue to shrink as the technologies for creating sex-biased semen improve in the years to come, fostering greater usage of sexed semen. The key strategies for successful use of sexed semen require consideration of sire and dam choice, timing of AI, and straw handling on the day of AI, and are summarised in Box 1.

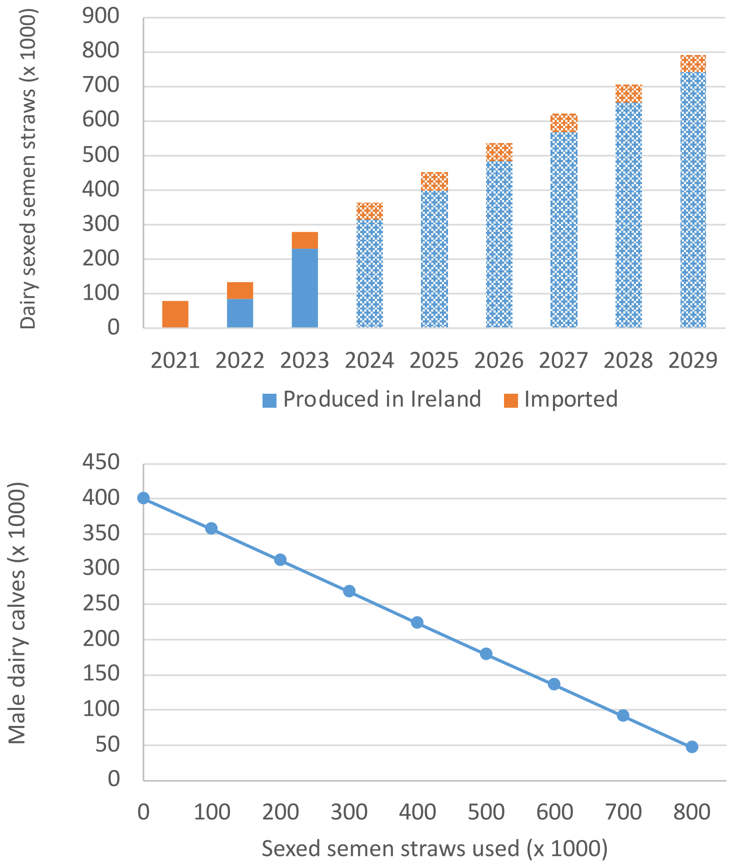

Figure 3. *Top panel: approximate figures for sexed semen source and usage during 2021 to 2023 (solid bars) and projection for potential usage in the years 2024 to 2029 (hatched bars). Bottom panel: relationship between the number of dairy sexed semen straws used and the number of male dairy calves born*

Sire and dam choice

- **Bulls**
  - Pick highest EBI bulls available
  - Use a large team of bulls
- **Dams**
  - **Top 50% of herd based on EBI**
    - Heifers
      - Target live-weight and BCS ≥3.25
      - Cycling regularly
    - Cows
      - Parity 1 to 4
      - >50 days in milk on day of AI
      - BCS ≥3.00
      - Cycling regularly
      - No postpartum disorders or uterine disease

When to use?

- First 3 weeks of the breeding season
- Within first 10 days if possible.

Timing of AI

- 14 to 20 h after heat onset

Fixed time AI

- Costly, but mitigates risk
- Facilitates targeted usage of sexed semen on MSD

Straw handling on day of AI

- Organise sexed straws into one goblet
- Thaw 2 sexed semen straws at a time MAX
- Thaw straws at 35 to 37°C for 45 seconds
- Load straws into pre-warmed AI guns, keep warm
- Deposit semen in uterine body
- Complete inseminations within 5 mins

Box 1. *Strategies to maximise success with sexed semen*

Future innovations

Three characteristics dictate whether a trait should be considered for inclusion in breeding indexes like the EBI or DBI:

- Is the trait economically, socially or environmentally important?
- Are there genetic differences among animals for the trait in question?
- Can the trait be measured on a large number of animals or correlated with a measureable trait?

Traits being explored currently relate to feed intake, methane emissions and nitrogen use efficiency. All are important and genetic variation exists for all. None of the traits are easily measurable, however, and how selection for these traits influence the production system as a whole has not yet been characterised. While research on new traits is on-going, improvements to the on-going genetic evaluations for current traits is also important; one such trait is gestation length.

While sexed semen will reduce the number of male dairy calves born, one of the implications of greater usage of sexed dairy semen targeted at the highest EBI dams will be a reduction in the numbers of high EBI male dairy calves. Hence, the next generation of AI bulls will need to be generated using an alternative approach. One viable approach being researched is the use of in vitro produced embryos generated by harvesting oocytes (or eggs) from elite genetic merit dams, fertilizing these in a lab using semen collected from high EBI bulls, and allowing the resulting embryo to develop for one week before either freezing (for later use) or transferring into a suitable recipient dam that that been synchronized to be at the same stage of the cycle as the age of the embryo (i.e. day 7). Using this approach for several weeks allows an individual dam to generate up to 20 pregnancies with several different sires in a single breeding season. It is also possible to use sexed semen for fertilization, allowing the breeder to produce mostly male offspring (Y-sorted semen) or female offspring (X-sorted semen) as desired. Of note, this method can be applied to both dairy breeds and beef breeds, ensuring that genetic gain can be achieved in both EBI and DBI when the methods are used appropriately.

Conclusions

Breeding and reproductive programs contribute approximately 50% of the observed improvements in productivity on Irish dairy farms over time. Substantial scientific advancements have been made in recent years, which have translated into breeding and reproductive tools to exploit these developments. The EBI is for selecting dairy cows and bulls for breeding dairy replacements, the DBI is for selecting beef bulls to mate to dairy cows and the CBV is applied to genotyped calves as a measure of their beef value. Sexed dairy semen can be used to generate replacement dairy females from suitable high EBI cows with the remainder of the cows mated to beef semen to increase the value of the resulting calves.

Appendix 1 - Dairy Breeding Guidelines

EBI will continue to be the tool to deliver on the three pillars of on-farm sustainability

- All farmers should use sexed semen to generate some or all of their dairy heifer calves. Plan to use at least two sexed semen straws to generate each dairy female required.
- Ideally only consider the top 50% EBI females in your herd for mating to high EBI dairy bulls when using sexed semen. All remaining females should be considered for mating to beef bulls with a high Dairy Beef Index value from the start of the breeding season.
- Select a team of high EBI AI bulls from the ICBF dairy active bull list to breed your dairy herd replacements. Use the team of bulls equally with no more than 15% of mating's to any individual bull to minimise genetic and fertility risks. For a typical 100 cow dairy herd, at least 8 bulls should be used, with no more than 15 straws (i.e., 15% mating's) to any individual bull.
- Ensure that inseminations with sexed semen are completed in the first 3-weeks of the breeding season and prioritise usage on maiden heifers, younger cows, earlier calving cows, and cows without health issues. Use a large team of high EBI bulls to minimise genetic and fertility risks. Contact your AI technician in advance of using sexed semen, pay careful attention to AI procedures, and the optimum timing of AI for sexed semen is 14 to 20 h after the onset of standing heat.
- To ensure saleable, profitable, and sustainable dairy-beef cattle are generated, use beef AI bulls from the ICBF Dairy-Beef Active bull list. It's recommended to firstly select bulls with a calving difficulty percentage range suitable for the females being mated (i.e., first calvers, second calvers, mature cows), and then select bulls with the highest Beef sub-index value.
- Use the ICBF HerdPlus Sire Advice Tool. It will simplify the process of bull selection and identify the optimum mating for both dairy and beef bulls. The tool will allocate dairy bulls to cows based on their strengths & weaknesses, as well as manage inbreeding. The tool also identifies the optimum beef AI bull mating to minimise calving issues and maximise beef merit.

Grassland – the source of a sustainable future

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Summary

- During the four year period from 2019-2022, the difference in annual grass DM production between the top 25% and bottom 25% of farms recording data in PastureBase Ireland was 4.9 t DM/ha.
- By optimising soil nitrogen (N) mineralisation, incorporating clover into grass swards and refining chemical N fertiliser input, the total N supply available to a sward can range between 450-500 kg N/ha (soil N + legume N + chemical N).
- Precision N management (using grass growth predictions and grass measurement) is a key tool to optimise grass production and minimise N loss.
- Grass-clover swards with 20% clover content can produce between 12.5 to 14.5 t DM/ha with 150-200 kg chemical N/ha.
- Incorporating white clover into swards and reducing chemical N fertiliser application according to sward clover content can reduce farm gate N surplus.
- Over-sowing clover is an effective option to increase white clover content in grazing swards without reducing farm pasture DM production.

Introduction

The EU Green Deal Farm-to-Fork strategy has set a target to reduce nutrient losses by at least 50% and fertiliser use by at least 20% by 2030. Water quality is regulated in the EU and Ireland by the Water Framework Directive (WFD; EC, 2000), which requires at least "good" water quality in all EU water bodies (rivers, lakes, groundwater, and transitional coastal waters). In Ireland, this must be achieved by 2027. The ecological status of Irish surface waters and groundwater are better than most EU countries; 54% of Irish surface waters have either a good or high status compared with 44% in the EU, and 92% of groundwater has good status compared with 80% in the EU (EPA, 2022). The average annual national use of N during the four year period from 2018 to 2021 was 373,365 t/year, peaking at 408,495 t in 2018. In 2022, the nitrogen (N) use in Ireland reduced to 343,000 t, in part due to increased cost as well as supply issues. The current target for N use in the agriculture sector is to reduce N fertiliser application to 300,000 t by 2030.

On grazed grassland, excessive N application in the form of chemical N fertiliser, slurry and N fixation are drivers of N loss to waterways, particularly in the form of nitrate leaching. Climate factors such as rainfall and soil temperature impact N mobility within the soil, and have a major influence on nitrate leaching. There are many challenges facing Irish agriculture, including environmental emissions reduction targets, reduced N fertiliser allowances and rising production costs. Grassland continues to be the lowest cost feed for milk and meat production systems in Ireland and ensuring optimum production of adequate quantities of high quality pasture must continue to be an important management focus of dairy farmers. In addition, grassland contributes to carbon (C) sequestration and increased biodiversity. This paper will provide the latest research findings and current best practice in pasture-based dairying systems, specifically looking at herbage production, and use of grass-white clover swards to reduce the environmental footprint and improve productivity. In the current environment of reduced chemical N fertiliser allowances and use, it is crucial that grazing and conservation legumes (white and red clover) are seamlessly incorporated into pasture-based production systems.

Current herbage DM production on dairy farms

The number of grassland farmers using Pasturebase Ireland (PBI) has increased significantly in recent years. Using PBI to provide information on grass supply on farm, combined with current and predicted grass growth rates has facilitated more efficient use of grazed grass.

From 2019-2022, overall DM production on the milking platform has declined from 13.6 t DM/ha to 12.2 t DM/ha (Table 1). Much of this reduction is a result of a decline in the quantity of silage harvested from the grazing platform. While the average number of defoliation events (i.e. grazing or silage harvesting) over the four year period was static at 7.9, two additional grazing events occurred on the top 25% of PBI farms compared with the bottom 25%. In many cases, the extra grazing events occurred because the frequency of grazing was quicker on these farms, especially in the earlier half of the grazing season. Each grazing event equates to approximately 1,300-1,600 kg DM/ha. Over the last four years, the difference in pasture DM production between the top 25% and bottom 25% of farms in PBI was 4.9 t DM/ha, which equates to enough feed (grazed grass and grass silage) for approximately one full livestock unit. The impact of grazing management decisions on herbage production is often overlooked when examining the variation in production performance between farms.

Table 1. *Average herbage DM production and the range in performance of the top and bottom 25% of farmers completing >30 covers in PastureBase Ireland from 2019 to 2022*

	Total DM production (t DM/ha)	Grazing DM production (t DM/ha)	Silage DM production (t DM/ha)	No. of grazings	No. of silage cuts	No. of defoliation events (grazing and/or silage) per paddock
2022						
Average	12.2	10.8	1.3	7.7	0.4	8.1
Top 25%	14.4	12.8	1.6	8.6	0.4	9.0
Bottom 25%	9.9	8.9	0.95	6.8	0.3	7.1
2021						
Average	12.7	11.1	1.7	7.4	0.5	7.9
Top 25%	15.2	13.0	2.1	8.3	0.5	8.8
Bottom 25%	10.2	9.1	1.2	6.5	0.4	6.9
2020						
Average	12.9	10.8	2.1	7.0	0.6	7.6
Top 25%	15.6	13.1	2.5	8.0	0.7	8.7
Bottom 25%	10.1	8.6	1.5	6.0	0.5	6.5
2019						
Average	13.6	11.3	2.2	7.2	0.7	7.9
Top 25%	16.0	13.2	2.8	8.0	0.7	8.7
Bottom 25%	11.5	9.7	1.7	6.5	0.5	7.0

Grazing management

In grazing systems, there is a very strong relationship between overall farm financial performance and grass utilised per hectare (Hanrahan *et al.*, 2017). The two key drivers of grass utilisation are stocking rate and supplementary feed levels. If the overall stocking rate is greater than or less than the grass growth and utilisation capacity of the farm, farm profitability will be reduced. It is critical that farms are stocked appropriately based on an accurate assessment of average grass growth and grass utilisation. For grassland farmers that can grow ≥14 t DM/ha, the appropriate stocking rate is 2.5 cows/ha, feeding approximately 500-700 kg concentrate/cow.

The key factors that influence pasture productivity include soil fertility, using high Pasture Profit Index (PPI) perennial ryegrass varieties, achieving a high number of grazing's per paddock and achieving the grazing targets throughout the year. The key grazing targets across the year are:

- >900 kg DM/ha opening farm cover – early February
- 550-600 kg DM/ha average farm cover – early April
- 160-180 kg DM/LU - mid-season
- 1,100 kg DM/ha - mid September

Mid-Season Management

The primary objective during the main grazing season is to maintain high animal performance from an all-grass diet, while at the same time maintaining high pasture quality. In general, from late April onwards, grass supply exceeds demand, and pre-grazing herbage mass should be maintained at 1,300 to 1,600 kg DM/ha, with a grazing residual of 50 kg DM/ha (4 cm post-grazing height). Excellent pasture quality is required to maximize animal performance from pasture in summer. From mid-April to mid-August, farm cover should be maintained at between 160 to 180 kg DM/cow with a rotation length of 18-21 days. During this period, aim to achieve six grazing rotations and utilize 8,000 kg DM/ha. Paddocks with surplus grass should be removed as they are identified to maintain grass quality while keeping them within the grazing rotation. In periods of exceptionally high growth rates, however, paddocks identified as surplus can be held for an additional period of time to increase silage yield and to better match growth rates and demand. Maintaining high herbage quality offers the potential to achieve further increases in animal performance from pasture.

During mid-season when grass growth exceeds herd demand, the N fertiliser application strategy needs to be carefully considered. For example, reducing chemical N fertiliser application will reduce the number of rotations with surplus grass which needs to be harvested as bales. Developing a mid-season N fertiliser plan for your farm in PBI can improve the management of N fertiliser as well as managing grass quality and supply.

Autumn Management

Typically, the grazing rotation length is extended from mid-August (+ 2 days/week) to allow for the build-up of large quantities of herbage before the decline in grass growth, allowing for the extension of the grazing season into November. Peak farm cover should be achieved in mid-September (~1,100 kg DM/ha). Achieving this will reduce supplementation requirement for the remainder of the grazing season. Autumn closing date is the main management factor influencing the supply of grass in early spring. To ensure that adequate quantities of grass are available at the start of the first rotation (early February), an average farm cover, at closing (1st December), of between 650-750 kg DM/ha is required and is dependent on individual farm demand (stocking rate). Farmers must calculate their own spring grass demand based on planned start of the first rotation, stocking rate, calving pattern and previous five year average spring grass growth rates on their farm, and implement an autumn closing strategy to facilitate the required opening farm cover in spring. The final decisions regarding closing strategy also require some consideration of the expected grass growth rate over the winter period.

Nitrogen supply in grassland systems

There is now a major focus on N fertiliser use in grassland systems. The N supply in pasture-based production systems comes from three sources:

- The soil (through N mineralisation)
- White clover in grazing swards (through biological N fixation)
- Applications of N (chemical and slurry).

All three of these N sources in pasture-based systems work alongside each other, and can influence each other. Improved grazing management allows for better coupling of C and N cycles with herbage production, soil organic matter and soil microbial biomass that increases overall plant growth. The expectation is that soil can supply between 100 to 200 kg N/ha per year through mineralisation of the N stored in the soil organic matter. The quantity supplied is very much dependant on the soil organic matter content, weather/climate conditions, soil microbial activities and grazing management practices. Chemical fertilisers can have both positive and negative impacts on soil N mineralisation. Chemical fertilisers provide essential nutrients (mainly N, P, K and S) that enhance plant growth and pasture DM production. This increased plant growth can lead to increased C and N inputs to the soil through increased root and shoot biomass, which can stimulate soil microbial activity and N mineralisation. Excessive use of chemical fertilisers can lead to an imbalance of nutrients in the soil and the leaching of nitrates, adversely affecting soil microbial communities and leading to soil acidification. This can result in a decrease in soil organic matter and a reduction in the capacity of the soil to retain nutrients. It is important to use chemical N fertiliser in moderation and in conjunction with other soil management practices.

Table 2. *Herbage DM production, herbage N yield from soil N mineralisation, herbage N yield from biological N fixation via clover and total herbage N yield (soil, chemical N fertiliser and biological N fixation) at Moorepark and Clonakilty*

Location	Sward type	Chemical N application rate (kg N/ha)	Paddock herbage DM yield (t DM/ha)	Herbage DM yield from zero N plots within each paddock (t DM/ha)	Herbage N yield from soil mineralisation (N from soil) (kg N/ha)	Herbage N yield from biological N fixation via clover (kg N/ha)	Total nitrogen yield (kg N/ha) (Sum of N yield from chemical N fertiliser, soil N mineralisation and biological N fixation)
Moorepark	Grass-only	225	14.7	7.8	182	0	407
	Grass-clover	150	12.5	9.1	185	101	436
Clonakilty	Grass-only	200	12.1	8.0	202	0	402
	Grass-clover	200	13.4	11.5	202	103	505

Source: *(Murray and Hennessy, unpublished)*

White clover has the capacity to fix atmospheric N and make it available for plant growth. This occurs through a symbiotic relationship whereby rhizobia bacteria in the soil infect clover root hairs and form root nodules. The clover then supplies the bacteria with energy (from photosynthesis) to fix N, which is available to the clover plant and other plants for growth. Biological N fixation is very dependent on the sward clover content. A number of Teagasc experiments reported that the quantity of N fixed in grass-white clover swards was generally around 100 kg N/ha once the clover content is >20% (see Table 2). If the clover content is too high, however, total DM production can be reduced due to inadequate levels of perennial ryegrass in the swards to utilise the additional N fixed by the clover and can result in an increase in N losses.

The pasture DM production and N yield from grass-only and grass-clover swards in Moorepark and Clonakilty is summarized in Table 2. The overall N supplied to the grass-only and grass-white clover sward was 407 kg N/ha and 436 kg N/ha, respectively, at Moorepark. At Clonakilty, the overall N supplied to the grass-only and grass-clover sward was 402 kg N/ha and 505 kg N/ha, respectively. Herbage N yield from soil N mineralisation accounted for 184 and 202 kg N/ha at Moorepark and Clonakilty, respectively. At Clonakilty, the sward white clover content was 16.5%, while it was 22% at Moorepark. White clover contributed a herbage N yield of 102 kg N/ha via biological N fixation at both sites. The results of the research clearly show that biological N fixation can contribute to the N supply in well managed clover swards. At both sites, when the quantity of N supply from all three supply sources was combined (soil N mineralisation, chemical N fertiliser and biological N fixation), the N supply was greatest in the swards that included clover despite having a lower chemical N fertiliser input.

What is Precision Nitrogen Management and why is it required?

To-date, chemical N fertiliser application guidelines have very much followed a calendar pattern. In recent years, however, weather patterns in spring, summer and autumn have all been very unpredictable, with no two consecutive years following similar patterns for rainfall and daily temperatures. The pattern of monthly rainfall for the last five years for Moorepark is summarized in Table 3. While the pattern of rainfall is very inconsistent between years, the total end of year total is generally very similar, even when there have been very dry periods within years. What is striking though, is that in 19 of the last 63 months (30%) rainfall was <50 mm (Table 3), which can result in soil moisture deficits during the main grazing season (April to September). In 2018, there was four consecutive months with <50 mm of rainfall from May to August, which had a severe impact on pasture production (-3 t DM/ha). In 2022, three months (May, July and August) recorded <50 mm rainfall. If this pattern of inadequate rainfall during the main growing months of the year continues, management practises need to change. Specifically, N management during these periods, as well as in spring, needs to be refined to achieve a better response to fertiliser and reduce the risk of nitrate leaching in autumn. It is not practical to depend solely on traditional calendar dates to apply chemical fertiliser, and instead live grassland data from Pasturebase Ireland and Met Éireann should also be used to maximise grass production and response to chemical N fertiliser application.

Table 3. *Mean monthly and total rainfall from 2018 to 2023 at Teagasc Moorepark. Months where rainfall was <50 mm are highlighted in yellow*

	2023	2022	2021	2020	2019	2018
January	104	43	60	10	66	138
February	17	97	190	153	57	40
March	144	83	53	48	118	89
April	53	69	23	65	109	175
May	51	44	131	37	26	49
June		73	27	73	88	32
July		34	63	73	35	43
August		28	58	145	107	43
September		140	102	43	72	60
October		230	125	102	155	72
November		165	33	119	141	167
December		90	135	153	115	168
Total	**369***	**1,096**	**1,000**	**1,021**	**1,089**	**1,076**

**Rainfall year to-date 2023*

Key points to follow on Precision Nitrogen Management

- *Match chemical N fertiliser application rate to grass demand, use the predicted growth rates in the Grass 10 newsletter*
- *Avoid spreading chemical N fertiliser when heavy rainfall and low soil temperature are forecasted (for example - in March 2023 there was no appropriate window to spread N)*
- *Cease N fertiliser applications mid-season when grass growth is less than 30 kg DM/ha*
- *Target lower N fertiliser applications when sward clover content is >20%*
- *Soiled water can be used strategically to replace chemical N fertiliser in grazing swards*
- *Test slurry samples to determine N content and adjust chemical N fertiliser application rates accordingly*
- *Replace some chemical N fertiliser application levels in spring in line with slurry applied using low emissions slurry systems.*

Long-term Clover research at Moorepark

Eight years (2013-2020; Table 4) of research at Moorepark have been completed comparing the standard grass-only grazing system receiving 250 kg fertiliser N/ha with a grass-white clover system receiving 150 kg N/ha. Average sward clover content across the season was 22%. The chemical N fertiliser application rate for each treatment was similar until late April (83 kg N/ha spread), after which the grass-white clover 150 kg N/ha treatment received 9 kg N/ha/month.

Although there was a 100 kg reduction in chemical N application, there was no difference in cumulative herbage production (13.6 t DM/ha). Approximately 75 kg DM/cow more silage was fed during lactation to the grass-white clover cows, mostly in autumn to extend the grazing rotation and to ensure peak average farm cover was achieved. Milk yield and milk solids yield were greater on the grass-white clover system compared with the grass-only system. Reduced chemical N fertiliser inputs and increased milk production contributed to increased net profit in the grass-white clover system compared with the grass-only system, with an overall increase in net profit from the grass-white clover system in the region of €404/ha based on 2022 input and milk prices.

Table 4. *Average animal and sward production on grass-only swards receiving 250 kg N/ha and grass-white clover swards receiving 150 kg N/ha from 2013 - 2020*

	Grass-only 250 kg N/ha	Grass-white clover 150 kg N/ha	Difference
Stocking rate (cows/ha)	2.74	2.74	-
Annual herbage production (t DM/ha)	13.8	13.5	-0.3
Silage conserved (t DM/cow)	1.00	0.98	-0.02
Silage fed during lactation (kg DM/cow)	259	333	+74
Average sward clover content (%)	-	22.0	-
Milk yield per cow (kg)	6,068	6,331	+243
Milk solids yield per cow (kg)	490	510	+20
Concentrate fed (kg/cow)	438	438	-
Nitrogen use efficiency (%) (2013-2016)	40	58	+18
Nitrogen surplus (kg N/ha)	141	63	-78

The farm gate N surplus for the grass-white clover system was low at 63 kg N/ha compared with 141 kg N/ha for the grass-only system. The National Farm Survey reported that the participating farms had an average farm gate N surplus of approximately 176 kg N/ha. Reducing farm gate N surplus is possible when average annual sward white clover content is approximately 20% or greater.

Incorporating white clover on commercial farms – Clover150 project

In 2021, a group of 36 farmers from across the country were enrolled in the five year Clover150 project. The farms included a range of land types, geographical spread, climate conditions and farming enterprises. White clover is being established on the farms through a combination of reseeding and over-sowing. The project objectives are to:

- Maintain herbage production ≥ 14 t DM/ha grown
- Reduce farm gate N surplus to <130 kg N/ha and increase farm gate N use efficiency (NUE) to >40%
- Reduce chemical N fertiliser application to ≤ 150 kg N/ha per year
- Maintain average sward clover content >20%

Increasing the clover area on farm

In 2020, the Clover150 farms had clover on <10% of their milking platform area; by April 2022, the average area with clover present had increased to 45%, and by the end of 2022, 64% of the milking platform area had clover. The project aims to have an average annual sward clover content of >20% on 100% of the grazing platform. The increase in the clover area on the milking platform was achieved through a combination of reseeding and over-sowing, with approximately 15% of the milking platform over-sown annually. The main lesson learned from the first year of over-sowing (2020), was that it took place too late. Over-sowing must be completed early in the year (late March to early May) to have a successful impact. Data from the Clover150 farms shows that paddocks over-sown in the month of April had, on average, 20% sward clover content by the end of the sowing year, whereas paddocks over-sown from May onwards only achieved 14% sward clover content (Figure 1). Adequate soil moisture levels are essential at the time of over-sowing and in the first six weeks post-sowing. Over-sowing has proven to be a very successful method for rapid clover establishment on farms, and has been shown in the Clover150 farms to be as successful as reseeding in terms of establishing white clover. Across the farms, the over-sown paddocks had, on average, 15% sward clover content in the sowing year, while reseeded paddocks also had, on average, 15% sward clover content. The over-sown paddocks had greater herbage DM production in the establishment year compared with reseeded paddocks (13.2 vs 9.9 t DM/ha, respectively), mainly due to the over-sown paddocks remaining in the grazing rotation throughout the establishment period.

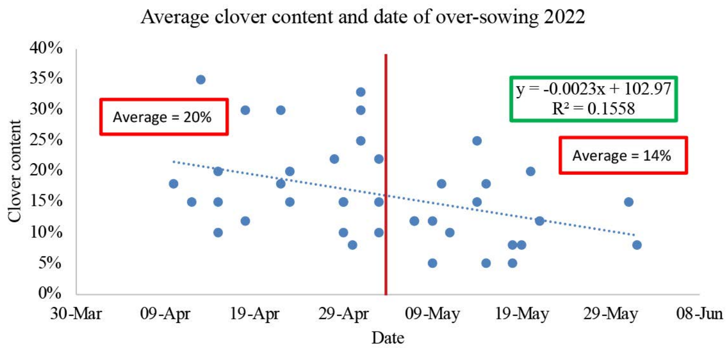

Figure 1. *The impact of over-sowing date on average sward clover content from three estimations in the sowing year on the Clover150 farms*

The impact of increasing the proportion of the milking platform containing clover on the Clover150 farms

PastureBase Ireland data for the last three years on the Clover150 farms shows that chemical N fertiliser application in 2020 was 232 kg N/ha and herbage production was 14.4 t DM/ha. In 2021 chemical N fertiliser application declined by 26 kg N/ha and pasture production was 14.1 t DM/ha. From 2021 to 2022 chemical N fertiliser application declined by a further 48 kg N/ha to 158 kg N/ha, and pasture production was 13.2 t DM/ha (Table 5), despite a considerable summer drought on the majority of farms in 2022. This reduction in chemical N application resulted in a significant improvement in farm gate N surplus and NUE on the Clover150 farms. Farm gate N surplus and NUE were 194 kg N/ha and 31%, respectively, in 2020. By the end of the third year (2022), the farm gate N surplus had reduced by 55 kg N/ha (to 139 kg N/ha), while farm gate NUE had increased to 39%. This improvement in farm gate N surplus and NUE was largely driven by the reduction in chemical N fertiliser application.

A worrying trend on the Clover150 farms is the increase in N/ha derived from purchased concentrate feeds, an increase of 11 kg N/ha from 2020 to 2022. It is vital that any reduction in chemical N fertiliser is not replaced by another form of purchased N, in this case N contained in concentrate or bought in feeds. When clover and N reductions are in place on farm, it is a vital that herbage production must be maintained on farms, highlighting the importance of targeted reductions in the use of chemical N fertiliser on clover paddocks within the farm.

Table 5. *Summary of Total N applied, chemical N applied and the annual dry matter produced*

	2020	2021	2022
Farm gate N surplus (kg N/ha)	194	179	139
Farm gate N use efficiency (%)	31%	33%	39%
Chemical N fertiliser application (kg N/ha)	232	206	158
Total N application (chemical and organic; kg N/ha)	254	240	197
Concentrate fed (kg N/ha)	41	43	52
Area under white clover (%)	10%	45%	64%
Herbage production (t DM/ha)	14.4	14.1	13.2

Altering nitrogen applications on grass-white clover swards

One of the major findings from the Clover150 farms has been the benefit of having a pre-planned paddock N fertiliser application plan in place. Regardless of the clover area on-farm, farmers should take the opportunity to plan the fertiliser N application for each paddock for the grass production year, which can result in reductions in chemical N fertiliser application, and better use of slurry N and soiled water N. The N Planner in PBI allows farmers to plan individual paddock requirements (grazing/silage and clover/non-clover) and tailor chemical and organic N fertiliser applications to individual paddocks. The level of clover in the sward, total N fertiliser applied and cumulative herbage production on paddocks on the Clover150 farms are summarised in Table 6. It is apparent that where sward clover content was >20%, a significant reduction in chemical N fertiliser application was achieved while maintaining high levels of herbage production. Reducing chemical N fertiliser application when sward clover content was <20%, resulted in a reduction in the quantity of herbage grown, highlighting the requirement for careful planning of the N fertiliser application strategy depending on the level of clover present in paddocks.

Table 6. *The impact of sward clover content and N fertiliser application on herbage production in paddocks on the Clover150 Farms*

Clover %	Area (ha)	Chemical N fertiliser application (kg N/ha)	Organic N application (slurry and soiled water) (kg N/ha)	Total N application (chemical and organic) (kg N/ha)	Annual pasture production (t DM/ha)
0%	430	180	24	204	12.6
<10%	455	161	21	183	12.4
10 - 20%	370	158	27	185	12.4
21 - 30%	266	130	29	160	12.9
> 30%	108	82	43	125	13.4

Conclusions

Careful planning of chemical N fertiliser application is necessary to increase pasture production and N responses, while also reducing the potential loss of N to the environment. New grazing management practises encompass improved seasonal grazing management, incorporation of legumes into grazing and silage swards and precision N management across the grazing season. White clover plays and will continue to play a key role in reducing the requirement for chemical N fertiliser, but also reducing farm gate N surplus while maintaining herbage production levels on-farm. Increasing sward clover content to >20% will allow herbage production to be maintained on farms, allowing chemical N fertiliser to be reduced. The major focus for dairy farms in the next two to three years will be to increase the clover content in swards (through reseeding and over-sowing), but also improving soil fertility and grazing management practises. Farmers should now begin accounting for the farm gate N surplus generated on their farms and identify avenues to reduce this surplus without compromising the overall pasture DM production of the farm.


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Grassland Village

The milk production benefits of incorporating white clover in grass swards

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Summary

- Dairy cows grazing grass-white clover swards have higher daily milk yield (+1.1-1.3 kg per cow) and milk solids yield (+0.07-0.11 kg per cow) compared with cows grazing grass-only swards.
- Increased milk yield is associated with higher dry matter intake by cows grazing grass-white clover swards compared to cows grazing grass-only swards (+0.5-1 kg DM per cow per day) in summer and autumn.

Introduction

The sustainability of Irish milk production systems is underpinned by the efficient conversion of grazed grass to milk. Irish pasture-based milk production systems are amongst the most efficient in the world, converting a low cost, home-grown feed source, grass, into milk. Dairy cows convert a human in-edible protein source (pasture) into a human edible protein (milk). Sustainable grass-based systems require the introduction of white clover to reduce the use of chemical nitrogen fertiliser, achieved through the nitrogen fixing capacity of white clover (see McCarthy *et al.* elsewhere in this publication). Another benefit of white clover for the dairy farmer is increased milk production. A number of grazing systems experiments have been undertaken since 2013 at Moorepark and Clonakilty examining the role of white clover in pasture-based milk production systems. This paper will summarise the research findings in terms of milk production.

Results

Milk production is influenced by the dry matter intake (DMI) of the dairy cow and the quality of the feed ingested (Table 1). Data from Moorepark shows that, on average, cows grazing grass-white clover swards with an average annual white clover content of 21% had 1.0 kg/cow greater total DMI compared to cows grazing grass-only swards. At Clonakilty, cows grazing grass-white clover swards (average clover content of 16%) had 0.5 kg/cow greater total DMI compared to cows grazing grass-only swards. The increased DMI occurred in summer and autumn, when sward neutral detergent fibre (NDF) content (fibre) was lower in grass-white clover swards compared to grass-only swards (Table 2). Lower fibre content allows faster passage rate of feed through the cows rumen, promoting greater DMI.

Cows grazing grass-white clover swards at Moorepark and Clonakilty had higher milk yield (+1.2 kg/cow per day) and milk solids yield (+0.09 kg/cow per day) compared to those grazing grass-only swards (Table 1). The milk constituents were similar (fat and protein %), and so the increased milk solids yield was as a result of increased milk volume.

Table 1. *Average dry matter intake and milk production from cows grazing grass-only and grass-white clover swards, and sward quality parameters, at Moorepark and Clonakilty*

	Grass-only	Grass-white clover
Moorepark research		
Dry matter intake (kg per cow)	16.3	17.3
Milk yield (kg per cow per day)	20.5	21.6
Milk solids yield (kg per cow per day)	1.74	1.81
Fat (%)	4.83	4.89
Protein (%)	3.71	3.69
Clonakilty research		
Total dry matter intake (kg per cow)	16.7	17.2
Milk yield (kg per cow per day)	19.1	20.4
Milk solids yield (kg per cow per day)	1.61	1.72
Fat (%)	4.79	4.75
Protein (%)	3.84	3.84

Table 2. *Sward quality parameters, at Moorepark and Clonakilty, in grass-only swards in spring (May), summer (July) and autumn (September)*

	Spring		Summer		Autumn	
	Grass-only	Grass-white clover	Grass-only	Grass-white clover	Grass-only	Grass-white clover
Moorepark Research						
Sward clover content (%)	-	18.9	-	31.3	-	37.7
Crude protein content (%)	21.2	20.8	20.7	21.7	24.1	24.5
NDF content (%)	34.9	34.4	39.6	36.4	39.8	36.2
Organic matter digestibility (%)	86.1	86.2	82.4	82.2	82.5	82.1
Clonakilty Research						
Sward clover content (%)	-	9.0	-	14.2	-	23.7
Crude protein content (%)	19.7	21.6	18.0	21.3	17.5	21.1
NDF content (%)	36.0	35.3	41.4	39.6	41.2	36.9
Organic matter digestibility (%)	78.9	78.8	78.6	78.8	77.5	78.0

Conclusions

Incorporating white clover in grassland swards results in increased dairy cow DMI and increased milk yield and milk solids yield compared to cows grazing grass-only swards.

Acknowledgements

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Using white clover to reduce nitrogen fertilisation

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Summary

- Reduced nitrogen fertiliser use at farm level will require greater utilisation of white clover in grazing swards in order to maintain herbage production.
- White clover can fix up to 220 kg nitrogen/hectare per year.
- Similar grass DM production can be achieved from grass-white clover swards receiving 100 kg less nitrogen/hectare than grass-only swards.

Introduction

Recent European Union and Irish Government policy changes have placed a greater emphasis on reducing nitrogen (N) fertiliser use at farm level to improve the environmental sustainability of agriculture. The updated Climate Action Plan, released by the Irish Government in 2022, has set a maximum limit of 300,000 t of N fertiliser use for the agricultural sector in Ireland by 2030. To put this into context, in 2021 399,000 t were used and a reduced level of 343,193 t were used in 2022. This was a 14% reduction from 2021 levels and was largely driven by the huge increase in fertiliser price in 2022. Clover, both red and white, will play a significant role in offsetting the reduction in N fertiliser use on Irish farms while helping to maintain adequate grass dry matter (DM) production at farm level. This is achieved through the biological N fixing ability of red and white clover. Red clover is likely to play a significant role in silage swards where it can reliably produce high yields of high quality silage with little to no N fertiliser application. White clover inclusion will be the main mechanism to facilitate reductions in N fertiliser use in grazing swards. White clover is the most commonly sown legume species in temperate grassland due to the fact that it grows well in association with grass, can persist within the sward when established and maintained, and is tolerant of grazing.

Biological N fixation

Clover can fix N from the atmosphere and make it available for plant growth. Rhizobia bacteria live in nodules on the roots of clover and fix N making it available for plant growth. Research has shown that between 0 to 220kg N/ha per year can be fixed when clover is included in grass swards (Figure 1). The rate of N fixation is influenced by N fertiliser supply to the sward and the sward clover content. Generally, an average annual sward clover content of at least 20% is required for sufficient N fixation. In fertilised swards, as N fertiliser application rate increases, N fixation generally declines (Figure 1).

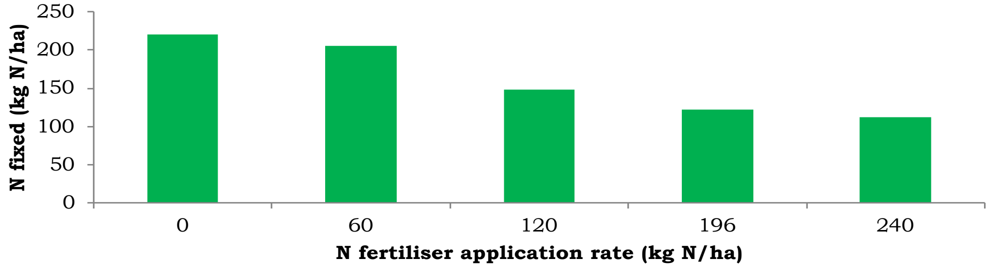

Figure 1. *Nitrogen fixation (kg N/ha) on grass clover swards receiving 0, 60, 120, 196 and 240 kg N fertiliser/ha over three years*

White clover research

A number of systems research experiments have been undertaken in recent years. These experiments have shown very positive results in terms of reducing N fertiliser application to grass-white clover swards whilst maintaining similar total pasture DM production to grass-only swards receiving higher levels of N fertiliser. Table 1 shows the grass DM production from three systems experiments where grass-clover swards receiving 100 kg less N fertiliser produced on average only 0.4 t DM/ha less than grass-only swards (14.1 vs 14.5 t DM/ha, respectively).

Table 1. *Grass DM production and sward clover content from three systems experiments comparing grass-only and grass-clover swards*

	Grass-only 250 kg N/ha	Grass-clover 150 kg N/ha
Moorepark Experiment (2013 – 2020)		
Grass production (t DM/ha)	13.8	13.5
Sward white clover content (%)	-	22
Clonakilty experiment (2019-2021)		
Grass production (t DM/ha)	15.2	14.6
Sward white clover content (%)	-	18
Clonakilty experiment (2022)		
Grass production (t DM/ha)	14.4	14.3
Sward white clover content (%)	-	14

Within the Moorepark experiment in 2021 and the Clonakilty experiment in 2020 and 2021, zero N exclusion plots (5×5 m) were included within a subset of the grass-only and grass-clover paddocks. These plots were fenced, received zero N fertiliser or slurry, and were not grazed. The plots were mechanically harvested at the same time as the surrounding paddock was grazed by dairy cows, and herbage yield and N content were measured. This allowed the calculation of N yield (which is an indicator of N mineralisation from the soil) and N fixation. On average the zero N grass-only plots yielded 7.5 t DM/ha and had an N yield of 193 kg/ha, whereas the zero N grass-clover plots yielded 10.3 t DM/ha and had an N yield of 296 kg/ha, indicating N fixation of 104 kg N/ha per year. The pattern of N fixation across the grazing season is illustrated in Figure 2.

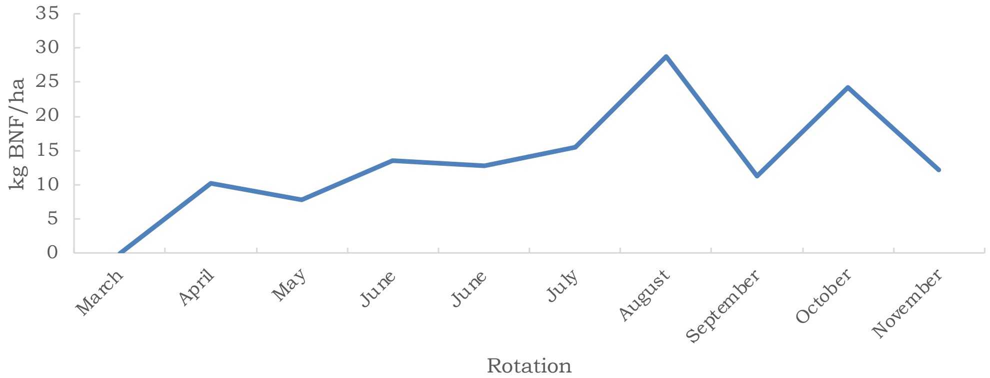

Figure 2. *Pattern of biological N fixation across the grazing year (average of Moorepark (2021) and Clonakilty (2020-2021)*

Conclusions

White clover, by utilising its biological N fixing ability, can offset reductions in N fertiliser use to maintain grass DM production and its use at farm level should be increased significantly in future.

Clonakilty update: the effect of sward type and varying levels of nitrogen application on a spring calving dairy grazing system

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Summary

- Sward type and nitrogen (N) fertiliser rate had an effect on grass DM production.
- The grass-clover 150kg N/ha treatment produced a similar amount of grass as the grass-only 225 kg N/ha treatment.
- The grass-clover 150kg N/ha treatment cows produced 29 kg per cow of milk solids (5.5%) more than the grass-only 225kg N/ha treatment cows for the full lactation in 2022.

Introduction

Irish grazing systems have been predominantly perennial-ryegrass (PRG) based swards that required relatively large amounts of nitrogen (N) fertiliser to produce high grass DM yields. Increased pressure to reduce the environmental impact of agriculture, particularly greenhouse gas emissions and water pollution, will necessitate a reduction in the amount of chemical N fertiliser that farmers can use. White-clover has become a focus for more sustainable farming due to its capability to biologically fix N from the atmosphere into the soil. Other added benefits such as increased grass production and improved animal performance have also been observed from past research. The previous experiment in Clonakilty found higher milk solids yield per cow for cows grazing PRG-white clover swards compared to cows grazing PRG-only swards. This paper will present results of the most recent Clonakilty Agricultural College research experiment from 2022. The experiment entitled "Nitrogen sustainability in Irish dairy systems" investigated how utilising biological N fixation and varying nitrogen fertiliser inputs on different sward types effected grass growth and milk production.

Clonakilty experiment 2022

The experiment utilised the Clonakilty systems experiment and contained four treatments; a PRG-only sward receiving 150 kg N/ha (GO-150), a PRG-only sward receiving 225 kg N/ha (GO-225), a PRG-white clover sward receiving 150 kg N/ha (GC-150) and a PRG-white clover sward receiving 75 kg N/ha (GC-75). Each treatment had a separate farmlet of 20 paddocks for grazing. The treatment herds each contained 28 cows which gave a stocking rate of 2.57 cows/ha. The previous experiment conducted at Clonakilty from 2019-2021 was focused on improving sward white clover content on the farm. A systematic programme of reseeding and over-sowing was undertaken to increase white clover content. The current experiment follows from the previous experiment by continuing to look at white clover and how varying N fertiliser application rates impact overall farm production. By looking at varying levels of N fertiliser on different sward types, data can be collected to determine the feasibility of utilising biological N from clover as a more sustainable source to maintain grass production while maintaining high levels of milk production.

Results 2022

The average sward white clover content in 2022 was 15.5% with the GC-150 having a lower sward white clover content (14.0%) than the GC-75 treatment (16.9%). Sward type and N fertiliser rate had an effect on grass DM production. Comparing the sward types, PRG-only swards produced 14.1 t DM/ha while the PRG-white clover swards produced 13.5 t DM/ha. Within sward type, there was a difference of 0.7 t DM/ha between the GO-225 and the GO-150 swards and a difference of 1.6 t DM/ha between the GC-150 and GC-75 swards. There was no difference in grass DM production between the GO-225 and GC-150. The GC-75 treatment having the lowest grass DM produced led to a higher amount of silage fed during lactation compared to the other treatments. None of the treatments were able to reach their winter feed production requirement and when silage fed during lactation was accounted for, the GO-225 treatment had the highest winter feed made (68%) versus the GC-75 treatment with the lowest winter feed made (38%). Grass production was reduced in 2022 due to drought at different times of the year. Sward type was found to have an effect on total milk production while N fertiliser rate had no effect. The GO-150 treatment produced 348 kg of milk per cow less than the GC-150 treatment while there was no difference between the GO-225 and the GC-75 treatments. Fat and protein contents were similar across treatments but a difference of 29 kg of milk solids per cow (5.5%) between the GO-150 and GC-150 treatments was found. Bodyweight and body condition score (BCS) were similar across all treatments.

Table 1. *Production parameters of white-clover in a dairy grazing system at varying levels of nitrogen application rates from 2022*

	GO-150[1]	GO-225	GC-150	GC-75
Nitrogen fertiliser spread (kg/ha)	151	224	151	85
Grass production (t DM/ha)	13.7	14.4	14.3	12.7
Concentrate (kg/cow)	783	780	776	792
Silage made (kg DM/cow)	996	1,025	1,004	880
Silage fed – lactation (kg DM/cow)	287	214	251	422
Winter feed made (%)	59	68	63	38
Milk yield (kg/cow)	5,843	6,086	6,191	6,086
Fat content (%)	4.85	4.78	4.76	4.80
Protein content (%)	3.76	3.80	3.86	3.75
Milk solids yield (kg/cow)	492	509	521	509
Bodyweight (kg)	506	515	515	518
Body condition score	2.90	2.95	2.96	2.99

[1]*GO-150 = perennial ryegrass (PRG)-only sward receiving 150 kg N/ha, GO-225 = PRG-only sward receiving 225 kg N/ha, GC-150 = PRG-white clover sward receiving 150 kg N/ha, GC-75 = PRG-white clover sward receiving 75 kg N/ha*

Conclusions

The results from year one of this study show that white clover inclusion in PRG swards continues to have positive effects on grass DM and milk production. Although 2022 was a poor year for grass growth, due to the dry conditions for much of the summer, and none of the treatments produced enough winter feed, the results show the potential of white clover and the capabilities of reducing reliance on N inputs while being able to maintain production.

Transitioning to low N dairy systems on a wetland soil type in the border, midlands and western region

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Summary

- Recent studies suggest that the DM yield of swards incorporating white clover are comparable with perennial ryegrass (PRG) only swards in terms of DM yield, require fewer chemical fertiliser N applications and support enhanced animal performance at grazing.
- The initial results from the low N input dairy systems study show that the successful incorporation of clover within grazing swards in a wetland soil type can substantially reduce chemical N application requirements while maintaining total pasture DM production and animal performance in the Border Midlands Western region.

Introduction

As the pressure intensifies to reduce nitrogen (N) losses to the environment from pasture-based dairy systems, interest has increased in perennial ryegrass white clover (PRG WC) mixtures, where more N for pasture growth is supplied by biological N fixation. Together with rising energy costs, which have significantly increased fertiliser costs, the incorporation of legumes in grazing pastures to reduce reliance on chemical N application is of critical immediate importance. While a growing body of research has shown the benefits of WC in intensive grazing swards from an animal performance perspective, presently, there is little or no WC present on the majority of pastures on intensive commercial dairy farms. Moreover, the additional complexity of maintaining PRG WC swards on more marginal soil types and the impacts of transitioning intensive dairy systems from PRG only to PRG WC swards have received little attention and represents a major concern for commercial farmers. The Border, Midlands and Western Region (BMW) of Ireland consist of 13 counties including the six border counties with Northern Ireland. The regions wet mineral soils inhibit drainage and are associated with a shorter grazing season and reduced pasture utilisation and farm profitability. Previous studies indicate that the production and utilisation of increased quantities of higher quality grazed grass can significantly increase productivity on dairy farms in the region. The objective of the current study was to investigate the effect of incorporating clover into PRG swards on heavier soils under poorer drainage conditions. The initial focus of the trial is on observing the transition period (2021-2023) from PRG only to PRG-WC swards and the effect on pasture and milk production.

Experimental design

This is a five year systems trial (2021-2025), investigating the transition to lower N input dairy systems in the BMW region of Ireland by reducing purchased N inputs by 50% by the end of year three (2023). The trial consists of two sward types; PRG and PRG WC, which are established by reseeding 25% of each farmlet each year to new swards containing high Pasture Profit Index (PPI) varieties with or without white clover. A further 20% of the PRG WC area was oversown with five kg of white clover in each year. The target chemical N fertiliser application throughout the trial for the PRG swards was 250 kg N/ha per year whereas the PRG WC swards where clover had been established had a target of 125 kg N/ha with the remaining N supplied by clover biological N fixation within these swards. Each sward type was further sub-divided into two feed N input systems, where animals were fed either high (1,200 kg/cow) or medium (600 kg/cow) levels of concentrate during the grazing season. The design resulted in four treatment groups namely: 1) PRG/High concentrate, 2) PRG/Medium concentrate, 3) PRG WC/High concentrate, and 4) PRG WC/ Medium concentrate with total purchased N inputs (feed plus fertiliser) of 325, 285, 200 and 160 kg N/ha per year, respectively. All treatments receive the same level of slurry application in addition to this.

Results to-date

The preliminary results for the trial from 2021-2022 are presented in Table 1. Clover establishment was excellent within the study, with both full reseed and oversown methods resulting in 30% clover content during the first grazing season post sowing. Consequently, and despite large differences in chemical N fertiliser application (actual applications for PRG and PRG WC were 238 vs. 147 kg N, respectively) and concentrate level (actual concentrates fed were 571 and 1,027 kg/cow for Medium and High, respectively), there were no significant differences in pasture production between the four farm systems evaluated (12.8 t DM/ha) over the initial two years.

Table 1. *Effect of sward type (Perennial ryegrass, PRG; Perennial ryegrass clover, PRG WC) and concentrate feed level (Medium, MC; High, HC) on pasture and animal performance (2021-2022)*

	Sward type		Concentrate level	
	PRG	PRG-WC	MC	HC
Concentrate fed (kg/cow)	797	801	571	1,027
Chemical N (kg N/ha)	238	147	200	185
Pasture yield (t DM/ha)	12.7	12.9	12.7	12.9
Milk yield (kg/cow)	5,280	5,233	5,109	5,405
Fat content (%)	5.04	5.09	4.98	5.14
Protein content (%)	3.84	3.94	3.86	3.93
Milk solids (kg/cow)	467	458	447	478

Based on similar mean calving dates and lactation lengths, there was no significant difference between sward types in terms of milk production and composition during the initial two-year period investigated. In contrast, increasing concentrate feeding rate resulted in significantly increased milk (+296 kg) and milk solids (+31 kg) production for High concentrated compared to Medium concentrate during the study period.

Conclusions

The results of this study indicate that white clover can be successfully incorporated within dairy swards on a wetland soil type such as at Ballyhaise Agricultural College. Although not resulting in significant impacts on animal performance during the initial transition, these results indicate that substantial reductions in chemical N application can be achieved while achieving similar overall DM production thereby enhancing the overall sustainability of the dairy production system.

Lowering the carbon footprint of pasture-based milk production at Solohead Research Farm

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Summary

- A clover-based system can lower the carbon footprint of milk production by 25% with similar or higher profitability depending on milk and fertilizer N prices.
- A clover-based system receiving no fertilizer N supported an overall farm stocking rate of 2.45 livestock units per ha.
- High clover yields and high rates of biological N fixation (BNF) are key to this high level of productivity in the absence of fertilizer N.

Introduction

At Solohead Research Farm we have been investigating the potential for lowering the carbon footprint of pasture-based milk production by implementing best practices. A key focus has been using clover to replace artificial fertilizer nitrogen (N). Typical rates of fertilizer N cause a large accumulation of N in the soil; ranging between 30 and 120 kg per ha of N. This N is taken up by the sward at a rate of 1 to 2 kg per ha per day. Hence, there can be a lot of reactive N (ammonium or nitrate) sitting around near the soil surface for long periods at risk of being lost. A small proportion of this N is lost as nitrous oxide gas through denitrification. Nitrous oxide is a greenhouse gas with 265 times the global warming potential of carbon dioxide. Very small losses of nitrous oxide can have a disproportionally large impact on the carbon footprint of a farm. On the other hand, clover makes N available deeper within the soil on an on-going basis; at rates that are more-or-less in line with the uptake of N by the sward. Hence, with clover there are no large accumulations of reactive N in the soil and negligible losses of nitrous oxide from clover-rich grassland.

Productivity, carbon footprint and profitability

We have investigated different systems of clover-based dairy production at Solohead compared with a system reliant on fertilizer N input of 275 kg per ha (FN275). This FN275 system was based on perennial ryegrass swards containing an average of 9% clover (Table 1) and reseeded at an annual average rate of 6% per year. Our standard clover-based system received between 40 and 110 kg per ha of fertilizer N applied as protected urea in spring depending on growing conditions and averaging around 95 kg per ha per year (FN95). This system received no fertilizer N input from April onwards and had clover contents of around 22% per year (Table 1). For the last four years (2019 to 2022) we have been running a system receiving no fertilizer N input (FN0). Lowering fertilizer N input has resulted in higher clover contents; approximately 30% averaged over the year on FN0, and a 1:1 increase in biological N fixation (BNF). The swards in FN95 and FN0 were reseeded at an annual average rate of 12% per year. Cattle slurry was recycled back onto each of these three systems at rates proportional to the stocking rates on each of the systems (2.6 cows per ha).

Averaged over five years, the FN95 system produced 97% of the pasture of the FN275 system (Table 1). This includes 2018 when pasture production was curtailed by soil moisture deficit during the summer. Averaged over the last three years there has been no difference in pasture production between the FN95 and FN0 clover-based systems. The FN95 had a 16% lower carbon footprint than the FN275 system, whereas the FN0 had a 25% lower footprint, which is in line with the target outlined in the Climate Action Plan. These differences are mainly due to lower fertilizer N use. There was no difference or improved profitability with the clover-based systems compared with FN275 mainly because there was similar milk and other sales with lower input costs. We discontinued the FN275 system at the end of 2021 because it was obsolete.

Table 1. *Pasture and clover production at Solohead Research Farm between 2017 and 2022*

System	FN275	FN95	FN0	FN275	FN95	FN0
Year	Pasture production (t DM/ha)			Clover production (t DM/ha)		
2017	15.9	14.9		1.2	2.9	
2018	13.0	12.5		1.0	1.7	
2019	14.6		14.9	1.0		2.9
2020	14.5	14.4	14.9	1.7	3.6	4.6
2021	15.3	14.9	14.8	1.9	4.0	4.8
2022		14.5	14.6		4.1	4.8

Measured using cut data. PBI data for the same paddocks is 1.5 t DM/ha less.

Maintaining clover and BNF and avoiding bloat

The management of clover-based swards is different to that of N-fertilized ryegrass swards. There are a number of management practices necessary for maintaining perennial high clover DM yields and high rates of BNF on the grazing platform:

- High soil lime status (pH 6.5 to 7.2), high soil K (index 3/4) and soil P Index 3.
- Reseed 10% per year to get productive clover swards established on the platform.
- The seed mixture should contain per acre pack: 2 kg white clover varieties that are on the Irish recommended list and 2 kg of red clover. Recommended red clover varieties are Milvus, Aberclaret, Aberchianti, Fearga and Lemmon.
- Apply a clover-safe post-emergence herbicide to the establishing crop.
- Minimise fertilizer N input and maximise BNF. BNF typically commences around 6 weeks after sowing and can exceed 150 kg/ha following an April reseed.
- Minimal (in February and March) or no fertilizer N in subsequent years. Apply the saved fertilizer N on non-clover paddocks if concerned about overall pasture production on the farm. This will give best economic response to fertilizer N.
- High input of fertilizer N favours grass production to the detriment of the clover component of the sward, e.g. FN275 (Table 1). Likewise, very high rates of BNF over a number of years can also be detrimental to clover content. This can be rectified by taking off a cut of silage; a 5 t DM crop of herbage harvested for silage will remove between 150 and 200 kg/ha of N from the soil. It is good practice to integrate a cut of silage (baled surpluses) into the grazing rotation.
- Where there are very high clover contents this problem will normally solve itself; high yields of clover results in high rates of BNF, which favours the grass component of the sward. Closing up a paddock early in the last rotation and leaving a heavy pasture cover over the winter will rapidly deplete the clover content.
- Clover is very vulnerable to competition from grass over the winter. The lower the winter cover the better in terms of higher clover production and BNF in the following year.
- Bloat has not been much of a problem over 20 years at Solohead; partly because cows get conditioned to clover during the grazing season. There is always clover in the cow's diet; clover contents increase from 15% at turnout to 50% in August. Putting more fibre into the diet is the key to avoiding bloat. We typically build pasture covers during August and early September as a means of extending the grazing season. This means we are grazing higher covers (up to 3,000 kg DM per ha above 4 cm) when clover contents are at their highest. The biggest risk of bloat that we have encountered is when overall farm cover declines during October and cows are grazing lower covers (1,200 kg DM/ha) of lush low DM pasture. Feeding 2 kg DM per cow of wilted silage/haylage (35-40% DM) per day prevents bloat under these circumstances as well as helping to lift yield of milk solids and extend the grazing season.

Conclusions

A clover-based system can substantially lower the carbon footprint of a dairy farm with no loss of profitability or with improved profitability primarily depending on the cost of fertilizer N and the price received for milk.

Johnstown Castle winter-milk herd update – increasing the environmental sustainability of winter-milk systems

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Summary

- Winter-milk systems must reduce their carbon footprint as well as increase their protein self-sufficiency.
- Home-grown diets/home-grown protein sources provide mechanisms to achieve this; however, reduced animal performance has been observed.
- Preliminary data suggests that a commercially available methane reducing feed additive is effective when fed to Irish autumn-calving dairy cows.

Introduction

Ireland must reduce its greenhouse gas emissions to help mitigate climate change and to comply with international and European Union climate commitments of net-zero emissions by 2050. In tandem, there is renewed focus within the European Union to reduce its dependency on imported protein sources. Currently, there is a major deficit in plant proteins, with the EU agricultural sector importing the majority of its requirements. Home-grown or EU-grown protein sources could provide economic and environmental benefits to European farmers as well as food security to Europe as a whole. Within Ireland, these issues are particularly pertinent to winter-milk systems due to the nature of milk production from conserved forages. Therefore, over the last number of years, a series of experiments have been performed with the Johnstown Castle winter-milk herd to investigate strategies of reducing the carbon footprint and increasing the protein self-sufficiency of winter-milk systems.

Johnstown Castle winter-milk herd

The Johnstown Castle winter-milk herd consists of 90 high-EBI (€205) Holstein Friesian cows, grazing 26 ha of the 54 ha grazing area on the dairy platform. Autumn calving starts on September 11th and is complete by December 1st with 80% calved by October 29th (median calving date 9th Oct). The herd's average calving interval is 369 days with a six-week calving rate of 77%. During the 2021/2022 lactation, the herd averaged 7,669 kg of milk, 3.69% protein, 4.37% fat and 623 kg of milk solids per cow. Concentrate supplementation was 1,660 kg of fresh weight fed per cow.

Standard compared with home-grown diets

In the first experiment, which was performed over the lactations of 2019/20 and 2020/21, a standard winter-milk diet of grass silage, maize silage and concentrate containing imported protein sources was compared with a diet of grass silage and concentrates containing native cereals and protein sources (i.e. field beans). As maize silage was imported into the standard treatment, an increased grazing platform stocking rate of 3.8 LU/ha was utilised compared with 2.8 LU/ha on the home-grown treatment. Life cycle assessment modelling suggests a lower carbon intensity per ha and per kg of milk when cows consumed the home-grown treatment; however, reduced animal performance was observed (-20 kg of milk solids/cow/lactation) when compared with cows fed the standard treatment. As there were a number of dynamic factors among the treatments (i.e. concentrate ingredients, concentrate feeding level, maize silage inclusion) it was difficult to pinpoint the cause of the reduced performance.

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Imported compared with home-grown protein sources

In the second experiment, which was performed over the lactation of 2021/22, home-grown concentrate protein ingredients (i.e. field beans and rapeseed meal) were compared with imported concentrate protein ingredients (i.e. soybean meal and maize distillers). The objective of this experiment was to isolate the effect of concentrate protein source ingredients and quantify the impact on animal performance. To achieve this, a diet of 7 kg of DM grass silage, 7 kg of DM maize silage and 8.2 kg of DM experimental concentrate containing either imported or home-grown protein sources were fed to two groups of autumn-calving cows over an 8-week indoor feeding period. The experimental concentrates were formulated to be similar in terms of crude protein and energy concentration. After the eight-week indoor feeding period, a carry-over measurement period of six weeks was performed. Cows consuming the home-grown concentrate protein ingredients reduced milk production performance (-15 kg of milk solids per cow across the 14 week experimental period) when compared with cows fed the imported concentrate protein ingredients. It is likely that the home-grown concentrate protein ingredients reduced animal performance due to inadequate metabolisable protein/amino acid supply. Further experiments will be performed to investigate if rumen-protected amino acid supplementation can alleviate this reduction in animal performance while supporting a lower carbon footprint of milk production.

Methane reducing feed additive

In the final experiment performed to date, a commercially available methane reducing feed additive was investigated. The feed additive contained an ingredient which inhibits an enzyme required to complete methanogenesis in the rumen. The experiment was performed over the indoor feeding period of 2022/'23. A diet of 7 kg of DM grass silage, 7 kg of DM maize silage and 8.2 kg of DM concentrate was fed with or without the methane reducing feed additive. The feed additive was simply added to the mixer wagon with the other dietary ingredients each morning and fed to the corresponding treatment group. Separate mixer wagons were used to prevent contamination of the control diet. Greenfeed machines were used to measure methane output. While data analysis is still on-going, preliminary results suggest a 25% reduction in methane production/day when fed to Irish autumn-calving dairy cows.

Conclusions

Although home-grown diets/home-grown protein sources can reduce the carbon intensity and increase the protein self-sufficiency of Irish winter-milk systems, reduced animal performance was observed. Future experiments will investigate strategies, such as rumen-protected amino acid supplementation, to alleviate this reduced animal performance while simultaneously increasing the environmental sustainability of winter-milk systems. Finally, the preliminary data, in regard to the effectiveness of a commercially available methane reducing feed additive, is promising for Irish winter-milk systems.

Acknowledgements

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Protected urea - protecting the environment and delivering for farmers

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Summary

- Urea + NBPT reliably grew the same amount of grass as CAN fertiliser.
- There was a 2,148 kg DM/ha difference in herbage production between the 150 and 250 kg nitrogen/ha treatments.

Introduction

Although nitrogen (N) fertilisers support high levels of grass dry matter (DM) production, they contribute to ammonia and greenhouse gas (GHG) emissions under Irish grazing conditions. Nitrogen fertilisers can be a major contributor to ammonia emissions (mainly from standard urea fertilisers) and to GHG emissions in the form of nitrous oxide (N_2O) losses (mainly CAN-based fertilisers). The Irish Government has set a target to reduce total GHG emissions by 51% by 2030, and agricultural GHG emissions by 25% compared to the baseline year of 2018. The simplest and most effective way available to farmers to contribute to achieving some of these reductions is by switching their straight N fertiliser use to a protected urea form. This switch in fertiliser type will in fact account for 5% of the 25% target.

Protected urea is standard urea that has been coated with a urease inhibitor to reduce ammonia emissions. Currently NBPT, NPPT+NBPT and 2-NPT are registered urease inhibitors under the EU fertiliser regulations with minimum and maximum levels of coating at the point of sale specified. These urease inhibitors reduce the release of ammonia to the atmosphere from urea by preventing the urease enzyme reacting with urea. Additionally as less N is lost to the atmosphere, more N is retained for grass growth.

Plot Experiment

A plot grazing study was set up to compare the grass DM production of CAN, urea and urea + NBPT under rotational grazing at a number of sites across Ireland. In 2019, plots were established at Moorepark and Clonakilty Agricultural College, with additional sites added in 2020 at Athenry and Ballyhaise. Plots were grazed by dairy cows at Moorepark, Clonakilty and Ballyhaise and by sheep at Athenry. The study ran until the end of 2021 with three years of data collected at Moorepark and Clonakilty and two years of data collected at Athenry and Ballyhaise. The three fertiliser types were compared at two fertiliser rates, 150 kg N/ha and 250 kg N/ha. Fertiliser was applied in late January/early February each year and was then applied after each grazing. Plots were grazed in March, early April and thereafter on an approximate 21-day rotation when the control plots receiving 250 kg N/ha of CAN reached a pre-grazing herbage yield of 1,500 kg DM/ha. Prior to grazing, plots were sampled for pre-grazing herbage yield, height and crude protein content.

Results

The response to N fertiliser type and N fertiliser rate was similar at all four sites. There was no difference between CAN and NBPT-urea in terms of pre-grazing herbage yield (1,485 and 1,480 kg DM/ha, respectively) or total herbage DM production (13,478 and 13,542 kg DM/ha, respectively) but lower for urea. As expected, the 250 kg N/ha fertiliser rates had significantly higher pre-grazing herbage yield (+242 kg DM) and total herbage DM production compared to the 150 kg N/ha treatments, delivering an additional 2.1 t DM/ha for the year (P <0.001).

Table 1. *Effect of nitrogen fertiliser type and rate on herbage production*

	CAN	Urea + NBPT	Urea	250 kg N/ha	150 kg N/ha
Pre-grazing yield (kg DM/ha)	1,485	1,480	1,436	1,588	1,346
Grass Grown (kg DM/ha)	13,478	13,542	13,087	14,424	12,221

All data are averages of four site, nine cuts at Clonakilty, Moorepark (three years) and 10 cuts at Ballyhaise, eight cuts at Athenry (two year); N type data are means of two N rates, N rates data are means of three N types

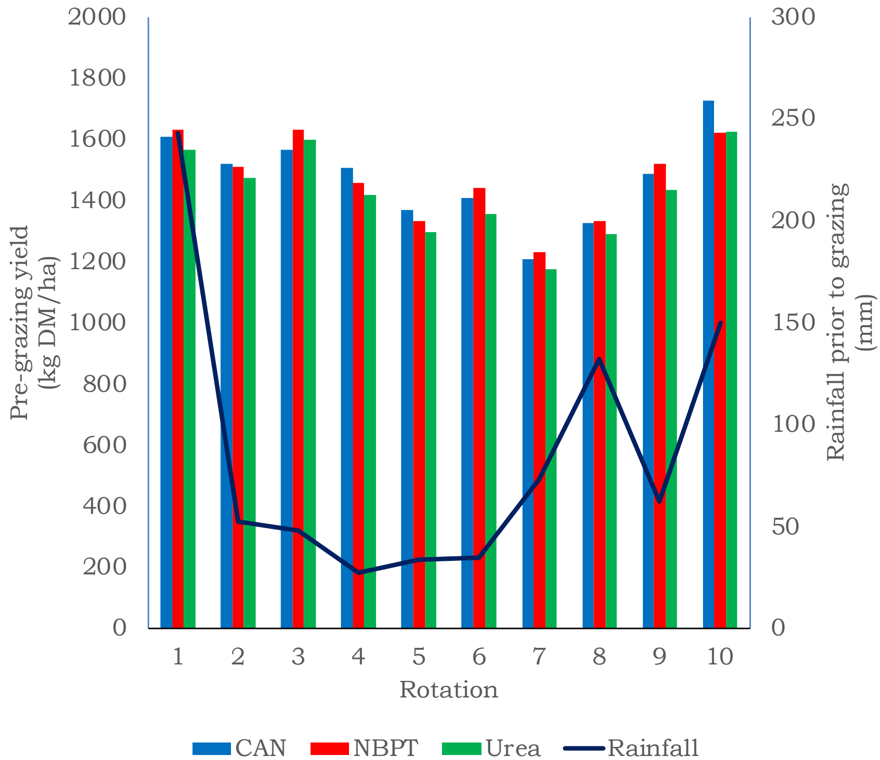

Figure 1. *The average herbage production by rotation for each nitrogen fertiliser type for all sites*

Conclusion

There was no difference in grass production at any rotation, at any site between NBPT-urea and CAN. There was an overall benefit (+424 kg DM/ha) detected over the 10 site-years from using urea protected with NBPT versus using urea.

The impact of nitrogen fertiliser application strategy on herbage production and nitrogen use efficiency in spring

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Summary

- Increasing the level of nitrogen (N) fertiliser in spring resulted in reduced levels of N response and N uptake.
- Applying 60 kg N/hectare in spring across two application splits in February and March provided the optimum combination of dry matter production N response and N recovery.

Introduction

Sufficient nitrogen (N) fertilisation is essential to achieve high levels of grass dry matter (DM) production. However, N fertiliser can have negative environmental implications, when used excessively. There are currently many new challenges facing Irish agriculture, such as achieving reduction in environmental emissions, reducing N fertiliser use, improving water quality and addressing rising costs of production. With increasing pressure for the agriculture industry to reduce emissions and chemical N fertiliser use, it is important that any reduction in N fertiliser application does not result in a decrease in grass DM production and increases N use efficiency (NUE). When precision N fertiliser application is practiced, there should be enough N available when plant growth is high and surpluses should be avoided during times of low growth, as this can lead to reduced N response and N recovery resulting in increased N loss and leaching.

Spring fertiliser work at Teagasc, Moorepark

A plot trial was established at Teagasc Moorepark in 2021 and 2022, the trail consisted of three N application rates (30 kg N/hectare (ha) (30N), 60 kg N/ha (60N) and 90 kg N/ha (90N)), on two N application dates; 3rd February and 19th March, with three different N application strategies in spring (split between February and March); 0:100 (S1), 50:50 (S2) and 33:66 (S3). All of the plots were defoliated on March 16th and the second defoliation was on April 23rd, in both years. Herbage mass, N response and N recovery were measured. The objective of the current study was to investigate the impact of N fertiliser application rate and strategy on spring DM yield, N response and N recovery.

Results

The 90N treatment had the greatest spring DM yield (3,026 kg DM/ha), with the 30N the lowest and the 60N intermediate (2,308 and 2,753 kg DM/ha), while N application strategy also had a significant impact on spring herbage production. The S1 (0 N in February and 100% in March), consistently across all N rates (90, 60 and 30) produced the lowest spring DM yield, while there was no difference between the S2 and S3 strategies. Nitrogen response reduced as N rate increased suggesting that high levels of N application in spring is in excess of plant requirements. The 30N treatment had the greatest N response of 19.6 kg DM/kg N applied across all N application strategies, however balancing DM yield and N response is key to ensure adequate grass growth in spring. As N rate increased to 60 and 90 kg N/ha, N response reduced to 17.0 and 14.3 kg DM/kg N applied. There was no significant difference between the S2 and S3 split in terms of N response regardless of N rate (18.2 kg DM/kg N applied), however the S1 (0:100) had the lowest N response across all N rates (14.3 kg DM/kg N applied). As N rate increased from 30 to 60 to 90 kg N/ha, so too did N recovery (16.2, 33.7, 48.5 kg N uptake/ha, respectively). However, the S2 (33:66) application strategy provided the greatest N recovery at 35.9 kg N uptake/ha, across all N rates, with no significant difference between the S1 and S3 strategies (31.2 kg N uptake/ha).

Table 1. *The effect of N rate and N application strategy in spring on cumulative spring DM production, N response and N recovery*

N rate (kg N/ha)	30			60			90		
N application strategy	F:M 0:100	F:M 33:66	F:M 50:50	F:M 0:100	F:M 33:66	F:M 50:50	F:M 0:100	F:M 33:66	F:M 50:50
Cumulative spring yield (kg DM/ha)	2,228	2,381	2,315	2,634	2,790	2,835	2,826	3,111	3,143
Spring nitrogen response (kg DM/kg N applied)	16.9	19.9	22.1	14.6	18.6	17.8	11.5	15.8	15.5
Spring nitrogen recovery (kg N uptake/ha)	13.5	19.0	16.2	29.8	35.6	3.58	42.5	53.3	49.8

Conclusion

The Climate Action Plan 2021 requires N fertiliser use to be reduced by 20% by 2030. Until recently application rates of 250 kg N/ha per year, with 90 kg N/ha in spring were recommended. It is important to apply N fertiliser in early spring to encourage grass growth but high applications of N in February are not recommended due to the increased risk of N leaching at this time. Nitrogen application date in early spring has a large impact of grass growth. Nitrogen fertiliser can be applied in early February and result in an increase in herbage DM production as well as N fertiliser response and N recovery. Precision grassland management techniques that use key information such as predicted rainfall, soil temperature and traffic-ability conditions will help to utilise N fertiliser better in spring and across the grazing season and, therefore, should be more routinely used on grassland farms. The current study reported that a reduction of 30 kg N/ha per year from 90 to 60 kg N/ha in spring and applied in February and March in a 33% and 66% application strategy provided the optimum combination of DM production, N response and N uptake.

Spring grazing management: the effect of silage supplementation on milk yield

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Summary

- Silage supplementation during early lactation reduces milk yield and milk protein content.
- If spring grass availability is low, silage supplementation should be offered during the first six weeks of lactation as it has less of a negative impact at this time.

Introduction

The diet of dairy cows during early lactation can have a significant impact on animal performance. Increasing the proportion of grazed grass in the diet has a positive effect on milk production due to the high nutritive value of spring grass. Closing farm cover in autumn has the biggest influence on spring grass availability, therefore, it is important to achieve a closing farm cover between 650-750 kg dry matter (DM)/hectare (ha) to ensure adequate grass supply during the subsequent spring. However, the seasonality of grass growth (i.e. periods of low grass growth) and adverse grazing conditions can lead to reduced grass availability in spring, resulting in the need for silage supplementation to meet herd demand. The spring rotation planner (SRP) should be used to ensure grazed grass in the diet throughout the first rotation, and concentrate and silage supplementation should be offered when necessary to avoid restricting cow's intakes. Restriction of intake during early lactation has a negative effect on animal performance. The timing and severity of grass deficits varies between years and is dependent on spring grass availability, growth rates, weather conditions and grassland management, therefore, it is essential to understand the effects of offering silage in the diet during early lactation.

Spring grazing research at Teagasc, Moorepark

A study was carried out at Teagasc Moorepark over a two-year period, investigating the impact of silage supplementation during the first 12 weeks of lactation on milk production. The objectives of the experiment were to investigate whether the rate and timing of silage supplementation had an effect on milk production. A high and a low opening farm cover (OFC) were established using two autumn closing strategies; the high OFC began closing on 27th of September and the low OFC began closing on the 11th of October. Cows were randomly assigned to the high grass (HG) or low grass (LG) treatment as they calved during the subsequent spring. For the first six weeks cows on the HG treatment were offered a high daily herbage allowance (DHA) with low silage supplementation and cows on the LG treatment were offered a lower DHA with high silage supplementation. From week 7 to 12 of the experiment cows on the HG treatment were offered a high DHA with no silage supplementation and cows on the LG treatment were offered a lower DHA with 3 kg DM silage/cow/day.

Results

During the first six weeks of lactation there was a difference of 2 kg DM/cow per day in silage DM intake (DMI) between the HG and LG treatments, however, this had no effect on milk production (Table 1). Cows on the HG treatment for weeks 7 – 12 had significantly higher milk yields compared to cows on the LG treatment. Total DMI were the same for both groups during this period, however, the inclusion of silage in the diet reduces feed quality, which had a negative impact on milk yield for the LG treatment. The HG treatment milk yields remained higher for a further 8 weeks once the experiment was finished and all cows had the same diet consisting of 17 kg DM/cow/day grazed grass plus 1 kg concentrate.

Table 1. *The effect of the high grass (HG) and low grass (LG) treatment on animal production during week 1 – 12 of lactation*

	Week 1 - 6		Week 7 - 12	
	HG	LG	HG	LG
Daily milk yield (kg/cow/day)	20.5	20.5	24.5	23.6
Milk fat content (%)	5.59	5.60	5.12	5.13
Milk protein content (%)	3.64	3.67	3.51	3.40
Milk solids yield (kg/cow/day)	1.91	1.92	2.09	2.01
Bodyweight (kg/cow)	495	499	492	485

Protein content was significantly higher for the HG treatment compared to the LG treatment from week 7 – 12 of the current experiment due to the inclusion of silage in the diet of the LG treatment (Figure 1). The HG treatment also had significantly higher grass DMI (+ 3.4 kg) compared to the LG treatment. The reduction in milk protein content is caused by the lower protein content and nitrogen retention of grass silage compared to grazed grass.

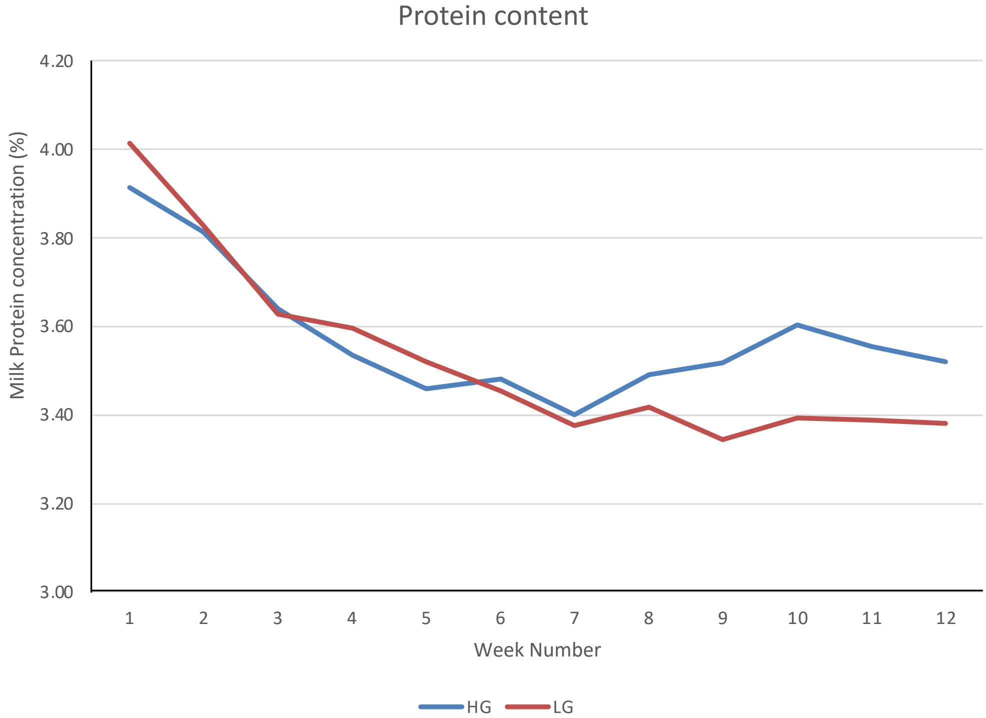

Figure 1. *The effect of the high grass (HG) and low grass (LG) treatments on milk protein content (%) during the first 12 weeks of lactation*

Conclusions

Increasing OFC allows for higher DHA which increases milk yield and milk protein content. Higher proportions of grazed grass in the diet improves the overall quality of the diet during early lactation and leads to improved animal performance. Silage supplementation is often required in spring due to unfavourable grazing conditions or low grass availability. Silage supplementation can be used to avoid restricting intakes or grazing ahead of allocated areas in the SRP. However, it is best to offer silage supplementation during the first six weeks of lactation if grass supply is inadequate to meet herd demand throughout the first rotation.

Spring grass availability and silage supplementation impact on dry matter intake and enteric methane emissions in spring calving dairy cows

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Summary

- Enteric methane is the largest contributor to Ireland's agricultural greenhouse gas emissions.
- Greater grass dry matter intake and reduced silage supplementation in early lactation resulted in lower methane emissions, methane intensity and methane yield.
- Increasing the proportion of grass in the diet throughout early lactation can aid in reducing methane emissions of spring calving dairy cows.

Introduction

Spring is a period of low grass availability due to low grass growth rates over winter and into spring, however having a sufficiently high opening farm cover ensures adequate spring grass availability for dairy cows during this period. Increasing grass utilisation in early lactation extends the grazing season and improves animal performance and the economic efficiency of pasture based dairy systems. As a result, 84.9% of Irish dairy herds implement a compact spring calving system in the months January - April to incorporate grazed grass into the diet of cows (ICBF, 2022). This ensures a calving pattern that is synchronised with feed supply resulting in the demand for feed to be greatest during periods of high grass growth. Silage supplementation has been reported to reduce milk production when fed to dairy cows, due to reduced digestibility when compared to grazed grass. Also, the impact of grass availability and silage supplementation on enteric methane emissions in early lactation has not been reported in spring calving dairy cows. Ireland's large ruminant livestock production sector has resulted in enteric methane being the largest contributor to agricultures total greenhouse gas emissions (63.1%). Ireland is now enrolled in the EU effort sharing regulation on greenhouse gas emissions and as a result the agricultural sector has been set a target to reduce greenhouse gas emissions by 25% by 2030 relative to 2018 levels.

Two year early lactation grazing experiment at Teagasc, Moorepark

At Teagasc Moorepark a research trial was conducted from 1st of February – 18th of April 2021 (Year 1) and from the 31st January 2022 – 22nd April 2022 (Year 2). The trial compromised of two six-week periods (P1 – week 1–6; and P2 – week 7–12) with 80 dairy cows allocated to two treatments of 40 animals each. Cows were randomised and allocated to treatments one week after calving. The dietary treatments were as follows; the high grass (HG) treatment involved cows grazing an area with a high opening farm cover (1,238 kg DM/ha), where animals were allocated a high daily herbage allowance (DHA) with minimal silage supplementation (2.5 kg dry matter (DM)/cow per day) when required in period 1 and no silage supplementation in period 2. While the low grass (LG) treatment animals grazed an area with a low opening farm cover (900 kg DM/ha) and were allocated a low DHA with grass silage supplemented (4.5 kg DM/per day) daily across both Period 1 and Period 2. Concentrate supplementation was the same for both treatments (2.8 kg/cow per day). After Period 1, 20 animals within each treatment crossed over dietary treatments for Period 2, while the remaining 20 animals remained in the same dietary treatment. Milk yields were recorded daily with milk composition determined once weekly. Individual animal dry matter intake (DMI) was determined at six time points over the experimental period (three in P1 and three in P2) using the n-alkane tracer technique. Daily enteric methane emissions were measured using Greenfeed technology with each treatment having access to one Greenfeed unit daily.

Results

Throughout period 1 of the experiment both treatments had similar total DMI (14.4 kg DM/cow per day; Table 1). The HG treatment had greater grass DMI although cows in this treatment still required silage in both years due to adverse grazing conditions in period 1. The LG treatment had reduced grass DMI (-1.4 kg DM) and consumed greater levels of silage DMI (+ 1.3 kg DM) in period 1. This resulted in similar daily methane emissions between both treatments in period 1 (321 g/day; Table 2). In Period 2 the HG treatment had 28.3% greater grass DMI with no silage supplemented compared to the LG treatment. However, total DMI was similar between both treatments (16.7 kg DM). Greater grass DMI in the HG treatment resulted in a 7.9% reduction in daily methane emissions (HG 292 g/day, LG 315 g/day). Greater milk production in the HG treatment in Period 2 resulted in a 12.3% reduction in methane intensity (g/kg MS), while methane yield (g/kg DMI) was also significantly reduced in the HG treatment compared to the LG treatment.

Table 1. *Total dry matter intake (DMI), Grass DMI, Silage DMI, Concentrate DMI of dairy cow within the HG and LG treatments with the difference (%) within each period*

	Period 1		Period 2		Difference	
	HG	LG	HG	LG	P1	P2
Total DMI (kg)	14.4	14.4	17.0	16.8	0.0%	1.2%
Grass DMI (kg)	7.5	6.1	14.5	10.4	18.7%	28.3%
Silage DMI (kg)	3.5	4.8	0.0	3.8	-37.1%	N/A
Concentrate DMI (kg)	3.5	3.4	2.6	2.6	2.9%	0.0%

Table 2. *Methane emissions, intensity and yield of dairy cows within the HG and LG treatments with the difference (%) within each period*

	Period 1		Period 2		Difference	
	HG	LG	HG	LG	P1	P2
Methane (g/day)	320	322	292	315	-0.6%	-7.9%
Methane/milk yield (g/kg)	14.2	14.7	12.7	14.1	-3.5%	-11.0%
Methane/milk solids (g/kg)	162.6	164.9	144.4	162.2	-1.4%	-12.3%
Methane/TDMI (g/kg)	22.0	22.8	17.5	19.3	-3.6%	-10.3%

Conclusions

The results of this experiment indicate that increasing grass DMI and reducing silage supplementation in early lactation reduced methane emissions, methane intensity and methane yield of spring calving dairy cattle.

Acknowledgements

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Increasing the usage of PastureBase Ireland on dairy farms

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Summary

- PastureBase Ireland (PBI) now has over 6,200 users of which 93% are dairy farmers.
- Over 2,000 dairy farms completed 20 farm covers or more in 2022.
- Dairy farmers recording farm cover regularly on PBI have grown between 11.1 and 14.4 t dry matter/ha per year over the last eight years.
- Farmers are encouraged to download the 'PBI Grass' app which now has increased functionality.
- A number of new applications for fertiliser and clover management are now available on PBI.

Introduction

PastureBase Ireland (PBI) has a range of grassland decision support tools available to farmers to assist in short, medium and long-term farm management decisions. Clover has an ever widening role to play on dairy farms and a number of new initiatives have been developed within PBI to cater for this requirement. A range of new tools and reports have been developed in recent years and PBI continues to expand its functionality to meet the demands of grassland farmers. Each year, both the number of farmers using the application and the measuring intensity of these farmers continues to increase. In 2022, over 90,000 grass covers were recorded in PBI, an increase of 12,000 grass covers on the previous year. The number of covers entered on a weekly basis over the summer months peaked at 3,000 grass covers per week. There has been a clear, continual increase in grassland measurement on dairy farms over time, which has been assisted by the grassland measurement requirement for farmers with a nitrates derogation.

Grass growth

In the last four years grass growth in Ireland varied by 1.4 t dry matter (DM)/ha where the average annual tonnage recorded on farms was 12.2, 13.0, 12.6 and 13.6 t DM/ha in each of 2022, 2021, 2020 and 2019, respectively; average growth in 2018 was 11.3 t DM/ha although this was an atypical year. In 2022, grass growth was significantly reduced in the months of June, July, August and September mainly due to moisture deficits at different points in the season (see Figure 1). In general grazing and silage events are being maintained between 7.5 and 8 per season, however the level of silage being harvested from the grazing platform is reducing, a consequence of less nitrogen (N) being spread on the grazing area. More farmers are routinely recording the level of N applied on farms, which, over time, will allow a better investigation of grass growth and N usage.

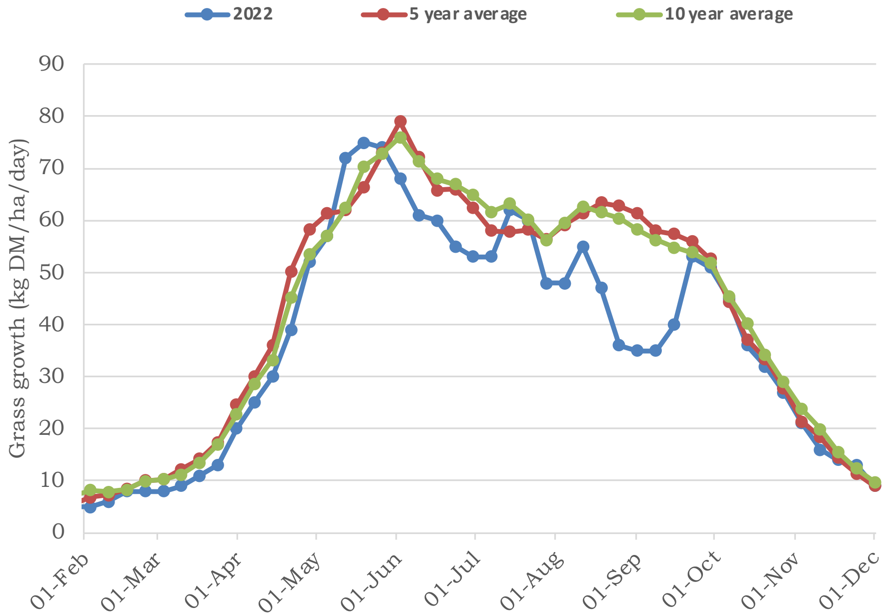

Figure 1. *Daily grass growth rates for PBI farms throughout 2022 compared to the five and 10 year averages*

Nitrogen management planning

Improving N usage on farms is a major focus to reduce N surplus, however this means that more focussed nutrient management planning is required before spreading. Nitrogen usage should be targeted differently across the farm depending on paddock clover content; a key management aspect of clover is to have a well thought out approach to N application. One of the new aspects of PBI is being able to record fertiliser application easily on the App. The introduction of the 'Nitrogen Planner' tool can assist farmers to plan their N application before the season starts. As the season progresses and data is uploaded on the App, a summary of the Nitrogen plan establishes on the system. The Clover 150 Programme farms have refined their N application significantly with this approach over the last two years.

Conclusion

PastureBase Ireland is a multi-purpose tool that allows farmers to improve grazing and nutrient management. It is an ever evolving decision support tool and the next planned addition to PBI is to integrate the MoSt grass growth model into the system; this development will allow individual farms to predict their own weekly grass growth.

PastureBase Ireland is freely available to all Irish grassland farmers. If you wish to sign up or require more information please call our dedicated help centre on 046-9200965 or email support@pbi.ie.

Update on the MoSt Grass Growth prediction model

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Summary

- The MoSt Grass Growth model has been developed to predict grass growth, grass nitrogen content and nitrogen leaching at the paddock and farm level.
- The MoSt Grass Growth model is currently used weekly on 84 commercial farm to predict grass growth for the following week.
- Access to the predicted grass growth data is available through the Grass10 Newsletter and PBI website.
- The integration of the MoSt Grass Growth model into PastureBase Ireland has begun.

Introduction

PastureBase Ireland (PBI) is a grassland management tool for farmers. It helps farmers to manage the grass on their farm, identify grass supply surpluses or deficits and to take appropriate action. Currently within PBI, farmers can only make decisions based on historical information. Even though the Irish temperate climate allows grass growth throughout the year, grass growth is highly seasonal and depends heavily on climate conditions and soil type. The integration of grass growth predictions, using the MoSt Grass Growth model, into PBI has huge potential to help farmers make better grassland management decisions based on the future grass growth and not on historical grass growth.

Model description

The MoSt grass growth model was developed at Moorepark for Irish grazing systems and Irish meteorological conditions. The model predicts daily grass growth (grass-only swards - kg dry matter (DM)/hectare (ha)) depending on weather conditions, soil type and grazing management. Farmer decisions that impact grass growth within the model are nitrogen fertiliser application rate and timing as well as the pre- and post-grazing sward height, or the pre- and post-cutting height. The model takes into account the impact of soil type and the grazing animal (through urine and dung patches) on grass growth. The MoSt GG model has also been developed with the aim of recreating the nitrogen flows in the soil and the plant to predict the nitrogen content of the grass as well as nitrogen leaching at the paddock level. This can be used to predict the impact of different grazing management strategies on nitrogen leaching.

On farm grass growth prediction

The number of farms participating in the grass growth prediction project started at 30 and currently has 84 farms. These farms are mostly commercial farms. Most of the data required to do the prediction are captured in PBI. The data necessary to run the grass growth model in PBI for each farm are: the paddocks and their area, the grazing and cutting dates, the number of animals grazing and their supplementation and the nitrogen fertilisation (chemical and organic). The other data necessary are the soil type for each paddock, which is determined using the Irish Soil Information System, and the weather data, both historical and forecasted, furnished by Met Éireann. The 84 farms chosen in this program are farmers who are measuring grass at least weekly during the main grazing season and are recording their nitrogen fertiliser applications on PBI, as without this the model could not accurately predict grass growth. The farms are geographically spread across the country to take into account the variability in growth due to location and soil type. A recent evaluation of the model showed that the average error of the current version of the model is 13.5 (39 farms), 17.5 (56 farms), 15.7 (78 farms) and 14.3 kg DM/ha per day (78 farms) for the years 2019 2020, 2021, and 2022, respectively (Figure 1). It has also been observed that the model accuracy increases as the number of grass measurements conducted by the farmer increases.

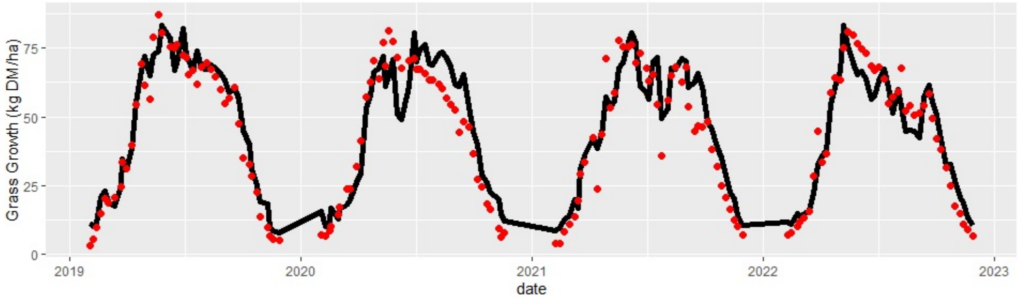

Figure 1. *Average weekly measured growth rate (black line) compared to predicted growth rate (red dots) with the current version of the model*

Where can I access the grass growth predictions and how to use them?

The grass growth predictions are sent weekly to the farmers involved, in the form of a map, and also by email to Teagasc advisors, with other information such as predicted rainfall and predicted soil temperature for the coming week to help them advise farmers. The grass growth predictions are also fully available to the public weekly trough the Grass10 newsletter, which is on the PBI website. Since August 2020, the grass growth predictions are also presented each Sunday on National Irish television by Met Éireann on RTE 1 during the Farming Forecast.

While the grass growth predictions are currently shown in the form of a precise number, each farm is different. This is why the trend of the grass growth prediction (i.e. increasing or decreasing compared to the previous week) is more important than the actual number. A specific farm could be consistently growing less than the prediction but the overall trend should be similar.

The future of the prediction

The integration of the current version of the MoSt GG model into PBI has started and should be available for every PBI user entering enough information (at least 30 grass measurements a year, chemical nitrogen fertiliser and slurry applications). In its current form, the model can only predict growth on grass-only swards. This autumn, the development of a new sub model will start to allow the simulation and prediction of growth on grass-clover swards.

Defining grass silage quality requirements for dairy herds

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Summary

- Most pasture-based dairy farms will feed at least 40% of the annual silag budget to milking cows and youngstock; this ratio increases with stocking rate
- Target 68-70 DMD silage for dry cows and 74+ DMD for milking cows and youngstock.

Introduction

While the focus for pasture-based dairy farms must be on maximising the proportion of grazed grass in the milking cow diet, there are inevitably times of the year where silage constitutes part or all of the daily forage fed to the herd. Having an adequate rolling stock of appropriate quality silage is therefore centrally important to resilient pasture-based systems. Silage strategy for the farm should take into account the varying nutritional needs of milking cows, dry cows and young-stock.

Defining annual demand for quality silage on dairy farms

During the milk quota era, grass silage for dairy herds became widely viewed and managed as a maintenance-type dry cow feed, due in part to short lactation lengths, and also to low milking platform stocking rates. However, dry cow silage demand is typically fixed at 0.75- 0.85 t dry matter (DM)/cow annually (65-75 days at 11-12 kg DM/day), which is only a proportion of the annual silage budget. All remaining silage will by definition be consumed by stock with a requirement for quality feed i.e. milking cows and growing heifers. The relative proportion of high quality in the silage budget varies across farms and years (Table 1). The volume and proportion of high quality silage needed per cow increases in scenarios where the milking platform is less self-sufficient for forage (i.e. higher stocking rate and/or lower annual grass dry matter production).

Table 1. *Effect of grazing stocking rate and annual grass growth on silage demand*

Annual Grass t DM per ha	12	12	15	15
Milking Platform Stocking Rate	**2.5**	**3.2**	**2.5**	**3.2**
Silage t DM to milking cows	0.58	0.94	0.45	0.62
Silage t DM to dry cows	0.75	0.75	0.75	0.75
Total annual silage fed t DM per cow	1.33	1.69	1.2	1.37
Quality silage* (%)	44%	56%	38%	45%
Silage from external land (non-platform ground) (%)	52	75	0	43

**Add another 0.40 t DM per cow as high quality silage reserve*

Contingency silage stocks (for drought, poor spring weather etc.), should also be of high quality; this will reduce concentrate inputs and simplify feeding plans during grass deficits. Even in scenarios where the milking platform has a balanced forage supply and demand, approximately 38-40% of annual silage is fed to milking stock. When allowance for drought reserves and young-stock are included, a significant proportion of spring-calving dairy farms will require over 50% of their silage as high quality. The parameters used to define silage quality are summarised in Table 2.

Defining silage quality characteristics for different dairy stock types

All silage fed should be well-preserved, palatable, and free from anti-nutritional factors (e.g. mould/toxins, excessive soil contamination). It is recommended to test for these factors where animal health and performance on silage diets is suboptimal. The target preservation metrics of pH, ammonia, lactic acid and ash content are consistent across silages of different feed value (Table 2). The key factor differentiating optimal feed value for dry or milking cows is dry matter digestibility (DMD). This determines the total nutrient intake from forage through a combined effect on dry matter intake and energy (UFL) density. Feeding high DMD silage to dry cows, increases risk of excess body condition gain and metabolic problems at calving. Feeding low DMD silage to milking cows results in poor milk solids output and higher rates of concentrate supplementation during times of grass deficit.

Table 2. *Key parameters for assessing quality of grass silage*

Measure	Dry cows	Milking cows and youngstock	Comment
Feed value metrics			
DMD %	68 to 70	74+	Key determinant of overall feed value
UFL (energy) per kg	0.72 to 0.75	0.83 to 0.88	Higher UFL means more feed energy for milk solids and weight gain
Crude protein % (CP)	12	14+	Lower DMD and/or N application reduce CP.
PDIE g/kg (protein)	75+	80+	Determined by UFL and CP levels in silage
Intake value g/kg LW0.75	90 to 95	>105	Higher values indicate better intake potential
Potassium (K) content	<2.2% for dry cows	>2.4% no issue for milking cows	High K silage fed from 2wk pre-calving creates milk fever risk.
Preservation metrics		Comment	
Dry matter %	24-28%	Silage should be costed on a DM basis	
pH	4.0 to 4.2 (4.4 for drier crops)	Too high pH indicates poor preservation, too low may affect intake	
Ammonia	Less than 8% of N	High ammonia indicates poor preservation and reduces intake.	
Lactic acid	8-10% of DM	Higher values indicate a stable, palatable silage.	
Ash	<8% of DM	High ash indicates soil contamination.	

Conclusion

Herd feeding decisions are simplified by having an adequate supply of the appropriate quality silage for each type of stock on the farm. Silage making should be managed accordingly, with specific targets set out based on projected annual demand.

Making cost-effective grass silage for dairy systems

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Summary

- Total silage dry matter (DM) yield per ha is the single most important determinant of cost per tonne DM. Focus on annual DM yield per hectare rather than yield from an individual cut.
- Delaying first cut beyond optimal cutting stage increases annual feed supplementation costs and limits animal performance. It also may reduce annual grass DM yield by impacting on second cut and/or autumn grazing yields.
- To achieve target silage yields in tandem with feed quality, manage soil fertility for optimal soil fertility and apply adequate nitrogen to ensure crops reach target yield before digestibility decline.

Introduction

Grass silage makes up around 22-25% of the annual feed budget on the average dairy farm. Where land type is heavy and/or grazing platform stocking rates are high (>3.5 cows per ha), this could be closer to one third of annual forage intake. The direct and overhead costs associated with grass silage production have increased significantly in recent seasons; it is therefore essential to have an annual plan in place to meet supply and quality targets for all stock in the system.

Balancing silage DM yield, quality and cost objectives

Dry matter (DM) yield per hectare (ha) is an important determinant of cost per t DM from an individual cut due to the potential dilution effects on overhead costs (e.g. contractor costs, land charge etc.). For this reason, delaying first cut harvest date to allow crops to 'bulk up' is often practiced to reduce cost per tonne in the pit and ensure adequate winter stocks. Does this policy of maximising first cut yield pay off, particularly in a high cost-per-hectare context?

Table 1. *Effect of cutting date and yield on cost and quality*

Silage cutting date	26th May	2nd June	6th June
DM Yield	5,500	6,000	6,400
DMD	73	68	65
Utilisable DM (uDM)	4,015	4,080	4,160
€950 per ha cost			
Cost per t DM	€173	€158	€148
Cost per t uDM	€236	€233	€229
€800 per ha cost			
Cost per t DM	€145	€133	€125
Cost per t uDM	€199	€196	€192

Table 1 outlines a typical range of scenarios in terms of cost, DM yield and DMD for a first cut grass crop (grazed in spring). While DM or 'bulk' yield increases with delayed cutting, DMD declines rapidly after heading-date such that total utilisable feed DM (uDM) does not accumulate significantly. The cost savings per tonne are modest on a DM basis and negligible uDM basis; the same pattern holds even when costs per ha are increased as crop DMD and yield effects are independent of input costs. In addition, the cost of purchasing feed supplements to offset poorer silage quality is usually elevated in years of a high commodity prices, therefore balancing poor quality silage is more expensive in this scenario.

The comparison outlined in Table 1 raises the valid concern of reduced silage yield with earlier first cuts, and the risk of silage shortages later in the year. Figure 1 shows the effect of different first-cut dates on total grass silage DM and forage energy (UFL) yield per ha, in a two-cut system with a fixed second cut date in late July. There was no advantage in total DM production to delaying first cut, due to lower yield at second cut. Delaying second cut further for the later first cut swards would have reduced availability of autumn after-grass and negated any silage yield benefit. It is essential to consider the yield of forage DM across the year as a whole, not just from a single cut.

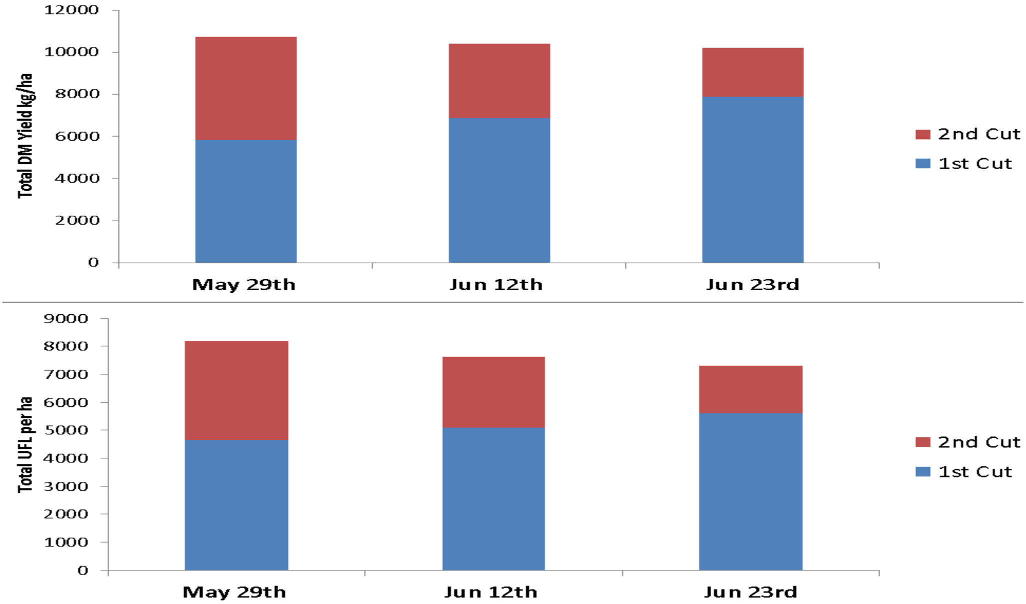

Figure 1. *Effect of first cut date on total silage DM and UFL yield in a 2-cut system*

Conclusions

Dry matter yield per ha at first and subsequent grass silage cuts should be maximised, but not at the expense of meeting DMD targets. Appropriate sward management/nutrition and soil fertility should deliver a crop that can be harvested at target yield, before the point at which DMD declines below optimal. The most cost-effective silage plans consider yield and quality in tandem, not as competing objectives.

Reducing nitrogen emissions from grazing dairy cows

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Summary

- There is an increased focus on nitrogen emissions from agricultural sources.
- Strategic low nitrogen supplementation strategies can reduce nitrogen excretion while maintaining animal performance.
- Experiments are underway, as part of a DAFM-funded project PASTURE-NUE, to further investigate the interactions involved.

Introduction

European Union policies such as the Water Framework Directive and the Nitrate Directive have increased the focus on nitrogen (N) emissions from agricultural sources. As a result, the European Green Deal and Farm to Fork Strategy have set an ambitious target to reduce nutrient losses to the environment by at least 50% by 2030. In the most recent Environmental Protection Agency report on 'Water Quality in Ireland', 47% of river sites had unsatisfactory nitrate concentrations (>8 mg/l). Irish agriculture will have to contribute towards achieving these reduction targets or be at risk of imposition of fines, limitations on overall production and reputational damage.

Nitrogen metabolism in the grazing dairy cow

Due to the high N demand of perennial ryegrass, excessive amounts of N relative to the dairy cow's requirements can accumulate in the sward. Once ingested, microbial digestion of the N increases rumen ammonia concentration with the excess ammonia being absorbed into the bloodstream, transported to the liver, and converted to urea (along with other sources) in a process termed ureagenesis. The majority of this blood urea is then circulated to the kidneys where it is destined to be excreted back onto the pasture in the form of urinary urea N. While approximately 41% of this N can be recycled through pasture uptake, 35% can be lost via ammonia, nitrous oxide and/or nitrate leaching. Although many factors affect the amount of N lost, it is critical to minimise any further excess N intake by grazing dairy cows.

Low nitrogen concentrate supplementation

On average, pasture N concentration is higher than the cow's N requirements; therefore, it is hypothesised that no additional feed N is needed. Studies have shown that reducing concentrate crude protein (CP; i.e. the amount of N in the feed multiplied by 6.25) concentration from 18%-14% CP/kg of DM, equivalent to a 1% CP reduction on a total diet basis, results in a 10% reduction in manure N excretion. The reduction in manure N was driven by a 16% reduction in urine N rather than reduced faeces N. This is important to note as the principle N component in urine; namely, urea, is more likely to be lost to the environment as it is more soluble and volatile than faecal N components, which are organically bound. Importantly, this reduction in urine N excretion was achieved while maintaining animal performance.

A number of other researchers have investigated reducing concentrate CP concentrations to grazing dairy cows, however, results are equivocal. For example, some studies found reductions in N excretion but animal performance was also reduced, whereas others found no reduction in animal performance. Across the studies, there are a number of dynamic factors such as the investigated concentrate CP concentrations, the pasture CP concentrations, level of concentrate supplementation, season/stage of lactation and method of N excretion quantification. If these interactions can be understood, it could be possible to achieve a consistent reduction in N excretion while maintaining animal performance. There is also opportunity to further reduce N excretion as there are a lack of experiments investigating concentrate CP concentration less than 14% CP/kg of DM across the grazing season.

Metabolisable protein and amino acid supply

Other experiments have demonstrated that the addition of rumen-protected amino acids can negate decreased animal performance when low N supplements are fed. This is somewhat counterintuitive as pasture CP concentration is typically on the higher side of animal requirements (i.e. >17% CP). However, pasture protein has been demonstrated to undergo extensive rumen breakdown and substantial loss before it can be absorbed at the small intestine resulting in a high dependency by pasture-fed cows on their microbial protein synthesis ability to meet metabolisable protein/amino acid requirements. Furthermore, there are a number of studies that demonstrate increased milk production performance when pasture-fed cows are supplemented with rumen-protected protein ingredients. Due to the variability in pasture CP throughout the grazing season and the extensive breakdown in the rumen, rumen-protected amino acid sources may have a role in maintaining or increasing animal performance when low N concentrate are offered to grazing dairy cows.

PASTURE-NUE

As part of a DAFM funded PASTURE-NUE project, a series of experiments are currently being conducted at the Teagasc Dairygold Farm, Kilworth. The objective of these experiments is to provide insight into strategic low N supplementation strategies. Concentrates ranging from 9%-17% CP/kg of DM are being investigated, across the grazing season, along with a concentrate containing rumen-protected amino acids. A large-scale commercial farm experiment, characterising pasture CP concentration across the grazing season, is also included in the project. Finally, experiments are underway investigating concentrate CP concentration when grass silage or grass-red clover silage are offered to lactating dairy cows in early and late lactation.

Conclusions

Pasture-based systems must reduce their N emissions to the environment. Strategic low N supplementation strategies are a promising mechanism to achieve this. Further investigations are underway in order to consistently attain reduced N excretion while maintaining animal performance.

Acknowledgements

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Reduced milk fat synthesis on Irish dairy farms

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Summary

- Annual milk fat concentration has made considerable gains over recent years.
- However, there is a consistent reduction in milk fat concentration during the months of April through July.
- Reduced milk fat synthesis is likely multifactorial with both nutritional and non-nutritional factors playing important roles.

Introduction

Milk fat is important for the production of butter, cheese, cream and whole milk powder; hence, it contributes substantially to the economic value of milk. Milk fat is also considered the most variable milk component with many nutritional and non-nutritional factors proposed to affect its production. Data from the Central Statistics Office, reporting monthly co-op intake of cow's milk, demonstrates that Irish annual milk fat concentration has made considerable gains over recent years (4.01% in 2012 compared with 4.39% in 2022). However, further analysis demonstrates a consistent reduction in milk fat concentration during the months of April through July. As this time period coincides with peak milk production, an increase in milk fat concentration during these months, would provide opportunity for farmers to increase the economic sustainability of their system.

Stage of lactation has been proposed as a non-nutritional factor involved in reduced milk fat synthesis. While it likely contributes, previous research has shown that the highest prevalence of a reduction in milk fat concentration occurred in April and May for both spring and autumn calving dairy cows, suggesting that time of year was more important than stage of lactation. The association of a reduction in milk fat concentration with time of year warrants further investigation as it could be related to environmental factors (e.g. day length) or nutritional factors (e.g. diet composition) that are prevalent during this risk period.

Potential nutritional causes of reduced milk fat synthesis

One of the leading theories as to the cause of reduced milk fat synthesis focuses around the dietary intake and rumen biohydrogenation of polyunsaturated fatty acids (PUFA). Biohydrogenation involves the addition of hydrogen to unsaturated fatty acids in the rumen converting them partially or fully to saturated fatty acids. Changes within the rumen environment of the cow can affect this process and results in alternative pathways of biohydrogenation, ultimately producing intermediates that are potent milk fat synthesis inhibiting molecules. Examples of factors that can lead to such changes within the rumen include; 1) high rumen PUFA load 2) low rumen pH, and 3) increased rumen passage rate. Pastures containing high fat concentration and low fibre concentration during the April-July period have been suggested to contribute to these factors in grazing dairy cows. However, data to support this hypothesis are quite limited. In order to overcome this, during 2021 and 2022, 28 commercial dairy farms from a large geographical spread were sampled across the grazing season. In-depth laboratory analysis is currently on-going to quantify the fat concentration, fatty acid profile and fibre concentration of pasture.

Level of concentrate supplementation has also been suggested as a possible theory for reduced milk fat synthesis. High levels of concentrate supplement can reduce dietary fibre concentration and increase the amount of rapidly fermentable carbohydrate consumed by the cow, leading to lower rumen pH. Low rumen pH can negatively impact fibre digestion, which can lead to a reduction in the amount of acetate and butyrate production from fibre fermentation in the rumen. Acetate and butyrate are major precursor required for milk fat synthesis in the mammary gland.

Lactating dairy cow nutrition research

During 2021, an experiment was performed to investigate the effect of concentrate supplementation level and type on milk fat production. Our hypothesis was that as concentrate supplementation level increased, from 0-4 kg of DM/cow per day, milk fat concentration would decrease. While concentrate supplementation level increased milk fat yield, there was only a tendency for reduced milk fat concentration. This suggests that level of concentrate (up to 4 kg of DM/cow per day) does not have a major impact on milk fat concentration. Concentrate supplement type was also investigated in the experiment. A concentrate containing 10% sodium hydroxide treated straw and a concentrate containing 5% rumen-protected fat (RPF) were compared to an industry standard concentrate. At the inclusion levels investigated, the high fibre and the high RPF ingredients did not have an effect on milk fat concentration. However, the RPF ingredient significantly increased milk fat yield when compared with the industry standard concentrate (1.14 vs. 1.09 kg of fat/cow per day, respectively).

There is a growing body of evidence as to the effectiveness of RPF to increase milk fat concentration and yield for indoor-fed dairy cows. The fatty acid profile of this RPF seems to play an important role with higher palmitic acid concentrations shown to be more effective. During 2022, an experiment was performed at Teagasc to investigate the effect of RPF supplementation on milk fat production in grazing cows during the early to mid-lactation period. The cows received pasture plus one of three concentrate supplements containing either; 1) no RPF, 2) 5% RPF with a medium concentration of palmitic acid (58%); and 3) 5% RPF with a high concentration of palmitic acid (97%). Overall, the higher level of palmitic acid supplementation increased milk fat concentration but did not affect milk fat yield. During this experiment, the effect of animal genotypes on milk fat production was also investigated with three animal genotypes (high EBI Holstein-Friesian (HF), medium EBI HF and purebred Jersey) being incorporated into the experiment. The animal groups differed in terms of their predicted transmitting ability (PTA) for fat percentage with the purebred Jersey highest, high EBI HF intermediate and medium EBI HF lowest (0.54, 0.20 and 0.11 milk fat % PTA, respectively). Animal genotype had a significant effect on milk fat concentration with the purebred Jersey highest, high EBI HF intermediate and medium EBI HF lowest (5.71, 4.62 and 4.24% milk fat, respectively). On commercial farms, the PTA for fat percentage has also been demonstrated to be a strong indicator of milk fat concentration.

Conclusions

Reduced milk fat synthesis is multifactorial with both nutritional and non-nutritional factors playing important roles. This research has quantified some of the impacts of these factors on milk fat production; however, further investigation is required to identify the mechanisms involved and to develop robust mitigation strategies.

Principles of reseeding

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Summary

- Reseeding is one of the most cost effective on-farm investments.
- There is little difference in the outcome between reseeding methods once completed correctly.
- There is no loss in grass production in the establishment year with spring reseeding compared to permanent pasture.
- Management after reseeding is important to ensure good establishment.

Introduction

Reseeding levels in Ireland are low. Less than 2% of our national grassland area is reseeded annually. As grass is our dominant feed during the main grazing season, and the primary source of winter forage in the form of grass silage, the low level of reseeding must be addressed. Swards with low perennial ryegrass content are costing farmers up to €300/hectare (ha) per year due to reduced herbage production and reduced nitrogen (N) use efficiency. Reseeding costs approximately €750/ha, however the increased profitability of the new sward would cover the cost in just two years making reseeding one of the most cost effective on-farm investments.

Cultivation techniques

How paddocks are prepared for reseeding depends on soil type, quantity of underlying stone and machine/contractor availability. While there are many cultivation and sowing methods available, once completed correctly all methods are equally effective.

Key principles to follow when reseeding

- Aim to reseed as early in the year as possible, April, May, June, when soil temperatures are high and increasing, and there is adequate opportunity for weed control
- Soil sample for P, K and pH
- Spray off the old pasture with a minimum of 5 L/ha of glyphosate; allow a minimum of 7-10 days after spraying before cultivating
- Prepare a fine, firm seedbed
- Use grass and white clover varieties from the Teagasc Pasture Profit Index and the DAFM Recommended List
- Sow at a rate of 25 to 28 kg/ha of grass plus 2.5 to 5.0 kg/ha of a medium leaved clover
- Include no more than three or four grass cultivars per mix. Keep the heading date range in a mix narrow – no more than seven days
- Avoid sowing white clover seed too deep; sowing depth – approx. 10 mm
- Roll well to ensure good contact between the seed and the soil
- Apply a suitable post-emergence spray when weeds are at seedling stage

Timing of reseeding

Timing of reseeding depends to a large extent on weather conditions, and grass supply. Generally, total grass production from a spring reseed is as much as, if not more than, old permanent pasture in the establishment year. Establishing clover is more reliable in spring than autumn due to the stability of soil temperatures. Conditions for post-emergence weed control are also more favourable following spring reseeding. While autumn reseeding may make sense from a feed budget perspective, soil conditions deteriorate as autumn progresses, lower soil temperatures can reduce seed germination, and variable weather conditions reduce the opportunity to apply post-emergence spray and to graze the new sward.

Management of reseeds

Weed control is an essential part of the reseeding process. Weeds in new reseeds are best controlled when grass is at the 2-3 leaf stage. Docks and chickweed are two of the most critical weeds to control in new reseeds; it is important to control these at the seedling stage, by applying the herbicide before the first grazing. When clover is included in the swards, it is important to use a clover safe herbicide where available. All pesticide users should comply with the regulations as outlined in the Sustainable Use Directive (SUD).

Care must be taken when grazing newly reseeded swards. The sward should be grazed as soon as the new grass plants roots are strong enough to withstand grazing (root stays anchored in the ground when pulled). Early grazing is important to allow light to the base of the plant to encourage tillering and clover establishment. Light grazing by animals such as calves, weanlings or sheep is preferred as ground conditions may still be somewhat fragile, depending on the seedbed preparation method used. The first grazing of a new reseed can be completed at a pre-grazing yield of 600 to 1,000 kg dry matter (DM)/ha. Frequent grazing of the reseeds at lower pre-grazing yields (< 1,100 kg DM/ha) during the first year post-establishment will have a beneficial effect on the sward. The aim is to produce a uniform, well tillered, dense sward. If possible reseeded swards should not be closed for silage in their first year of production as the shading effect of heavy covers of grass will inhibit tillering of the grass plant and clover establishment resulting in an open sward which is liable to weed ingress.

Conclusion

Reseeding in spring and early summer is preferable to autumn reseeding. There is little difference between reseeding methods once a firm seedbed is established and good seed-soil contact is achieved. Many management factors affect the success of reseeded swards. Good management after sowing is just as important as decisions around timing and methods of reseeding.

Updates to the pasture profit index for 2023

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Summary

- The Pasture Profit Index (PPI) identifies the best perennial ryegrass varieties to sow when reseeding pastures.
- The index allows for the selection of varieties with the greatest overall production and allows trait specific variety selection choices to be made.
- The key traits in the PPI are Spring, Summer and Autumn DM production, Grass Quality, Silage DM yield, Persistence and Grazing Utilisation.

Introduction

Regular reseeding of pasture allows farmers to grow increased yields of higher quality grass, thereby increasing feed self-sufficiency and sustainability of their farms. The Pasture Profit Index (PPI) is used when deciding 'what varieties to sow in my reseeded sward?'. The PPI outlines, in economic terms, the agronomic differences between varieties for traits that influence the profitability of ruminant production systems.

Using the PPI

The 2023 PPI list is displayed in Table 1. Variety performance data is collected and assessed by the Department of Agriculture, Food and the Marine Recommended List trials, which take place at five sites across Ireland. Varieties are ranked based on their overall PPI value which is calculated by adding its performance in each of the sub-indices or traits that make up the PPI. These sub-indices (and their relative emphasis within the PPI) are Spring (19%), Summer (6%) and Autumn (8%) dry matter (DM) production, Mid-season Quality (measured as DM digestibility; 25%), Silage DM yield (13%) and Persistency (29%). The relative emphasis of a trait within the PPI is based on its economic value and the level of variation between varieties for that trait. Aberclyde is the top ranked variety for 2023 with a PPI value of €253. This value indicates that by sowing Aberclyde on your farm, net profit will increase by €253/hectare per year relative to the national average sward performance in Ireland. The higher the € value for a trait the greater the varieties performance. Cognisance should be taken of a varieties strengths and weaknesses as indicated by the PPI. The grazing utilisation sub-index does not contain € values but ranks varieties on a scale of 1-5 stars, with five stars indicating greatest grazing efficiency.

Farmers should select varieties using the PPI to ensure best return on investment when reseeding. Selecting based on the sub-indices allows for system specific seed mixtures to be designed. When choosing varieties for intensively grazed paddocks on the milking platform, those performing strongly in the grazing utilisation, quality and spring/autumn DM sub-indices should be selected. Variety selection for paddocks destined for regular intensive silage harvesting would benefit from prioritising the silage and spring yield traits. Paddocks located on the grazing platform but destined to be closed for silage should aim to combine high silage and utilisation traits. Research investigating variety mixtures found that the trait performance of a mixture could be accurately predicted as the average of the component varieties for all traits.

Table 1. *2023 Pasture Profit Index*

			PPI values €/ha per year							
			Total	Sub-indices						
Variety	Ploidy	Heading date	PPI	Spring	Summer	Autumn	Quality	Silage	Persistency	Utilisation
Aberclyde	T	25-May	253	51	66	46	44	46	0	****
Barwave	T	22-May	244	93	61	59	-20	50	0	****
Abergain	T	4-Jun	241	34	61	50	47	49	0	****
Gracehill	T	4-Jun	241	46	60	58	10	67	0	**
Abermagic	D	28-May	215	31	64	78	18	24	0	***
Nashota	T	3-Jun	214	53	57	39	28	38	0	*****
Aberwolf	D	28-May	209	54	54	48	11	43	0	**
Moira	D	27-May	209	108	39	57	-32	36	0	***
Glenfield	T	3-Jun	207	59	63	40	3	41	0	*****
Astonconqueror	D	26-May	206	75	52	48	-10	42	0	****
Aberplentiful	T	8-Jun	204	59	63	50	11	26	-6	**
Ballintoy	D	11-Jun	195	36	60	43	23	32	0	****
Meiduno	T	3-Jun	195	45	56	46	27	21	0	****
AberGreen	D	30-May	193	38	69	70	5	11	0	*
Anurad	T	5-Jun	191	54	52	41	31	19	-6	***
Aberchoice	D	31-May	190	15	65	58	22	30	0	***
Aberbann	T	24-May	190	5	81	75	-25	54	0	***
Fintona	D	3-Jun	190	49	52	49	-5	45	0	*****
Ballyvoy	T	29-May	186	65	46	47	19	10	0	*
Dunluce	T	4-Jun	184	23	58	52	24	34	-6	****
Gusto	T	27-May	176	50	51	64	2	9	0	****
AberBite	T	1-Jun	175	-2	56	53	32	36	0	*****
Bowie	D	31-May	170	19	53	54	28	16	0	-
Briant	T	1-Jun	156	10	58	46	13	29	0	***
AstonEnergy	D	2-Jun	151	5	47	43	49	6	0	*****
Oakpark	D	5-Jun	149	32	52	52	-12	25	0	*
Drumbo	T	10-Jun	146	23	44	42	24	13	0	*
Xenon	D	28-May	143	12	49	35	29	17	0	*****
Triwarwic	D	3-Jun	141	20	53	30	7	32	0	-
AstonKing	T	3-Jun	141	61	50	36	-25	18	0	***
Aspect	T	2-Jun	136	11	50	30	27	23	-6	*****
Callan	D	5-Jun	126	71	39	35	-35	16	0	****
AstonKing	T	3-Jun	141	61	50	36	-25	18	0	***
Aspect	T	2-Jun	136	11	50	30	27	23	-6	*****
Callan	D	5-Jun	126	71	39	35	-35	16	0	****

Conclusion

The PPI identifies the best varieties for Irish farms. A variety's strengths and weaknesses should be noted to make informed decisions when choosing varieties.

Dry matter production persistence of perennial ryegrass swards on commercial grassland farms

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Summary

- Stability of pasture dry matter production has a significant impact on farm economic sustainability.
- Results from on-farm evaluation suggest little difference between varieties in terms of persistence in swards up to eight years old.
- Dry matter production was similar between one and 5-8 year old swards for all varieties evaluated.

Introduction

Maximising pasture intake of dairy cows is a key factor in determining profitability on Irish dairy farms. This is due to the low cost of producing pastures in Ireland where the most expensive aspect of pasture production is often reseeding, which is most recently estimated at €1,100/ha by Teagasc. Perennial ryegrass (PRG) is the predominant pasture species used on commercial grassland farms in Ireland. As it is a perennial species PRG should, by definition, produce similar amounts of dry matter (DM) each year where all other factors affecting growth remain optimal.

In recent years, Teagasc researchers have been utilising data from PastureBase Ireland (PBI) to evaluate PRG variety performance on commercial farms. This ongoing evaluation has been operational for almost a decade and many paddocks on the trial have aged to eight years. This has allowed for the evaluation of varieties in a state of 'permanent pasture' (defined as pasture older than five years) on commercial grassland farms; such work is facilitated by the use of PBI and has not previously been possible. Up to now variety persistence values were derived from ground score measurements of Recommended List (RL) plots; however, measuring the actual DM production of varieties as they age is a more accurate method of assessing persistence. The persistence of a given variety has two major impacts at farm level: (1) where varieties are not persistent there will be an increased need for pasture reseeding to maintain adequate levels of forage production and (2) where varieties are persistent the cumulative difference in DM production between high and low yielding varieties will increase with each year post sowing.

Commercial farm research trial

Monocultures of eight varieties of PRG were sown in 649 paddocks across 101 Irish grassland farms between 2012 and 2021. These paddocks were treated similarly to all other paddocks on-farm in terms of grazing, fertilisation and weed control practices. Growth data for each paddock was taken from PBI; farmers on the trial were required to complete a minimum of 30 farm walks per year and where this standard was not met paddocks were excluded from the dataset for that year.

The eight varieties (along with the associated ploidy and heading date in parenthesis) sown as part of this work were: AberChoice (D; 9 June), AberGain (T; 4 June), Astonenergy (T; 2 June), Drumbo (D; 7 June), Kintyre (T; 6 June), Majestic (D; 1 June), Twymax (T; 7 June) and Tyrella (D; 4 June). These varieties were chosen as they were all RL varieties that provided a fair representation of the varieties sown on progressive grassland farms in Ireland from 2012–2021.

Results

Dry matter production was associated with sward age (Figure 1) but there was little change in the differences in DM production between varieties as they aged. One year old swards produced 955 kg DM/ha more than the average of 2-4 year old swards; however, there was no difference in DM production between one and 5-8 year old swards (Figure 1). Variety affected total DM production; AberGain had the highest DM production (15,376 kg DM/ha per year), growing 1,389 kg DM/ha per year more than the lowest producing variety.

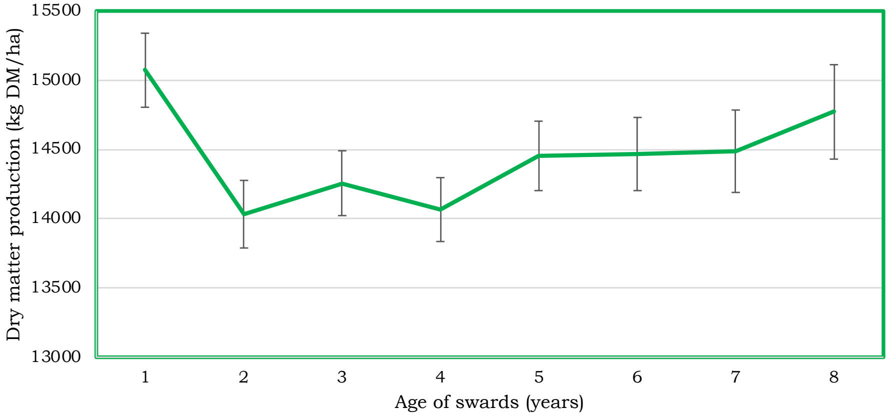

Figure 1. *Mean total dry matter production (kg DM/ha) of eight perennial ryegrass varieties (error bars represent standard error) from ages 1-8*

These results underline the persistence of PRG varieties on the Irish RL when they are utilised on well managed grassland farms. The pattern of DM production over time was similar for all varieties in the current trial as they aged to eight years old. This work emphasises the importance of choosing high performing RL varieties when reseeding paddocks as the differences between varieties will persist over time and can equate to an extra grazing per paddock per year. These results imply that the value of reseeding a paddock with improved PRG varieties may be underestimated when all other factors affecting grass growth (soil nutrient status, climate, grazing management) are optimised. This on-farm trial will continue indefinitely in order to assess the ongoing persistency of these varieties as the age to 10 years and beyond.

Conclusions

There is little difference between PRG varieties in terms of DM persistence on commercial grassland farms in Ireland up to eight years post sowing; selection of PRG varieties at reseeding will affect DM production throughout this period.

Acknowledgements

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New developments in the Teagasc-Goldcrop grass, legume and herb breeding programme

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Summary

- The breeding programme has adopted a multispecies breeding strategy targeted at increasing animal production potential, improving animal health and welfare, and reducing the environmental and climatic footprint of agriculture.
- Strong pipeline of new perennial ryegrass, white clover, red clover, chicory and plantain varieties for Irish farm systems.
- The breeding potential of complementary legumes, including birdsfoot trefoil and sainfoin, for growing with white or red clover is being investigated.

Perennial ryegrass

The majority of resources are committed to the improvement of perennial ryegrass (*Lolium perenne* L.), as it is the main forage species sown in Ireland. The traditional traits for improvement (e.g. yield, nutritional value, persistency and disease resistance) that were important 20 years ago are still relevant today. However, the programme continues to evolve and introduce new traits. We are the first breeding programme to select for residual grazed height or grazing utilisation. Grazing utilisation is a function of multiple components including sward architecture, quality, palatability and disease resistance. Modern technology, including advances in machinery, optical sensors (e.g. near infrared spectroscopy), machine learning and genomic selection, is being applied to accelerate genetic gain. These advancements are evident in a new late diploid perennial ryegrass variety, named Bandon (Table 1).

Table 1. *Bandon perennial ryegrass and comparable late diploid varieties on 2023 Ireland PPI*

Variety	Total €	Spring €	Summer €	Autumn €	Quality €	Silage €	Breeder
Bandon	216	39	68	58	29	21	Teagasc
AberChoice	190	15	65	58	22	30	
Ballyvoy	186	65	46	47	19	10	
Bowie	170	19	53	54	28	16	

White clover

The Teagasc white clover (*Trifolium repens*) breeding programme is arguably the strongest in north-western Europe supplying the majority of new varieties to the Ireland and UK Recommended Lists over the last decade. Its success is built on the rigorous evaluation and selection of the best plants under cutting and sheep grazing.

A number of new varieties from our last selection cycle are presently in test in the Ireland and UK Recommended List trials. The first of these, named Clodagh, has completed testing in the UK. Clodagh was found to be the highest yielding white clover variety in the UK (Table 2) and was added to the England/Wales and Scotland Recommended Lists in 2023. Clodagh is a large leaf variety selected for increased persistency, enhanced reliability and greater productivity thereby conferring greater sward quality, animal production potential and biological nitrogen fixation potential.

Table 2. *Clodagh white clover and comparable varieties on UK Recommended Lists*

Variety	Leaf size (% Aran)	Total clover yield	Total grass + clover yield	Ground cover (%)	Breeder
Clodagh	0.75	108	103	60	Teagasc
Barblanca	0.76	93	98	60	
Violin	0.75	99	100	56	
Dublin	0.73	100	100	53	Teagasc

Red clover

The Teagasc red clover (*Trifolium pratense*) breeding programme is a relatively small and new initiative that commenced in 2008. The focus is on greater persistency and productivity under grazing and silage production. There are no official red clover trials in Ireland. Thus, farmers choosing varieties should look to the UK Recommended Lists. The first ever Irish red clover variety bred by Teagasc at Oakpark and named Fearga was added to the UK Recommended Lists in 2018 (Table 3).

Table 3. *Fearga red clover and comparable varieties on UK Recommended Lists*

Variety	Total 3 year yield	Protein (%)	Ground cover (%)	Breeder
Fearga	106	18.0	60	Teagasc
AberClaret	104	18.0	60	
Merviot	98	18.5	56	
Sinope	104	18.5	53	

Other legumes

Swards high in white or red clover can cause bloat due to the rapid breakdown of clover protein. Condensed tannins, found in some other nitrogen fixing legumes, protect protein in the rumen resulting in not only reduced bloat but also reduced nitrogen loss, methane emissions, internal parasite burden and improved animal productivity. Legumes such as birdsfoot trefoil (*Lotus corniculatus* L.) and sainfoin (*Onobrychis viciifolia* Scop.) produce condensed tannins but are short lived under continuous grazing. The programme is investigating the potential to breed grazing-persistent birdsfoot trefoil and sainfoin varieties that can be grown as a complementary legume with white or red clover.

Herbs

Chicory (*Cichorium intybus*) and plantain (*Plantago lanceolata*) are deep-rooting, broad-leafed forage herbs. Included as part of a multispecies sward they offer a number of benefits including high productivity and feed value, yield stability under adverse weather conditions, reduced greenhouse gas emissions, lower nitrogen losses, enhanced biodiversity and reduced internal parasites in livestock. However, the persistence of these herbs is a major obstacle. Thus, the programme has bred two new grazing-persistent varieties of chicory and plantain. The new varieties are presently in test at Oakpark with a view to future release.

Acknowledgements

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The cost of producing home-grown feeds on Irish farms

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Summary

- Growing and efficiently utilising high-quality home-produced feed, rather than purchasing concentrates, remains the most cost-effective option for feeding livestock.
- Grazed grass is the lowest cost feed source available, with white clover inclusion in swards providing further opportunities to reduce costs.
- With high purchased concentrate costs, it is vital that farms produce sufficient winter feed of appropriate quality.

Introduction

The purpose of this article is to outline the cost of producing home-grown feeds on Irish farms in 2023.

Feed cost analysis

The "Grange Feed Costings Model" was used to determine the cost of commonly grown feed crops in April 2023. Assumptions applied for each feedstuff are outlined in Table 1. Organic slurry was applied to all crops, which consequently lowered fertiliser requirements. Based on market prices in April 2023, protected urea cost €730/tonne (a straight nitrogen product used for each feed) and rolled barley was valued at €360/tonne fresh weight. Contracting costs were based off Farm Contractors Ireland reference figures; pit silage = €175/acre, mowing = €28/acre, tedding = €16/acre, baling = €8.50/bale, maize harvesting = €200/acre, beet harvesting = €180/acre. It is acknowledged that these prices may change throughout 2023. All prices include VAT. Land charge was assumed to be €300/acre. Red clover was assumed to be reseeded every six years.

Results and conclusion

The results of the estimated feed costs in April 2023 are outlined in Table 1. The estimated cost of baled silage is outlined in Table 2. Grazed grass is the cheapest feed resource, with white clover inclusion adding further reductions in cost. Fodder beet has somewhat lower production costs compared to grass silage when expressed per unit of energy utilised basis (although these crops have a greater demand for protein and mineral supplementation, which were not included in this analysis, when compared to grass crops). Purchased concentrates such as rolled barley remains an expensive feed resource, compared to grazed grass.

Prices quoted in this article are those prevailing at the time of the analysis (first week of April 2023) and are subject to high levels of volatility.

Table 1. *Feed assumptions and estimated costs (€) to produce feed in April 2023*

	Grazed grass	Grass+ white clover	First + second cut pit silage[1]	First + second cut bale silage[1]	3-cut red clover silage	Maize silage (open)[2]	Fodder beet[2,5]	Purchased rolled barley @ €360/t
Feed Assumptions								
DM yield (t/ha)	13	13	6 + 4	6 + 4	5.6 + 4.0 + 3.5	13	15	
DM (%)	17.4	17.4	21.7	32.4	30	30	19	
UFL/kg DM	1.03	1.02	0.82	0.82	0.82	0.8	1.12	
DM digestibility (%)	82	81	73	73	73	70	86	
Total fertiliser nitrogen (N) kg/ha	250	125	115 + 82	115 + 82	50	145	145	
Inorganic fertiliser N kg/ha	225	100	87 + 69	87 + 69	0	112	114	
Feed costs April 2023								
Total costs/ha (incl. land charge) (€)[3]	1,399	1,201	2,145	2,416	2,750	3,112	3,601	
Total costs/ha (excl. land charge) (€)	658	460	1,645	1,915	2,105	2,371	2,860	
Total costs/t DM grown (incl. land charge) (€)[3]	108	92	215	242	210	243	240	
Total costs/t DM grown (excl. land charge) (€)	51	35	164	192	161	185	191	
Relative cost to grazed grass per energy utilised (UFL)[4]	1.0	0.7	4.2	4.5	4.2	4.3	3.4	6.1

[1]*First- and second-cut silage were assumed to be cut on 29 May and 17 July, respectively;* [2]*The extra cost of protein supplementation required is not included;* [3]*Land charge of €300/acre (€741/ha);* [4]*This value excludes land charge associated with feeds. Including land charge, purchased barley is 2.9 times more expensive than grass;* [5]*When slurry is excluded from production, the cost to produce fodder beet rises to €214/t DM (excl. land charge) (€41/t fresh weight)*

Table 2. *Estimated cost (€/bale) to produce 2-cut baled silage in 2023*

Fertiliser (incl. spreading)[1]	Harvesting	Other (feeding, herbicides etc.)	Fixed costs (reseeding/ facilities)	Total excl. land charge	Total incl. land charge
€9.32	€23.86	€2.48	€2.66	€38.32	€48.33

[1]*2,500 and 2,000 gallons/acre of slurry was applied for first and second cut, respectively. The remainder of nutrient requirements is applied via inorganic N*

Dry matter production of grazed multispecies swards over three grazing seasons

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Summary

- The inclusion of white clover in grazed multispecies swards was crucial to increased dry matter production.
- Seasonal sward dry matter production was not altered by the inclusion of herb species.
- Trial will continue until December 2024 to assess persistency of herb species under grazing.

Introduction

Currently, there is spotlight on the use of legumes, specifically red clover (RC) and white clover (WC), in Irish grassland systems. A large amount of research has been carried out in this area, particularly with regard to WC in combination with perennial ryegrass (PRG) for grazing systems. Such work has shown that nitrogen (N) fertiliser input can be reduced, and sward dry matter (DM) production maintained, where sufficient WC is present in the sward. Further to this, international research has shown that the inclusion of herb species in grass and clover swards can have benefits in terms of wider ecosystem services, seasonal DM production and nutrient cycling. In contrast to the grass clover research undertaken to date the MS research work is in its infancy and there is very little research completed under intensive grazing. Productive herb species, such as chicory (CH) and plantain (PL), are often sown in complex multispecies (MS) mixtures with several other forage species and it can be difficult to measure species specific contributions to sward DM production. A deficit in knowledge exists regarding the DM production of MS swards in grazing systems and the actual contribution of the individual species to overall MS sward performance. Teagasc, Moorepark has undertaken a number of MS studies under grazing; the current work was set out to assess the DM production potential of various MS swards within a dairy grazing scenario with varied levels of N fertiliser application.

Project work

Multispecies plots of varying species complexity were sown in June 2019 at Teagasc Moorepark; the sward sowing treatments ranged in complexity from a PRG monoculture to a five species combination of PRG, WC, RC, PL & CH (see Table 1 for all sward species mixtures); three different nitrogen (N) application rates of 100, 150 and 200 kg N/ha per year were applied. These plots were managed to mimic a conventional Irish dairy grazing scenario where the PRG only sward receiving 200 kg N/ha per year was the control treatment within the study. Plots were grazed when pre-grazing herbage mass of the control reached 1,200-1,400 kg DM/ha and cows grazed all plots until the average post-grazing sward height across the plots was 4 cm. Data was collected from 2020-2022 and included three full grazing seasons where plots were grazed on 8-9 occasions each year.

Results

There was a clear DM production advantage of swards which included WC over the three-year period of this study (Table 1) where these swards produced an average of 1,619 kg DM/ha more than those which did not include WC. This represents a substantial difference in DM production and highlights the importance of WC in grazed MS sward mixtures. While both RC and WC fix N from the atmosphere to make it available in the soil it is clear from these results that WC was more effective for increasing sward DM production in an intensive grazing scenario over the three years of this study. This effect was clear across N fertiliser application rates; swards including WC receiving 100 kg N/ha produced comparable levels of DM to swards without WC receiving 200 kg N/ha (Table 1). No clear trends in increased seasonal DM production were observed in swards containing either CH or PL. Previous work has shown that PL is more winter active than conventional grass or clover species but no early season increase in DM production was observed in swards where PL was sown compared to PRG and WC swards. Similarly, swards including the summer active CH did not show increased summer growth compared to swards sown without CH.

Table 1. *Mean dry matter production (kg DM/ha) of multispecies swards over three years for three nitrogen application rates (kg N/ha)*

Species mixture	100 N	150 N	200 N
Grass	8,983	9,645	10,094
Grass & chicory	9,555	9,781	10,497
Grass & plantain	9,883	10,763	10,354
Grass, chicory & plantain	9,303	10,328	10,921
Grass & red clover	9,262	9,498	10,898
Grass & white clover	11,124	11,254	12,375
Grass, white clover & red clover	11,042	11,610	11,675
Grass, white clover & plantain	10,595	12,480	12,346
Grass, white clover, plantain & chicory	11,153	11,963	12,015
Grass, white clover, red clover, plantain & chicory	10,721	11,298	12,396

Conclusions

Sward species mixture had a significant effect on sward DM production across all rates of N application. While the inclusion of herb species did not affect sward DM production, either annual or seasonal, compared to PRG and WC swards in the current study they may provide other benefits to grassland systems including more efficient nutrient cycling and utilisation; work is currently underway to assess these aspects of MS swards. Over the course of the current trial it became apparent that PL was more persistent under grazing than both CH and RC although further measurements are required to validate this persistency. This grazed plot trial will run for a further two years to fully assess the DM production persistency and the N fertiliser response of MS swards under grazing in Irish dairy systems; other work is currently underway to investigate the impact of herb species inclusion on milk production.

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MultiMilk: an investigation of the impacts of sward and animal characteristics on grazing dairy system performance

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Summary

- Diverse legume-based multispecies pastures have been shown to enhance nutrient use efficiency and forage quality while also enhancing biodiversity, and long-term carbon sequestration.
- The initial results of this study indicate that productivity of swards incorporating additional plant species are comparable with perennial ryegrass only swards in terms of DM yield, require fewer chemical fertiliser applications and support enhanced animal performance at grazing.

Introduction

As part of the management of simplified systems, monocultures of perennial ryegrass (PRG) have traditionally dominated Irish grazing swards. Although such swards are capable of producing annual DM yields of 13-16 t dry matter (DM)/hectare (ha) of high quality forage, the continuation of such systems is questionable due to their reliance on high levels of chemical nitrogen (N) application (250 kg/ha). To reduce chemical N requirements and improve nutrient use efficiency and forage quality, the incorporation of legumes and herbs within grazing swards is considered as one practical farm-scale response. Recent studies suggest that the production of grass-legume swards are comparable with PRG-only swards in terms of DM yield, require fewer chemical fertiliser applications and support enhanced animal performance at grazing. More recently, a number of additional plant species with high forage production potential have also been identified which provide additional sward complementarities. Among these diverse plants, chicory and plantain are deep-rooting broad-leafed forage forbs that have been identified as valuable complementary forage species with high productivity and feed value. Previous and ongoing Irish and pan-European grassland research is showing that increasing pasture species diversity can also increase N use efficiency and soil carbon sequestration and provide necessary adaptation to climate change, in particular in terms of reducing the impacts of dry summer conditions on pasture and system productivity.

Curtins Farm - The MultiMilk research project

The objective of the project on Curtins farm is to compare the performance of three farmlets with PRG, PRG-White clover (PRWC) and an 8-species multispecies sward (MSS). Each of the three swards are grazed by high Economic Breeding Index Holstein-Friesian (HF) and Jersey Holstein-Friesian crossbred cows (JFX). Each farmlet is managed with a stocking rate of 2.50 cows/ha and in line with the objective of reducing the chemical N fertiliser, the PRG farmlets receive 250 kg N/ha per year while both the PRWC and the MSS farmlets receive 125 kg N/ha year. To evaluate the performance of these three swards, detailed pasture and animal performance measurements are undertaken and this paper documents the results of the initial two years (2021 and 2022) of this farm systems evaluation. During the first two trial years, and despite a large differential in N fertiliser application (250 vs 125 kg/ha), total pasture DM production was similar for all three sward types (11.3, 10.7 and 11.0 t DM/ha for PRG, PRWC and MSS, respectively). Pasture clover contents were also similar between the PRWC and MSS swards (9% clover in year 1 and 17% in year two). Equally, pasture nutritive value characteristics (for 2021 only) were also similar between sward types during the grazing season (Figure 1). On average, pasture organic matter digestibility (OMD) was 81.4% for both PRG and PRWC sward and 80.2% for MSS while pasture crude protein (CP) content was 21.4% for all swards.

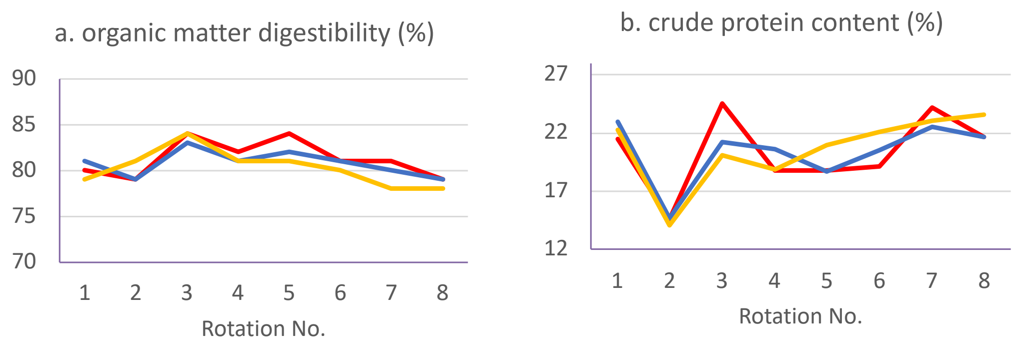

Figure 1. *Impacts of sward type (PRG, red line; PRWC, blue line; MSS, yellow line) on a) organic matter digestibility and b) crude protein content during the initial grazing season (2021 only)*

The impacts of both sward type and breed group on milk production performance during the initial two years of the study are presented in Table 1. Over the two year period, cows grazing MSS produced significantly more milk (+ 259 kg) and milk solids (+15 kg fat plus protein) than cows grazing PRG-only swards, while the PRWC group where intermediate. Sward type had no significant effect on milk fat, protein or lactose content. Similarly, breed had a significant effect on milk characteristics with JFX cows achieving superior milk solids (+ 14 kg/cow) compared to HF cows due to increased milk fat (+ 0.32%) and protein (+ 0.15%) contents. There was no significant sward by breed interaction observed for milk production characteristics.

Table 1. *Impacts of sward type (ST; PRG, PRWC and MSS) and breed (B; HF and JFX) on milk production performance during the initial 2 years of the study (2021-2022)*

Sward type	PRG		PRWC		MSS	
Breed	HF	JFX	HF	JFX	HF	JFX
Milk yield (kg/cow)	5,135	5,006	5,154	5,150	5,407	5,253
Milk solids (kg/cow)	451	468	459	472	468	482
Fat content (%)	5.04	5.48	5.21	5.51	5.06	5.36
Protein content (%)	3.67	3.87	3.73	3.79	3.75	3.89
Lactose content (%)	4.77	4.77	4.73	4.77	4.76	4.77

Conclusion

The results of the initial two years of this study indicate that increasing sward species diversity using clovers and herbs is one practical farm-scale response to significantly reduce N requirements while maintaining pasture nutritive value and increasing animal performance. The study will continue at Curtins farm to evaluate the performances of these swards over the longer term.

Red clover silage

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Summary

- Red clover silage swards can produce high yields without the need for chemical nitrogen (N) inputs due to its ability to fix in excess of 200 kg N/ha.
- Red clover is more suited to silage than grazing systems.
- Cutting at 6-8 week intervals will help swards persist for 3-4 years.

Introduction

Red clover (RC) can contribute substantially to organic, low-input and conventional animal production systems due to its ability to fix atmospheric nitrogen (N) and support of higher animal performance. Swards with a high RC content (75% on a dry matter (DM) basis) are capable of fixing 24-36 kg N/t (DM) produced, meaning swards of high clover proportion and DM production are potentially fixing in excess of 200 kg N/hectare (ha) per year. Given the rising cost of fertiliser and feed, and increasing environmental constraints, incorporating RC into swards can offer significant benefits to ruminant production systems. Despite the many benefits of RC inclusion, it has had limited uptake on pasture-based production systems in Ireland. The poor on-farm uptake of RC is likely due to its more complex management requirements, unsuitability to frequent grazing, reduced persistence (approximately 3-4 years), and the relatively low cost of chemical N fertiliser in the previous years.

Agronomy

Unlike perennial ryegrass (PRG) and white clover varieties, no Recommended List currently exists for RC varieties in Ireland, with Irish producers relying on information from the UK Recommended/National List to identify suitable varieties. Red clover should be grown in rotation, allowing for a four-year break to control diseases such as stem eelworm and Sclerotinia fungus (clover rot). Typically 7.5 to 10 kg/ha of RC in addition to 20 to 22 kg/ha of PRG should be sown on well drained soils with a soil pH of 6.5 to 7. Depending on soil moisture and temperature, seedbed preparation and sowing, establishment may be slow but not necessarily a failure. Spring reseeds offer the greatest window of opportunity to optimise pre and post-sowing management.

Red clover has a deep taproot, an erect growth habit, with a low density of large shoots. Stems are formed from the growing points located on the crown on top of the taproot. Reserves of carbohydrates and N are stored in the crown and taproot, where they are remobilised to fuel regrowth after defoliation. The crown/growing point of RC is solitary and exposed, making it vulnerable to physical damage by machinery and animals. This means that RC is best suited to infrequent silage cuts rather than regular grazing. Cutting intervals of six to eight weeks allow sufficient time for the canopy to intercept sunlight to replenish energy reserves. Increasing the defoliation frequency beyond three cuts can reduce yield due to insufficient replenishment of plant reserves and thus persistence. 'Late' silage harvests (beyond mid-September) can be difficult to ensile (insufficient wilting) and are of relatively low yield making it difficult to justify economically. Red clover has a low water soluble carbohydrate concertation and high buffering capacity, reducing its ensilability. The inclusion of perennial ryegrass as a companion species will improve the overall ensilability of RC silages as well as wilting (24-48 hours) to increase DM concentration, while ensuring that the leaf is not damaged (shattered) as a result of over wilting and excessive machinery passes.

Feeding value

Red clover silage can support higher animal performance than PRG-only silage. The feeding vale of RC silage appears lower than that of PRG, with lower levels of digestibility because of high fibre levels. The elevated fibre levels are likely due to the higher levels of stem required to support the plants erect growth habit. Despite overall lower digestibility increased DMI and animal performance can be achieved due to the faster rate of digestion of plant fibres and increased particle break down contributing to increased passage rate and lower rumen fill.

DM yield

Recent research from Grange has shown that Mixed RC and PRG swards receiving no chemical N were found to have similar annual DM production to PRG swards receiving up to 412 kg N/ha per year (15.8 and 15.7 t DM/ha, respectively).

Conclusion

The inclusion of RC into silage swards has great potential across Irish pasture-based production systems of all intensities. These swards have an enhanced ability over grass only swards to maintain high levels of herbage production and animal performance in the absence of chemical N fertiliser.

The role of soil fertility in successful clover adoption

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Summary

- The survival and productivity of red and white clover in grassland are dependent on near-neutral soil lime status and high availability of soil potassium.
- High rates of biological nitrogen fixation are dependent on high clover herbage yields and near-neutral soil lime status.

Introduction

The growth habits of white and red clover are very different from perennial ryegrass. White clover produces stolons (like ivy or strawberries) that grow along the surface of the soil sending down very shallow roots at intervals as it spreads throughout the sward. Red clover produces a deep tap root. Nevertheless, when both white and red clover are grown with perennial ryegrass they typically make up only 15% to 25% of the root volume in the soil. Perennial ryegrass produces a dense and extensive network of fine roots that makes it very effective at competing for soil nutrients. This competition can very quickly drive the clover out of the sward.

The primary reason for including clover in grassland is to produce plant-available nitrogen (N). This process involves the conversion of atmospheric dinitrogen (inert gas) into ammonium (plant-available N); a process known as biological nitrogen fixation (BNF). This ammonium can replace artificial fertilizer such as calcium ammonium nitrate (CAN). *Rhizobia* bacteria are key to this process in a symbiosis whereby the clover shelters and feeds the *Rhizobia* in nodules on its roots in exchange for making ammonium available in the soil. Hence, when we consider management of soil fertility for clover in grassland we also have to take into account the *Rhizobia*. Adequate soil lime status is important in this regard.

Lime

Ground limestone is used to neutralise the degree of acidity of the soil. There are a number of reasons why soils are acidic including rainfall, which is mildly acidic and tends to make soils more acidic over time. Making soil less acidic through the application of ground limestone increases biological activity which increases the availability of a wide range of soil nutrients and trace elements.

White clover and, in particular, red clover does not persist under acidic soil conditions (low soil pH = 5). A near neutral soil pH = 7 is also important for BNF. At a low soil pH = 5, no BNF takes place even when clover is present in the sward. Increasing soil pH increases BNF up to an optimum at near neutrality. For this reason we aim to maintain soil lime status at Solohead between pH 6.5 and 7.2, which is higher than that recommended for monocultures of perennial ryegrass (pH ≥ 6.2). We routinely work lime into the seedbed during reseeding at a rate of 5 t ground limestone per ha (2 t per acre). Otherwise, we apply ground limestone depending on soil test results.

Nitrogen (N)

At Solohead we routinely grow close to 15 t pasture dry matter (DM) per ha per year on the grazing platform without input of artificial fertilizer N. Around one third is clover or 5 t DM per ha. It takes one t of clover DM to produce 50 kg of plant-available N in the soil. Hence

BNF is approximately 250 kg N per ha. Red clover has an even greater capacity for BNF and can supply in excess of 300 kg N per ha. Along with high soil pH (as outlined above) maintaining high soil fertility is important to increase the productivity and the longevity of clover in grassland.

Potassium (K)

Red and white clover have a higher requirement for K than grasses. Grasses are much more effective at competing for soil K than clovers. Hence, clovers can die out very quickly in fields with soil test K (STK) Indices 1 and 2. It is necessary to first feed the grass for there to be enough soil K available for the clover to meet its needs.

STK Index 3 (100 to 150 mg/L) is recommended for perennial ryegrass. To maintain high clover production on the grazing platform at Solohead we aim to maintain STK at high Index 3 or low Index 4 (150 to 200 mg/L). Taking into account the balance between imports of K in concentrates, exports in milk and livestock sold off the farm, K leaching and K getting locked up in the soil we routinely apply 30 kg/ha of fertilizer K per ha per year to maintain STK in the above range. This is in addition to slurry recycled back onto the grazing platform. The fertilizer K is applied in two splits of 15 kg/ha; the first in March or April and the other onto any paddocks where surpluses are taken off for silage. On paddocks that require build-up of STK (Index 2 or 3) we apply 60 kg/ha of K in four splits per year; after every second grazing; little and often to minimise the risk of grass tetany.

At Solohead we cut the red clover silage swards four or five times per year; three silage cuts and one or two zero-grazing cuts, which take off 300-375 kg/ha of K in the silage and zero-grazed grass. This is fed indoors and almost all of this K ends in the slurry tank. Red clover swards have a huge capacity for luxury uptake of soil K, which can lead to inefficient use of K, high K contents in silage and risk of milk fever. Therefore, we apply K before closing for each cut during the year. On ground with STK Index 1 and 2 we apply K at a rate of 25 kg K per t of herbage DM that we expect to harvest. For example, if we expect a first cut yield of 5 t DM per ha, we need to put on 125 kg/ha of K either as slurry, dirty water or artificial fertilizer.

High soil K status is necessary to maintain clover in swards. High K contents in pasture and silage entail the risks of grass tetany and milk fever, which need to be managed by appropriate supplementation with CalMag.

Sulphur (S) and phosphorus (P)

One aspect of zero or low fertilizer N input is that it limits the range of compound fertilizers that can be used. In such instances, the cheapest way of applying S is usually Single Super Phosphate, which contains 8% P and 12% S. Beware that 16% Super Phosphate does not contain S. Sulphate of Potash (SOP: 42% K and 18% S) is useful source of S although SOP tends to be relatively expensive. Other compounds are available. On soils that require S, an application of 20 kg/ha of S in late March or April is sufficient to maintain S requirements for the year along with slurry and dirty water. Avoid applying S where it is not needed because it can cause copper deficiency.

Similar to K, low soil P (STP Index 1 or 2) will lead to the rapid disappearance of clover from grassland. Maintaining STP in index 3 is sufficient to meet clover requirements. P fertilization of reseeds should be prioritized to ensure clover establishment.

Conclusions

Clover can substantially lower overall fertilizer costs on farms. There is little scope for complacency when it comes to maintaining soil lime status to maximise clover productivity and BNF. There needs to be a clear focus on ensuring adequate supply of available soil K to the clover over and above grass requirements.

Grass10 campaign - improving sustainability of our grass based systems

John Maher, John Douglas and Joseph Dunphy
Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

Summary

- The Grass 10 campaign promotes sustainable grassland excellence.
- The objective of the campaign is to achieve 10 grazings/paddock per year utilising 10 ton of pasture dry matter/ha.
- There is a huge requirement to focus on educating the industry in the establishment and management of grass/clover swards.

Introduction

The requirement for resilient sustainable systems of milk and meat production has never been as high. There is continual change in global agriculture due to fluctuation in markets, agricultural policy, societal expectations and environmental constraints. As a result there will be further requirement to increase efficiency and sustainability in Irish pasture-based systems.

Grass10 Campaign

The Grass10 campaign aims to promote sustainable grassland excellence on Irish livestock farms (dairy, beef and sheep). The Grass10 partners are Grassland Agro, AIB, FBD, Department Agriculture Food & the Marine and the Irish Farmers Journal. The primary objective of the Grass10 Campaign is to utilise 10 tonnes of pasture dry matter (DM)/ha per year by achieving 10 grazings per paddock on grassland farms. The following farm practice changes were prioritised:

- Improving grazing infrastructure.
- Soil fertility — improve soil pH, P and K levels.
- Increase the level of reseeding.
- Improving the level of clover in pastures.
- PastureBase Ireland (PBI) usage.
- Improving grassland management skills.

Given the success of the Grass10 campaign over the last six years it is critical to maintain this momentum. The Grass10 campaign will continue to focus on increasing grass growth and utilisation of home grown feed on Irish grassland farms. The main focus of the campaign is to ensure the long term sustainability of Irish pasture-based dairy, beef and sheep production systems.

Improving the level of grass measurement and management

Currently, there are over 50 Grass10 grazing courses operating across the country and this model of improving the level of grassland management and measurement locally has worked well. This is fundamental work carried out during the Grass10 campaign and the plan is to further develop this knowledge transfer model to increase farm level adoption of grassland measurement and management using PastureBase Ireland (www.pbi.ie). Every extra day the animal spends at grass reduces greenhouse gas and ammonia emissions. Emissions are reduced by animals feeding themselves and spreading their own manure but also because the animal is eating a superior diet.

Clover

There is now an increasing demand to include white clover in grazed pastures due to its ability to biologically fix nitrogen making it available for grass growth and thereby potentially reducing inorganic nitrogen fertiliser use, while maintaining or increasing pasture production and quality and improving animal performance. There are challenges in establishing clover in swards at farm level. These issues revolve around time of sowing, soil fertility, herbicide choice and grazing management. There is a huge requirement to focus on educating the grassland industry in the establishment and management of grass/ clover swards. Some of the key developments planned in the Grass10 campaign will be:

- Establishing clover pilot farms nationwide in conjunction with the Clover 150 Programme, across enterprises, building a knowledge transfer programme around these farms
- Hosting clover workshops on farm and in Teagasc Research farms
- Publication of a Clover Management Guide - weekly clover updates in the Grass10 Newsletter

Nutrient management

Grass requires a continuous and balanced soil nutrient supply to achieve its production potential. Many farms are capable of growing in excess of 13 tons DM/ha annually. This level of grass production requires reasonable quantities of nutrients such as nitrogen (N), phosphorous (P), potassium (K) and sulphur (S) supplied at the correct time. The return in grass production from correcting soil fertility is very high. Improving nutrient use efficiency has become a priority due to the ambitious targets to reduce fertiliser use outlined in the EU Farm to Fork Strategy (2030). PastureBase Ireland can facilitate the process of improving nutrient use efficiency, by providing farmers with up-to-date information on fertiliser use, level of fertiliser requirements and soil fertility. Improving nitrogen use efficiency, along with technologies such as protected urea, LESS, GPS, etc. will assist Ireland to achieve its commitments to reduce greenhouse gas and ammonia emissions from agriculture. To promote the concept of better nutrient management and nitrogen use efficiency, the profiles of farmers who excel in this area will be disseminated through the Grass10 weekly newsletter (www.teagasc.ie/crops/grassland/grass10) and social media platforms in the programme.

Nutrient management and soil fertility are critical for reducing reliance on fertiliser nitrogen and for mitigating N losses to air and water

David Wall and Mark Plunkett
Teagasc, Crops, Environment and Land-use Programme, Johnstown Castle, Co. Wexford

Summary

- Maintaining the fertility of grassland soils is critical for sustainable food production.
- Optimising soil pH through lime application is the single biggest step towards productive and sustainable grassland swards.
- Better targeting of organic manures and application with LESS offers opportunities to reduce fertiliser N requirements on farms and to save money.

Introduction

Maintaining the fertility of agricultural soils is critical for underpinning the production of sufficient quantities of grazed grass and grass silage to feed dairy and dry-stock animals. However, the majority of agricultural land currently has incorrect soil fertility, i.e. lower than optimal soil pH, P, K, or S supply. On average, less than 20% of soil sampled in the last three years is within the optimum soil fertility ranges for these nutrients. As farmers transition their grassland swards towards the incorporation of N-fixing legumes such as white- and red-clover, achieving balanced plant nutrition will be more critical in order to sustain the productivity and longevity of these legumes within these fields. In addition, farms that have achieved balanced soil fertility levels are better positioned to adapt to reduced chemical N fertilizer use as set out under national climate and water quality regulations.

Increased efficiency of nitrogen fertiliser inputs by optimising soil fertility

Optimising soil fertility, especially optimising soil pH, P and K levels, leads to increased N use efficiency and opportunities to save chemical N fertilizer inputs on farms. A recent study across 15 intensive dairy farms in Ireland showed that where soil fertility was less than optimum (i.e. soil pH < 6.3, and P & K < index 3) N fertiliser use efficiency was only 35% (Table 1). Correcting soil pH alone gave the largest increase in N fertiliser use efficiency (53%) followed by optimising soil P and K respectively. Overall, highest levels of fertilizer N use efficiency were achieved in fields with balanced soil fertility (optimum soil pH ≥ 6.3, P and K (≥ Index 3)) on these grassland farms.

Table 1. *Percentage nitrogen use efficiency across grassland fields according to the status of soil pH, phosphorus (P) and potassium (K) fertility*

Mean nitrogen use efficiency by grassland (%)*	Soil pH with optimum range (pH>6.3)	Soil P within optimum range (>Index 3)	Soil K within optimum range (>Index 3)
63%	✔	✔	✔
54%	✔	✖	✔
57%	✔	✔	✖
53%	✔	✖	✖
35%	✖	✖	✖

Grassland nitrogen use efficiency was calculated as the percentage of the applied fertiliser and manure N recovered by the grass sward across the 446 fields (grazing block) on which measurements were taken over 2 years on commercial Irish dairy farms.

Realising the wider environmental benefits of optimising soil fertility

Recent research conducted at Teagasc, Johnstown Castle has demonstrated significant environmental benefits of optimising soil fertility through improved nutrient management. Greenhouse gas emissions in the form of nitrous oxide from soils were reduced by 22% where soil pH was increased to 6.3 (minimum soil pH for ryegrass swards) and reduced by up to 40% where soil pH was increased to 6.9. In addition, research has shown that optimising soil test P levels to index 3 (5.1-8.0 mg/L Morgan's P) helped to reduce nitrous oxide emissions by between 16-30% across well drained and poorly drained soils, compared to soils managed under suboptimal soil test P levels (Index 1).

Maximising the fertiliser replacement value of organic manures

Slurry is an important source of nutrients (N, P, K, S) and application to grassland must be properly timed to maximise the efficiency of slurry nutrient capture and utilization by the grass, as well as replenishing soil fertility levels. The targeted application of slurry in spring, based on soil test results to low P and K index fields, will ensure the most efficient use of slurry nutrients for grass production and will minimise potential ammonia-N losses. Slurry should also be recycled onto fields used for silage production in order to replenish the nutrients removed at harvest.

Conclusion

Through balanced nutrient management and maintenance of soil fertility a solid basis for high yielding grassland production can be created. Nutrient management planning and soil fertility are critical for increasing nitrogen fertiliser use efficiency and for enhancing the environmental sustainability and profitability of grass based dairy farms in Ireland.

Scan the QR code to view the boards

Signpost Village

Signpost Advisory Programme: helping farmers to reduce agriculture's greenhouse gas emissions

Tom O'Dwyer[1] and George Ramsbottom[2]

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Summary

- While Teagasc research has identified actions that reduce greenhouse gas emissions, the mix of actions for each farm will be different. What one change can you make to reduce your farm's greenhouse gas emissions?
- Teagasc is here to support you to identify the solutions for your farm. We promote "win-win" climate mitigation actions, which care for the environment and benefit the farmer. How can we help you?
- We have just appointed a team of 21 Climate Action and Sustainability Advisors to work with and support farmers across the country. Sign up to avail of our new, free Signpost Advisory Programme.

Introduction

The Teagasc Signpost Advisory Programme will support and help you to develop and implement a tailored Signpost Climate Action Plan for your farm. The Programme is free and available to all farmers. We have recruited 21 additional advisors to lead the delivery of the Programme in your area. They will offer a range of range of advisory activities, including:

- An assessment of your current climate actions;
- Support in interpreting your farm's greenhouse gas emissions and carbon footprint, including benchmarking your performance against targets;
- A farm specific Signpost Action Plan;
- Signpost workshops and short training courses focused on climate actions, including mitigation and adaptation measures;
- Invitations to participate in thematic discussion groups;
- One-to-one climate action advice from a Teagasc Advisor;
- Invitations to Signpost farm walks and seminars;
- Support with the implementation of your farm's Nutrient Management Plan; and
- A monthly Signpost e-Newsletter, updates and text messages.

Four steps to improving your farm's sustainability performance

Teagasc recommends a range of "good farming practices" that will enable farmers and growers to reduce gaseous emissions, protect and improve water quality, restore and enhance biodiversity, while also contributing to farm profitability. It is important that each individual farmer understands their farm's sustainability metrics (or numbers), what contributes to those numbers and the opportunities to improve them over time.

1. Know your farm's sustainability numbers

The starting point for any farmer on the journey to becoming more sustainable is to establish their farm's numbers or current performance. Farmers are familiar with a range of production-related indicators e.g. yield per cow, average daily gain, kg of beef sold per hectare or profitability related indicators, e.g. gross margin per hectare or net profit. Increasingly, farmers will have to understand new indicators, including greenhouse gas emissions, ammonia emissions, nutrient balance, nutrient use efficiency, biodiversity score, etc. Such indicators will be available to farmers through the new AgNav platform (see paper on AgNav, page 122).

2. Identify opportunities to improve your farm's sustainability numbers

There are many opportunities to reduce greenhouse gas emissions, capture carbon, reduce nutrient losses, improve water quality and enhance biodiversity; the potential will depend on the type of farming and your current practices. No two farms are exactly the same; so it follows that the solution will be different for each farm. Our advisers are on hand to help you to implement technologies and practices that can lead to improved sustainability. These include:

- Use of protected urea
- Application of lime to correct soil pH
- Correction of soil P and K deficiencies
- Use of LESS slurry equipment
- Timing of slurry application
- Reduced fertiliser N application rates
- Better grassland management/ use of PastureBase
- Incorporation of clover
- Provision of adequate slurry storage
- Improved herd health
- Breeding better/ more efficient animals (EBI/DBI)
- Earlier age at slaughter
- Optimum replacement rate
- Creation and management of field margins and buffer strips
- Appropriate management of hedgerows
- Retention or planting thorn saplings/ flowering trees

3. Implement your chosen actions

Teagasc recommends that farmers first identify, and then implement the priority actions on their farm. There are many possible actions that you could take, but your initial focus should be on those actions which are most suited to your farm and which can have the greatest impact. For example, in terms of reducing greenhouse gas emissions, Teagasc has estimated that for intensive grassland farms, switching to protected urea as your source of nitrogen fertiliser can have the greatest impact.

4. Keep records, monitor and review

Record keeping is essential to inform future decision-making, and to allow for the calculation of farm sustainability metrics over time.

How to get involved? Sign up today, or sign up online

Teagasc is here to help and support you to identify the tailored solutions for your farm. We promote climate adaptation and mitigation actions that can reduce greenhouse gas emissions, while also reducing your costs of production or improve margins. You can sign up to avail of our services at www.teagasc.ie/signpostsignup or by talking with your local Teagasc Advisor.

Update from the Signpost Demonstration Dairy Farmers

Siobhán Kavanagh[1], Tom O'Dwyer[2], Eoin Downing[3], Brian Moran[4] and Cathal Buckley[4]

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Summary

- The Signpost dairy farmers have adopted many of the climate mitigation technologies recommended by Teagasc, but there still exists scope to further reduce GHG emissions on these farms.
- The Signpost Programme has identified 12 Steps to reducing gaseous emissions on dairy farms and recommends that all dairy farmers check their position regarding each of the recommended actions.

Background

The Signpost Programme is designed to support and enable dairy farmers to farm more sustainably. This paper aims to benchmark the uptake of recommended climate mitigation practices for the dairy farms participating in the programme and describe changes over the first 24-month period (2021, 2022). These Signpost dairy farmers were not selected to be representative of the "typical dairy farmer" and operate at a higher level of productivity and profitability relative to the average National Farm Survey dairy farmers.

Results

There was a high level of technical performance on the 38 Signpost dairy farms in 2022 with an average milk solids output of 498 kg per cow using 173 kg of chemical nitrogen per ha and feeding 1,189 kg concentrates per cow. Similar to other dairy farms, on average Family Farm Income per hectare increased during 2022, largely due to higher milk prices (although costs also increased).

Looking at the usage of the recommended 12 steps to reducing emissions, Table 1 shows:

- These farmers are using protected urea as a source of more than half of their fertiliser N, but that there is still scope to increase its usage. Availability was an issue in 2022.
- These farms were extensively soil sampled in early 2022, and the farmers have used the results to target lime applications during both 2021 and 2022, with 77 tonnes spread per farm in 2022.
- Four out of ten soil samples had the correct soil pH, P and K. This is higher than is the case on a typical dairy farm (2 in 10 samples for 2022).
- There has been complete adoption of LESS by this group of farmers.
- These farmers have started the transition to a lower dependence of fertiliser N use, with fertiliser N usage 12% lower in 2022.
- Signpost dairy farmers utilised 12.0 t DM grass/ha last year with many exceeding the target of 12t DM grass utilised/ha.
- Milk was produced with a low SCC of 124,000 cells/ml on average.
- Herd EBI increased by €10 in 2022 and milk solids production was high on these farms at 498 kg/cow.

- On average these farmers achieved a 21% replacement rate in 2022, with their replacements calving at an average age of 24.2 months.
- The DBI of the sires used was €71 in 2022 with considerable scope for improvement.
- Finally, 86% of these farmers have incorporated clover into reseeds in 2022, setting them up for further reductions in chemical N use.

Table 1. *Performance of Signpost dairy farms for 2022*

		2022	Target
Family Farm Income €/ha		3,401	-
12 steps to reduce gaseous emissions			
Step 1	% total chemical N as protected urea	54	> 90%
Step 2	Lime usage t per farm	77	Soil pH 6.2+
Step 3	% samples with agronomic optimum soil fertility	42	90
Step 4	% slurry spread using LESS	99	100
Step 5	Kg chemical N / ha	173	150
Step 6	Tonnes DM grass utilised	12.0	12.0
Step 7	SCC, ,000 cells/ml	124,000	150,000
Step 8	EBI, € increase per year	+10	+10
Step 9	Milk solids, kg/cow	498	480
Step 10	Herd replacement rate % Age at first calving months	21 24.2	18 24
Step 11	DBI of beef sires € in 2022	71	150+
Step 12	% of farms incorporating high clover mix into reseeds	83	
Environmental Sustainability			
Total farm emissions t CO_2-e (IPCC[1])		974	-
Emissions t CO_2-e per ha (IPCC)		10.4	-
Emissions kg CO_2-e per kg FPCM (LCA[2])		0.87	0.76

[1]IPCC = intergovernmental panel on climate change; [2]LCA = life cycle assessment;

Conclusion

Considerable progress has been made on the Signpost dairy farms to implement the 12 steps to reducing greenhouse gas and ammonia emissions. There is more potential to further reduce total GHG emissions on the Signpost farms by further reducing chemical nitrogen use and increasing the proportion of their chemical N applied as protected urea. Improving both the pace and scale of adoption of climate mitigation technologies is the major focus for the Signpost Programme, both on the Signpost Farms and on all dairy farms.

AgNav: The new digital sustainability platform for agriculture in Ireland

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[3]*Teagasc, Oakpark, Carlow, Co. Carlow*

Summary

- AgNav is a newly developed digital sustainability platform that will be used to create farm specific sustainability plans.
- Streamlines the process by collating data from existing databases which will also improve accuracy of the assessment.
- Encourages and supports farmers in implementing management practices that improves the overall sustainability of their farming system.
- Supports clear communications on positive progress achieved at farm level and provides a mechanism to support the quantification of progress towards targets for the agricultural sector.

Introduction

A new digital sustainability platform, AgNav, is being developed to conduct robust sustainability assessments of farming systems in Ireland. Through years of collaboration Teagasc, Irish Cattle Breeders Association (ICBF), and Bord Bia have integrated Teagasc life cycle assessment (LCA) models into the ICBF infrastructure to calculate carbon footprints of Bord Bia certified farms. Using this infrastructure the collaboration has developed the AgNav platform, a digital platform for farmers and advisors that presents the environmental performance of commercial farms. Farm data residing in existing databases (e.g. ICBF and Bord Bia) will be collated to build a picture of each unique farming system. Collating existing data for individual farms streamlines the assessment process and improves the accuracy of results. For transparency, activity data is presented on user interfaces. The AgNav platform also provides the user with a live decision support tool that communicates the benefits of best practice adoption. This tool will be used for the creation of a farm specific sustainability plan.

Process

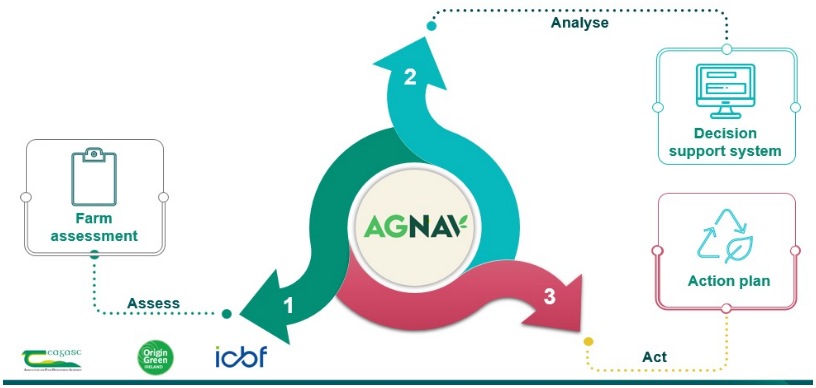

Figure 1. *The AgNav process in creating a farm specific sustainability plan*

Assess

Using collated data from ICBF and the Bord Bia sustainability survey, a farmer either individually or in consultation with a farm advisor can establish current farm performance for a number of relevant environmental sustainability indicators on the AgNav platform.

Analyse

Where farmers and/or advisors identify opportunities for changes to practices on farm that could result in improved performance, they can determine the impact of implementing these practices by using the "Forecast" decision support tool available in the AgNav platform.

Act

Following the identification of the most appropriate actions for their farm, a farmer and/or the advisor will use the "Action Planner" to create a sustainability plan for the farm which can include targets and timelines for implementation/completion. This plan will act as a guide for farmer/advisor engagement and demonstrate each farmer's commitment to delivering the action plan.

Future plans

The initial phase of the AgNav platform will be available for beef and dairy farms that are Bord Bia quality assured and have signed up for the Teagasc Signpost Advisory programme. The scope of AgNav will expand to accommodate all cattle systems as well as other enterprises (e.g sheep, tillage, pigs) as the work programme progresses, regardless of their affiliation to AgNav partners. Furthermore, while the initial phase of the AgNav platform focuses on greenhouse gas and ammonia emissions, future phases will include other environmental indicators such as biodiversity, water quality, carbon sequestration and others. Where possible AgNav will establish data flows with relevant databases to improve user experience and assessment quality.

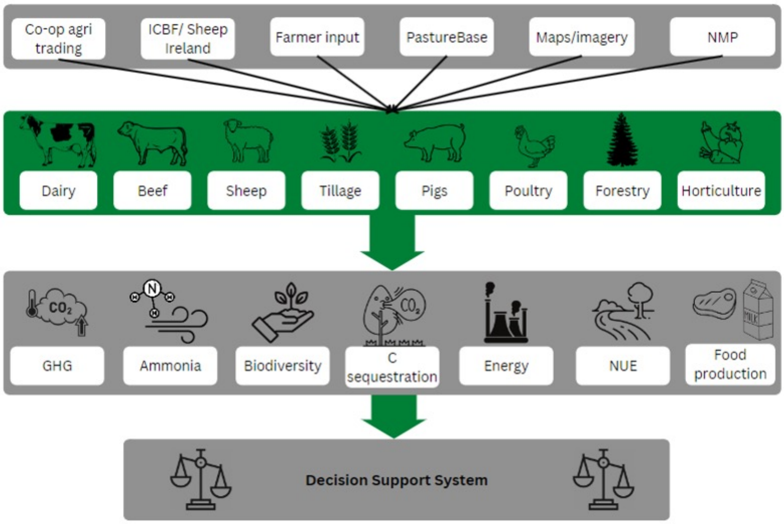

Figure 2. *Proposed AgNav structure*

Conclusions

AgNav is a digital platform that will assist farmers in improving sustainability of their farms. It will create farm specific action plans, which will support clear communications on positive progress achieved at farm and national level.

Case study: what one dairy farmer is doing to reduce total farm emissions

Seamus Kearney and Jonathan Herron
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Summary

- In this case study, the adoption of the main mitigation actions reduced total farm emissions by 13.2% and reduced farm costs by €20,750.
- Reducing reliance on chemical nitrogen and switching to protected urea are priority actions on all farms to reduce emissions.

Introduction

The Agricultural sector has been asked to reduce greenhouse gas (GHG) emissions by 25% by 2030. There is an urgency to undertake mitigation actions on-farm and the priority for all dairy farmers is the adoption of the mitigation technologies in the current Marginal Abatement Cost Curve (MACC) at farm level. A case study was conducted using the Moorepark Dairy Lifecycle Assessment (LCA) model to establish the impact of technology adoption on total farm GHG emissions and the financial impacts of those technologies on a dairy farm. The case study dairy farm was milking 113 cows with a stocking rate of 2.28 LU/ha. Cows were producing 556 kg milk solids (MS) per annum. Replacement rate was 22% and herd EBI was €156. The soil fertility status on the farm is presented in Table 1.

Table 1. *The soil fertility status of the farm*

Lime status	% of farm	P & K status	P%	K%
< 5.9 pH	0%	Index 1	0%	0%
5.9 – 6.2 pH	9%	Index 2	66%	12%
6.2 – 6.5 pH	61%	Index 3	27%	41%
above 6.5 pH (for clover)	30%	Index 4	7%	47%

Results

Using AgNav, a new digital sustainability platform for estimating on-farm emissions, a baseline emissions for the farm was established – "*Know My Number*". The total emissions for the farm was 700 t CO_2-e/annum. In the "*Make My Plan*" stage, an action plan was created for the farm. The priority on the farm was to reduce reliance on chemical nitrogen and switch to protected urea. The agreed actions were:

- Spreading the vast majority of chemical nitrogen as protected urea/low emitting compounds including 18:6:12 and 10:10:20 (95% protected urea)
- Reducing chemical nitrogen use by 80 kg nitrogen/ha by
  - Improving soil pH to over 6.5 and improving phosphorous and potassium status to Index 3 levels
  - Spreading all slurry in spring with LESS
  - Incorporating clover on whole farm
- Producing the same milk output by increasing milk yield by 20 kg MS/cow and reducing cow numbers by 3.5%.
- Reducing replacement rate by 4% (from 22% to 18%)

The impact of the mitigation actions on total farm greenhouse gas emissions are presented in Figure 1. A reduction of 13.2% in total emissions or 92.5 t CO_2-e was calculated for this farm. Switching to protected urea and reducing reliance on chemical N by 37% had the largest impact on GHG emissions, reducing total farm emissions by 9.7%.

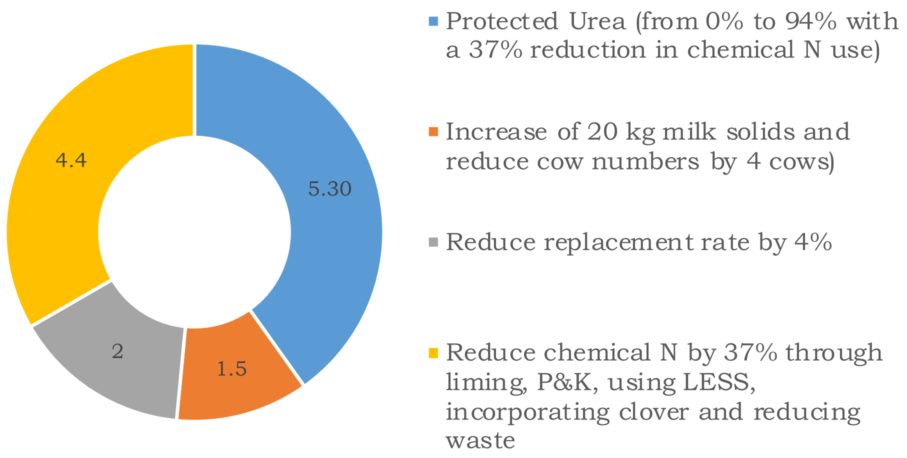

Figure 1. *The impact of mitigation actions on total farm emissions (% reduction in total GHG emissions)*

The implementation of these actions reduced total farm costs by €20,750 with the greatest contribution coming from reducing chemical nitrogen use by 37% but with a corresponding improvement in soil fertility, better use of slurry and incorporating clover into grassland swards.

Table 2. *The impact of mitigation actions on farm costs*

Action	Impact on costs
Switching to protected urea	-€4,520
Reducing chemical nitrogen application by 37%	-€7,840
Increasing milk solids per cow by 20 kg & reducing cow numbers by four	-€4,440
Reduce replacement rate by four percentage points to 18%	-€3,950
Total impact on farm costs	**-€20,750**

Conclusions

There is considerable scope on all dairy farms to reduce emissions while also reducing farm costs. Reducing reliance on chemical nitrogen and switching to protected urea for the nitrogen that is used on the farm is the starting point to reducing greenhouse gas emissions on all farms.

Teagasc sustainability report 2021

Cathal Buckley and Trevor Donnellan
Teagasc, Rural Economy and Development Programme, Athenry, Co. Galway

Summary

- Gross margin and income returns were 2-4 times higher on dairy farms versus non-dairy farms.
- Emissions per hectare of greenhouse gas, ammonia and nitrogen balances were between 2-5 times higher on dairy farms.
- Emissions intensity of milk production declined between 2014-2021.

Introduction

The 2021 Teagasc sustainability report considers Irish farm production systems in terms of their economic, environmental, social, and innovation sustainability dimensions. The report outlines the sustainability performance of dairy, cattle, sheep and tillage farms through data collected by the Teagasc National Farm Survey (NFS).

Results

Economic Indicators

Dairy farms show the strongest economic performance in terms of gross margin (per hectare), income per labour unit and family farm income per hectare, with returns two times higher than tillage (except per labour unit) and 3-4 times than that of livestock systems.

The farm systems are most similar in terms of market orientation, with dairy and tillage having the greatest share of output derived from the market. Dairy farms were the most economically viable, followed by tillage systems, but significantly higher than the other livestock systems as seen in Figure 1.

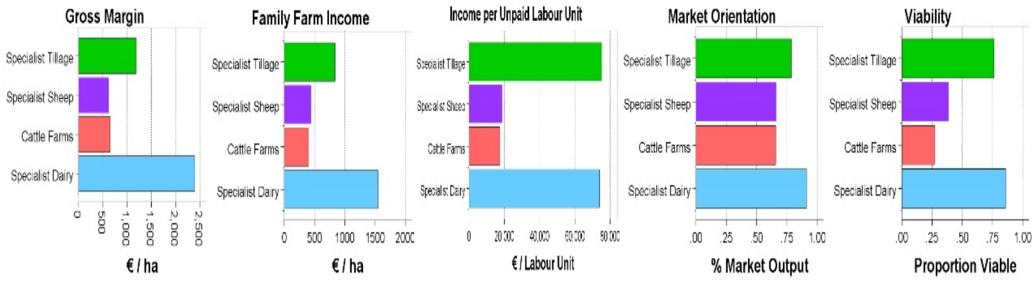

Figure 1. *Economic sustainability: farm comparison 2021 (farm system average)*

Environmental Indicators

Dairy farms had the largest greenhouse gas emissions (CO_2 equivalent) on a per hectare basis, 2-4 times greater than the other systems (Figure 2). The trend was reversed for kg of CO_2 equivalent emitted per Euro of output generated. Ammonia emissions per hectare were also significantly higher (2-5 times) on dairy farms compared to other systems. In terms of ammonia emissions per Euro of output generated, cattle farms emitted the highest level of ammonia (due to the generally lower levels of output) followed by sheep then dairy with tillage being the lowest emitter. Nitrogen balances (kg nitrogen surplus per hectare) on dairy farms were circa 3-4 times higher than the other farm systems. Higher dairy emissions are a function of greater stocking rates, more energy intensive diets and greater use of chemical fertilisers than the other livestock systems.

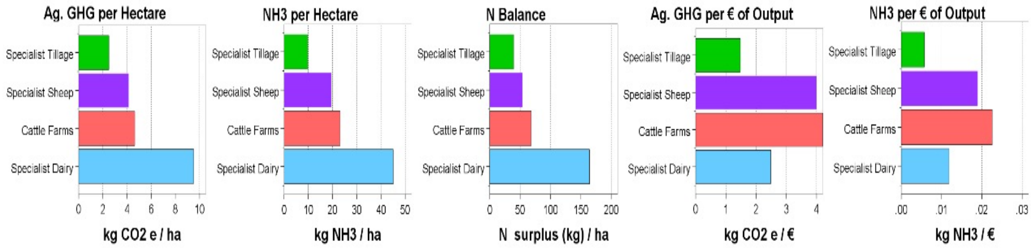

Figure 2. *Environmental sustainability: farm comparison 2021 (farm system average)*

Figure 3 illustrates that kg of CO_2 equivalent and ammonia per kg of Fat and Protein Corrected Milk (FPCM) (standardized to 4% fat and 3.3% true protein per kg of milk) followed a declining trend between 2014 and 2021 on a three year rolling average basis.

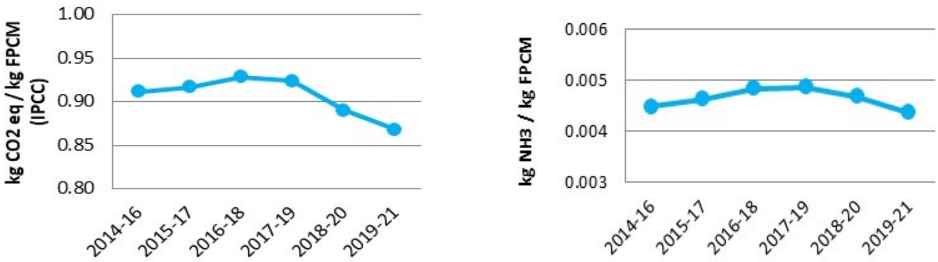

Figure 3. *Kg of CO_2 equivalent and NH_3 per kg FPCM (Dairy Farms)*

Social Indicators

Social sustainability indicators follow a similar pattern to economic performance, with dairy and tillage farms distinct from drystock systems. The greater labour intensity of dairying is illustrated by the longer hours worked on-farm, although other farm systems are more likely to incur hours on off-farm employment. Household vulnerability (non-viable with no off-farm employment within the household) and isolation risk was lowest across dairy farms. Dairy and tillage farmers were more likely to have attained agricultural education or training versus cattle or sheep farmers, on average (as seen in Figure 4).

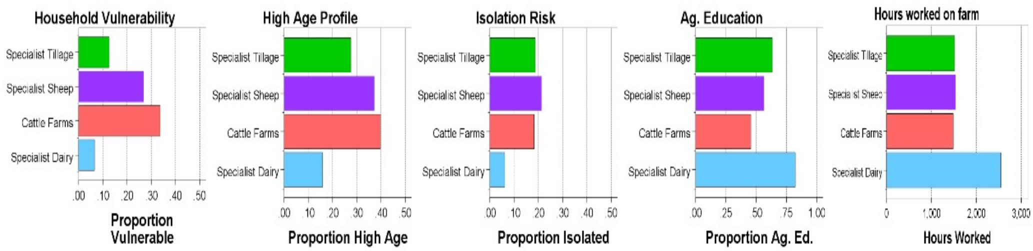

Figure 4. *Social sustainability: Farm system comparison 2021 (farm system average)*

Conclusion

Dairy farms generally tended to have higher economic and social sustainability but also higher levels of absolute environmental emissions due to the greater production intensity on these farms. While emissions intensity of milk production has improved, absolute emissions on dairy farms have increased over the study period.

Enteric methane emissions within Irish dairy systems

Ben Lahart, Charles Dwan, Hazel Costigan, Jonathon Herron and Laurence Shalloo

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Summary

- There is a seasonal nature to enteric methane output by grazing dairy cows which is related to differences in grass quality across the grazing season.
- Measured enteric methane output is less than what current models assume for dairy cows in Ireland.
- New emission factors for enteric methane will allow for more accurate accounting of methane output at a national level.

Introduction

Methane emissions from enteric fermentation are a by-product of feed digestion within the animal's rumen. Within the agriculture sector, methane emissions from enteric fermentation account for 63.1% of total greenhouse gas emissions. Given that the agricultural sector needs to reduce its greenhouse gas emissions by 25% by the year 2030 relative to 2018 levels, developing strategies to better measure and ultimately mitigate enteric methane will be crucial to meeting Ireland's agricultural sector's climate targets. Teagasc, in collaboration with VistaMilk, has acquired pasture-based GreenFeed units to measure methane at grass (See Figure 1). Cows are enticed to visit these units 2-3 times per day by offering a small portion of concentrate feed. When the cows enter the machine air is sampled from their breath which is then measured for methane output. These units are being used to profile the methane output of Irish dairy cows at grass as well as to evaluate strategies to reduce methane output relating to grazing management, feed additives and animal breeding.

Figure 1. *Cow being measured for methane emissions using a GreenFeed unit*

Methane profile

Results show that there is a seasonal nature to methane output from dairy cows at grass with lower enteric methane emissions observed in the spring period when cows are at peak milk production (Figure 2). The lower methane emissions in the spring are related to high quality pasture with low levels of neutral detergent fibre during this period. Lower levels of fibre can result in a reduction in the residency time of material in the rumen which means there will be less time for methane to be formed. Spring pasture can also lead to reduced pH levels in the rumen, which can inhibit the growth of methane producing micro-organisms. As the grazing season progresses, methane output increases while milk solids production decreases, in line with a deterioration in sward quality and an increase in the lactation stage of the herd. When compared to methane values calculated using international default methane emission factors there can be a considerable difference between calculated and measured methane output. When all data from grazing dairy cows collected to date is accumulated, the methane conversion factor for Irish dairy cows is ~9% lower than currently used within the national greenhouse gas inventory. This research can allow for more accurate accounting of methane on a national level, enabling policy makers to make better and more informed decisions when implementing mitigation strategies for methane emissions under Irish grazing conditions.

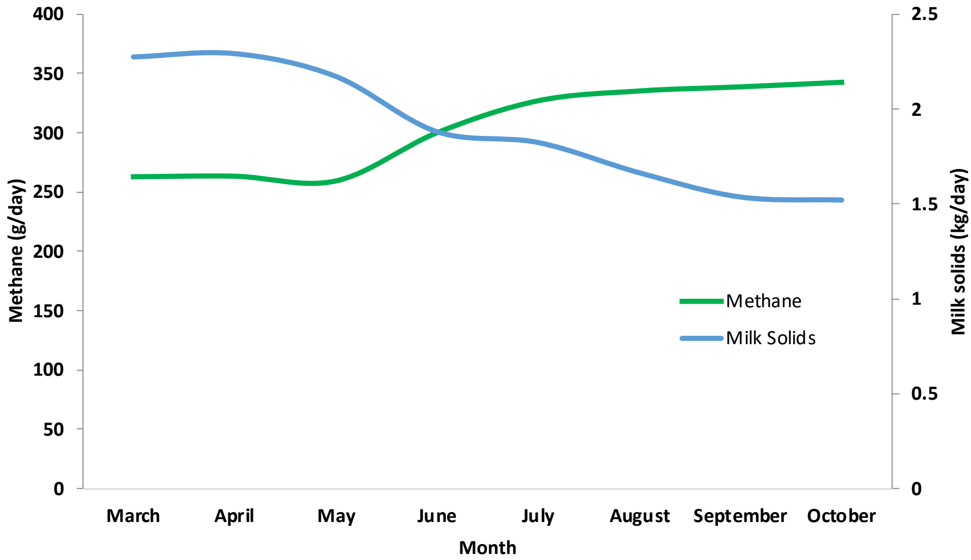

Figure 2. *Seasonal profile of methane emissions and milk solids production in grazing dairy cows*

Conclusion

Research has shown that there is a seasonal nature to methane output in grazing dairy cows. Additionally, models used to generate enteric methane output in Irish dairy cows currently overestimate enteric methane emissions. New emission factors for Irish grazing dairy cows will allow for more accurate accounting of methane output nationally.

Acknowledgement

This research was funded by Nutribio, Tirlán and Dairygold through VistaMilk.

The methane mitigation potential of feed additives for dairy cattle

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Summary

- Feed additives are effective at reducing methane, however their efficacy in pasture-based dairy cows may be enhanced by slow-release technology.
- Technologies must be developed to ensure feeding additives on pasture-based dairy farms is practical for farmers.

Introduction

Enteric methane, which accounts for 63.1% of Ireland's agricultural greenhouse gas emissions, is released as one of the by-products of animal feed digestion. Methane reducing feed additives can play a key role in achieving Ireland's greenhouse gas emissions reduction target of 25% by the year 2030 relative to 2018. Previous research evaluating methane reducing feed additives has demonstrated reductions of ~30%. This work has been undertaken in dairy systems where the cows are housed year-round and offered a total mixed ration diet. In these systems, the additive is mixed within the feed ensuring that each mouthful of feed consumed by the animal throughout the day contains the additive. The diet of a pasture-based dairy cow in Ireland, however, consists largely of grazed grass. In grazing systems, the most practical method of feeding additives is within compound feed at morning and evening milking. There is currently a large programme of work in place in Teagasc, Moorepark to evaluate the efficacy of feed additives when fed to pasture-based dairy cows in these scenarios.

Materials and methods

A series of studies, 8-10 weeks long, have taken place in which the methane emissions and productivity of treatment (additive) and control (no additive) cows were measured. Cows were randomised to treatment and control groups using pre-experimental data. Additives were weighed out, mixed within compound feed and manually fed to the cows on exit from the milking parlour using buckets. Trailer mounted GreenFeed machines, which are used to measure enteric methane emissions, were available to the cows during grazing. Milk sampling was carried out four times per week to ensure that additive supplementation did not impact milk quality and processability. Body weight (BW) and body condition score (BCS) were monitored weekly, while dry matter intake (DMI) was measured on one occasion during each study.

Results

Findings from the studies indicate that feed additives were effective at reducing methane emissions in grazing dairy cows (Figure 1). For 2.5 hours after consumption, the additive reduced methane by approximately 30% relative to the control, however, after this time had elapsed the enteric methane of the treatment and control cows was similar. The cows supplemented with the additive produced on average 6% less methane than the control cows across the entire day. The timing of supplementation (approximately once every 10-12 hours) limits the efficacy of additives, given their requirement to be constantly present in the rumen. Therefore, in order to enhance additive efficacy, future research should focus on slow release mechanisms. The studies also highlighted issues in terms of additive delivery on commercial dairy farms. At present, the most applicable method of feeding additives to grazing dairy cows is through supplemental feeding in the milking parlour twice daily. Incorporating additives into concentrate during pelleting so that it could be fed using in-parlour feeders would reduce workload for the farmer; however, it may be problematic in periods of low grass availability. Concentrate is formulated to a standard feeding rate (e.g., 1-2 kg), so if concentrate supplementation rate is increased intermittently when grass growth is poor; issues may arise as cows may exceed the legal threshold for an additive. The pelleting process may also damage active ingredients in the additives if they are sensitive to heat and pressure. Additive supplementation had no effect on milk production, milk processability, DMI, BW or BCS.

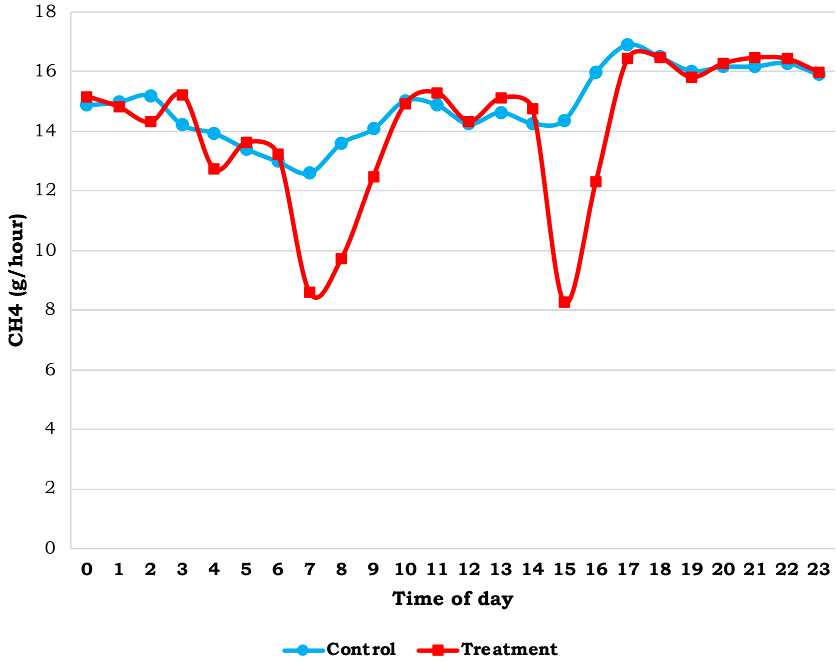

Figure 1. *The hourly variation in enteric methane emissions from cows supplemented with additives (Treatment) and cows without additive supplementation (Control)*

Conclusions

Although feed additives are effective at reducing enteric methane in grazing dairy cows, a key task going forward will be to extend their efficacy using slow release technology. Further research should focus on technologies to improve the practicality of feeding additives to grazing dairy cows.

Acknowledgements

This research was carried out as part of the FarmZeroC project. We would like to thank the farm staff at Teagasc Moorepark for their patience and assistance with data collection during the trial.

Low emission compound fertilisers

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Summary

- Compound fertiliser nitrogen has different nitrate to ammonium ratios ranging from 0.05 for 10:10:20, 0.53 for 18:6:12 and 0.8 for 27:2.5:5.
- We hypothesise that, similar to the protected urea research, nitrous oxide emissions will be higher from these high nitrate containing compound fertilisers.
- Emission factors will be generated for a range of compound fertilisers.

Introduction

Synthetic nitrogen fertiliser application is a significant source of the greenhouse gas (GHG) nitrous oxide (N_2O). Ireland uses the Intergovernmental Panel on Climate Change (IPCC) default emission factor (EF) for N_2O from soils of 1% for fertiliser application, irrespective of its form. However, N_2O emissions tend to be higher from nitrate-containing fertilisers, e.g. calcium nitrate, compared to urea, particularly in wet temperate grassland soils due to the immediate availability of the nitrate substrate for denitrification. Previous research has developed country specific EF for three types of straight nitrogen (N) fertilisers on the Irish market, calcium ammonium nitrate (CAN), urea and protected urea. Other fertiliser formulations include compound fertilisers, which contain a blend of N with other nutrients such as potassium (K), phosphorous (P) and sulphur (S) are commonly used. These fertilisers have different nitrate to ammonium ratios due to their formulation ranging from 0.05 for 10:10:20, 0.53 for 18:6:12 and 0.8 for 27:2.5:5. A preliminary field trial in 2020, showed a significant 40% reduction in N_2O emissions from the lower nitrate to ammonium ratio compound fertilisers compared to CAN (Figure 1). Compound fertilisers have an important role, that will continue in the future, in providing balanced (N, P, K, S etc.) grass nutrition, allowing for multiple nutrients to be applied in a single pass. Therefore, it is important to quantify EF associated with their use and advise on optimal nutrient management strategies that can reduce such emissions.

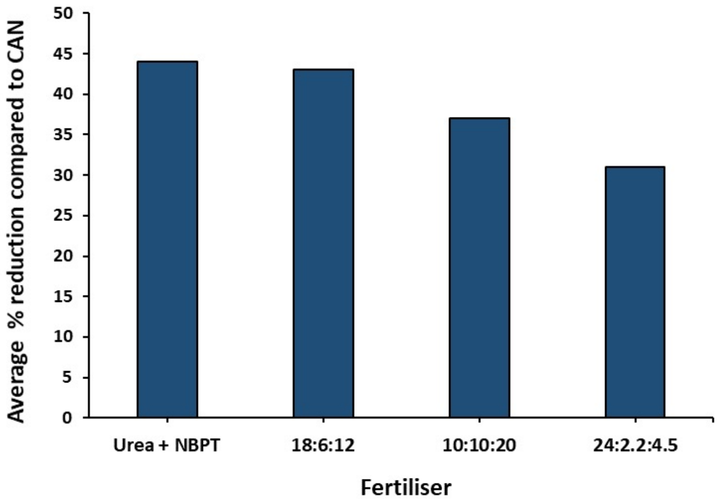

Figure 1. *Relative % N_2O reductions of Urea + NBPT and a range of common compound fertiliser compared to CAN*

Nitrous oxide measurement

Further research on the N_2O emissions of compound fertilisers is currently being undertaken on a moderately well drained grassland site at Johnstown Castle, Co. Wexford. Nitrous oxide emissions are being measured from nine fertiliser treatments applied to grassland soils in five equal splits (40 kg N/ha per split) to simulate a typical grazed grassland. Fertiliser treatments are zero N, 10:10:20, 18:6:12, 27:2.5:5, 24:2.5:10, ammonium sulphate, calcium nitrate, urea + N-(n-butyl) thiophosphoric triamide (NBPT) and liquid urea-ammonium nitrate 32N+3S. Treatments were established in a randomised block design with five replicate plots. Nitrous oxide emissions are being measured using the closed static chamber technique (Figure 2) and gas samples are analysed by gas chromatography. The experiment is being conducted over two full years and EF will be generated for each fertiliser type.

Figure 2. *Research quantifying the effect of fertiliser type on nitrous oxide emissions using the closed static chamber technique*

Acknowledgements

The authors would like to thank the laboratory and field staff at Teagasc Johnstown Castle with their assistance on this project. This research is funded by the National Development Plan, Research Stimulus Fund, Department of Agriculture, Food and the Marine (2021R550).

Alternative slurry amendments for cattle slurry storage

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Summary

- Some alternative slurry amendments to sulphuric acid were successful in reducing both methane and ammonia emissions including alum, lactogypsum and zeolite.
- Ammonium thiosulfate reduced methane emissions but did not impact ammonia emissions.
- Commercial amendments one and two, biochar and dairy processing waste did not reduce either methane or ammonia emissions during cattle slurry storage.

Introduction

Agriculture is responsible for 37.5% of national greenhouse gas emissions and 99% of national ammonia emissions. Manure management contributes a substantial proportion of these emissions, 11.7% of agricultural greenhouse gas emissions and 78% of agricultural ammonia emissions. The release of these gases pollute the atmosphere and local sensitive areas, as well as liberating nutrients from the slurry, decreasing the slurry's fertilisation value. Methane is responsible for the vast majority of GHG emissions from cattle slurry and is produced via a process known as anaerobic digestion. Anaerobic digestion is a process that is sensitive to temperature, pH and oxygen levels which are the main inhibition pathways. Ammonia emissions are emitted or volatilised from the slurry surface through a physicochemical process that is dependent on the concentration of nitrogen, wind speed, temperature and pH, all of which can be controlled to reduce the loss of nitrogen during storage. Cattle slurry is also an important organic fertilizer with many benefits for the soil that it is applied to and is a good source of both phosphorus and potassium for deficient soils. To-date, the most popular and well researched slurry amendment is sulphuric acid, which has been shown to be an effective and economic way of reducing greenhouse gas and ammonia emissions. There are however other amendments that have potential to achieve similar results. Therefore, in this study, alternative amendments were chosen in order to assess their ability to reduce both greenhouse gas and ammonia emissions to provide stakeholders with a wide range of options to reduce emissions from slurry storage.

Results

Slurry was collected from an underground storage tank on a commercial beef and dairy farm. The slurry was stored for 85 days and emissions were measured regularly throughout the storage period. As shown in Figure 1, a total of eight treatments were examined, along with a control slurry treatment that was not amended, for their ability to abate methane and ammonia emissions during storage.

Amendments that reduced methane emissions significantly were alum (64%), ammonium thiosulfate (37%), lactogypsum (47%) and zeolite (24%; Figure 2A). Emissions were increased significantly by all other amendments including both commercial additives one and two.

Figure 1. *Medium scale slurry storage experiment in which multiple slurry amendments were examined*

Amendments that reduced ammonia emissions significantly, shown in Figure 2B were alum (84%), lactogypsum (44%) and zeolite (28%). All other amendments had no effect on ammonia emissions. As such any amendments that reduced ammonia volatilisation had increased concentrations of total ammoniacal nitrogen compared to the control. All other amendments had reduced levels of total ammoniacal nitrogen, reducing fertilisation value.

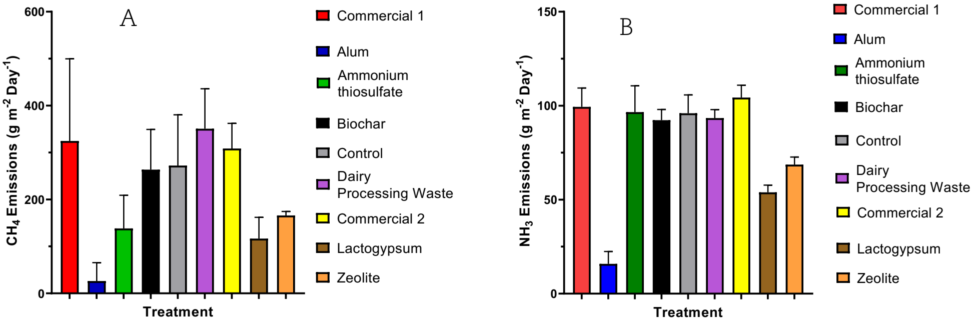

Figure 2. *A) Methane emissions from stored cattle slurry over 85 days; B) Ammonia emissions from stored cattle slurry over 85 days*

Conclusions

Alternative slurry amendments such as alum, lactogypsum and zeolite are effective in reducing both methane and ammonia emissions during slurry storage. Ammonium thiosulfate reduced methane emissions but had no effect on NH_3 emissions. All other amendments had either no effect or increased emissions as a result. Alum, lactogypsum and zeolite may be considered alternatives to sulphuric acid as amendment options to reduce methane and ammonia emissions from slurry storage.

Acknowledgements

This work was funded by the Department of Agriculture, Food and the Marine.

Managed hedgerows – biomass carbon stocks and stock changes

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Summary

- Hedgerows are a prominent feature in Irish landscapes that can enhance terrestrial carbon sinks.
- Relationships between remote and direct measurements of hedgerow biomass were established. Equations generated can be used to assess carbon stock changes between time steps, required for national inventory reporting of hedgerow biomass.
- Results showed that management regime has a strong effect on carbon stock changes with less intensively managed hedgerows having higher biomass sequestration potential than intensively managed hedgerows.

Introduction

The land use land use change and forestry (LULUCF) sector in Ireland, unlike most European states, has been a source of emissions every year from 1990-2021. Hedgerows are a prominent feature in Irish landscapes and can store carbon in wood biomass and leaves aboveground but also belowground in hedgerow roots, and through the decomposition of hedgerow litter that accumulates in the soil organic carbon pool.

Research and inventory requirements

Previous research has demonstrated the suitability of remote technologies to estimate hedgerow biomass volume. However, few studies exist that relate aerial imagery to ground-truthed biomass measurements. In order to include hedgerows in national inventory reports (NIR), a mechanism to assess carbon stock changes over time is required. Data required to achieve this include the extent/length of hedgerows, the size in terms of height and width and the type with respect to management. Also, the amount of carbon that is stored in different carbon pools – the soil, living and dead biomass pools.

Study approach

This study aimed to establish the relationship between measured and digital elevation model (DEM) data of managed hedgerows captured using remote techniques. The developed volume-biomass equations were then applied to a systematic grid sample with DEM data to estimate biomass stock changes in hedgerow above-ground biomass (AGB) and below-ground biomass (BGB). Key steps included the estimation of ABG and BGB measured using destructive and remote sampling, the development of biomass equations and the application to a pilot study across two time steps to estimate carbon stock changes.

Results

Two hedgerows classes were defined, regular (< 4 m width) and irregular (> 4 m width) (Table 1). Although no significant difference was found with respect to the AGB density of these two hedgerow types, the higher hedge area per linear metre of irregular hedgerows meant that the total biomass carbon stocks in irregular hedgerows was significantly higher compared to regular hedgerows. Two biomass models were derived and tested.

Robust relationships were found between remotely captured and measured data for the two hedgerow classes and solved coefficient values can be applied to remotely captured estimates of biomass to calculate C stock.

Table 1. *Summary statistics for sampled hedgerows. Values represent the mean and standard deviation (parenthesis) for measured parameters. Profile (irregular or regular) based upon model of cross-sectional profiles*

Hedgerow type	Irregular			Regular				
Age (est.)	40	30	50+	15	50+	15	13	20
AGB (kg/m^{-2})	27.3 (6.0)	17.5 (5.1)	18.3 (9.9)	24.7 (4.5)	21.1 (4.5)	20.3 (6.1)	10.8 (3.9)	21.0 (3.9)
BGB ($kg/\ m^{-2}$)	4.4 (1.9)	4.6 (2.3)	8.2 (6.2)	5.4 (1.4)	13.0 (3.5)	11.7 (5.0)	5.9 (6.1)	9.2 (1.8)
AGB C stock ($tC\ ha^{-1}$)	117.4 (20.3)	73.7 (17.9)	78.5 (42.2)	106.4 (19.3)	90.8 (19.6)	87.2 (26.1)	46.6 (17.1)	90.4 (17.0)
BGB C stock ($tC\ ha^{-1}$)	19.1 (9.5)	19.9 (10.8)	35.2 (30.8)	23.2 (6.7)	56.1 (17.0)	50.4 (23.8)	25.4 (29.3)	39.4 (8.6)
Hedge area ratio ($m^{-2}\ m^{-1}$)	5.13 (0.45)	4.57 (0.31)	4.36 (0.72)	2.73 (0.45)	0.87 (0.07)	1.92 (0.13)	1.18 (0.03)	1.12 (0.03)

Overall mean values between hedgerow types differed with irregular hedges having a significantly higher overall mean AGB (75.4 t carbon (C)/hectare (ha)) and BGB (14.0 t C/ha) compared to regular hedgerows (34.6 t C/ha and 6.3 t C/ha respectively). Emergent hedgerows showed the highest mean biomass carbon stock change values (3.69 t C/ha per year). Management impact within hedgerow classes differed with the biggest carbon stock change gain found for untrimmed irregular hedgerows (2.87 t C/ha per year). Largest biomass losses were found due to the removal or management of irregular hedgerows. Across the pilot study, hedgerow biomass carbon stock change were found to be a net emission of -0.3 t C/ha per year. Wider hedgerows have a higher biomass sequestration potential and accordingly, the removal and management regime of these hedgerows had the greatest impact on carbon stock change across the pilot study.

Conclusions

Variations in carbon stocks of hedgerows are dependent upon width, height, species and structure and especially the management regime. New hedgerow planting can enhance the terrestrial carbon sink with wider irregular hedgerows having a higher biomass sequestration potential than intensively managed hedgerows. On aggregate, hedgerow removals and management, in particular flailing and coppicing of irregular hedgerows had the largest impact on biomass C balance in the pilot study. As carbon stock losses due to removals and gains are close to net zero carbon stock changes, policy to enforce replacement may compensate for hedgerow area loss. Future policies and management should support increased width thresholds for hedgerows to maximise the sink potential of established hedgerows along with strategies to regenerate older hedgerows.

Soil organic carbon stocks in mineral grasslands

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Summary

- Ireland's mineral grasslands are a vast store of carbon, estimated to contain 30 years' worth of carbon emissions (~1,800 million tons of CO_2).
- Protecting and increasing soil organic carbon (SOC) stocks in mineral grasslands is key to meeting Ireland's carbon emission targets.
- Current approaches for estimating SOC stocks in the Irish carbon inventory poorly represent direct measurements from mineral grassland sites.
- The national carbon inventory struggles or cannot determine the effect changes in land management (e.g. liming or grazing methods) have on SOC stocks in grassland soils.

Introduction

Soil organic carbon (SOC) is the main component of organic matter, which is essential for soil health and grass growth. Grasslands have the capacity to store large amounts of soil organic matter and carbon, especially under Ireland's moist climatic conditions. With regard to climate change, protecting organic carbon in soil has an important role to play in meeting national emission targets. There is also capacity to increase SOC through a process known as carbon sequestration. This process essentially fixes atmospheric CO_2 in vegetation like grasses and legumes, and securely stores the decomposed fraction of carbon in stable pools within soil, thereby offsetting carbon emissions. However, before we can determine the possible carbon saving from this natural process, we first need to establish baseline SOC stocks for grassland.

Measuring SOC stocks

Deep soil sampling and flux towers provide reasonably accurate measurements of organic carbon. However, both are unfeasible to rollout at a large scale due to high costs, standardization issues and destructive sampling required. Given these challenges, several EU member states do not regularly monitor SOC through a national survey. Instead, most EU countries use the Intergovernmental Panel on Climate Change (IPCC) *"Guidelines for National Greenhouse Gas Inventories"* to estimate reference SOC stocks. The IPCC guidance provides a framework for any country, regardless of data, experience, or resources to produce estimates of changes in SOC stocks across multiple land categories, including grasslands.

Modelling SOC stocks

A cost effective alternative to measurement of SOC is computer modelling. Different models have been developed to simulate SOC dynamics in grasslands. Within the IPCC context, a three-tiered approach has been created to model mineral grassland SOC stocks and dynamics. Tier 1 is the basic method, Tier 2 intermediate and Tier 3 the most demanding in terms of complexity and data requirements. Moving to a higher tier should improve the accuracy of the estimation and reduce uncertainty as the complexity and data resources required for modelling SOC dynamics increases. Before moving to a higher Tier, it is necessary to assess the performance of Tier 1 and Tier 2 methods. Both of these modelling methods were evaluated against direct field measurements taken from 27 mineral grassland sites. The SOC stock was modelled according to the Tier 1 approach in the IPCC guidelines and the country specific method in the Irish National Inventory.

Early Findings

Figure 1 shows that neither the IPCC (Tier 1) nor the Irish national inventory (Tier 2) modelling methods accurately estimated SOC stocks for mineral grasslands.

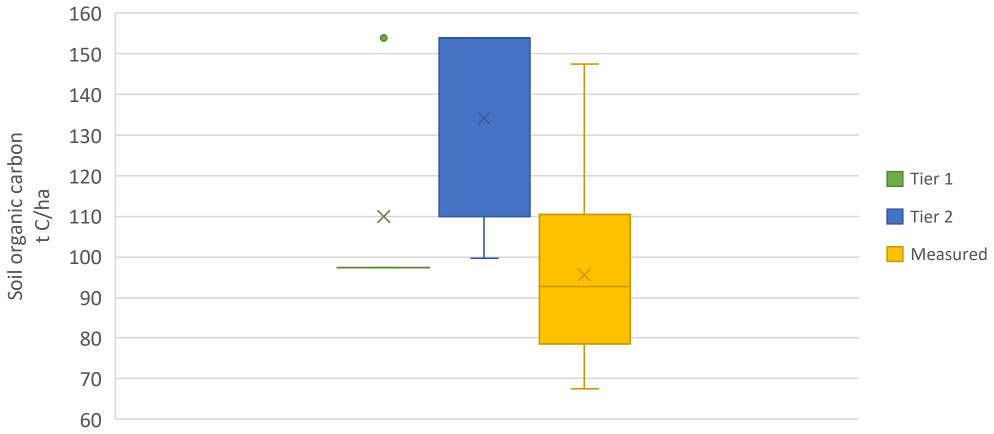

Figure 1. *Comparison of measured and modelled soil organic carbon stocks for mineral grasslands*

The IPCC Tier 1 approach, widely used in calculating SOC stocks for mineral grasslands in Ireland failed to capture the variability of SOC stocks present at selected sites. The Irish Tier 2 approach using national derived coefficients tended to over-estimate SOC field measurements. Overall, Tier 1 and Tier 2 approaches poorly represent SOC stocks at the selected sites. This warrants the use of more advanced tier 3 models with aims of improving SOC stock estimates.

Future work

Current IPCC and national inventory methods over or under-estimate SOC stocks found in mineral grasslands and fail to incorporate management practices that have been shown to increase SOC e.g. liming and grazing. The next step for this research is to accurately estimate SOC stocks with an advanced Tier 3 model, RothC. This model can be applied at different scales and requires readily available data input. It will be used to examine the influence of land management with a dynamic representation of environmental conditions (e.g. weather and soil type).

An analysis of the cost of the abatement of ammonia emissions in Irish Agriculture to 2030

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Summary

- Agriculture is responsible for almost all national ammonia emissions in Ireland
- The European Union (EU) National Emissions Ceiling Directive (NECD) sets emission reduction target for its member states relative to ammonia and other pollutant gases and the Republic of Ireland has exceeded targets over the last number of years.
- This paper outlines the most cost effective pathways to meet future ammonia emission reduction targets as mandated by the EU NECD.
- Results indicated that the adoption of low emission slurry spreading technologies for bovine slurry and the uptake of protected urea chemical fertilisers provided the majority (80%) of ammonia abatement potential.

Introduction

Ammonia is an air pollutant, which has adverse impacts on the environment and public health. Ammonia contributes to ecosystem acidification which endangers the survival of sensitive habitats. Additionally, ammonia plays a critical role in the creation of fine particulate matter, which poses a severe threat to human health and also represents a loss of nitrogen that could be utilised in agricultural systems. In the Republic of Ireland, the agricultural sector accounts for over 99% of national ammonia emissions and the country is currently in breach of its emission targets under the European Union's National Emissions Ceiling Directive (NECD). Reducing ammonia emissions is critical, both in terms of complying with the NECD and as a primary loss pathway for agricultural nitrogen. Improving nitrogen efficiency is a key focus for enhancing farm efficiency and sustainability while also reducing the ammonia, nitrate and greenhouse gas footprint of agriculture. Although numerous management practices exist to reduce ammonia emissions, their applicability and acceptability vary to a great extent at the farm system scale. It is unclear which options are most cost-effective for mitigating ammonia emissions. This paper discusses the most cost-effective strategies to achieve future ammonia emission reduction targets as required by the NECD. This analysis evaluates the best available techniques to reduce ammonia emissions based on scientific peer-reviewed research conducted by Teagasc and its national and international research partners, using cost and efficacy criteria.

Results

Compared to a future where no mitigation measures are deployed to address emissions by 2030 the average technical abatement potential was estimated to be approximately 15.26 kt ammonia at a net cost of €10.86 million per annum. The net cost (€10.86 million) is comprised of six measures that are cost negative i.e. Increases profit (€22.21 million) and seven measures that are cost positive i.e. reduced profit (€33.07 million). Some of the cost negative measures are predicated on efficiency gains driven by best management practice adoption (e.g. liming and clover measures with associated chemical nitrogen reductions). Amongst the thirteen mitigation measures selected for this analysis, 80% of the mitigation potential can be achieved by the full implementation of the mitigation pathways for protected urea (urea with urease inhibitor such as N-(n-butyl)-thiophosphoric triamide (NBPT)) and low emission slurry spreading (LESS) techniques for bovines.

Protected urea reduces ammonia emissions by releasing nitrogen into the soil more slowly than conventional urea fertilisers. This consequently improves the efficiency of the fertiliser by increasing the amount of nitrogen available for plant uptake which results in higher yields. Low emission slurry spreading techniques such as dribble bar, band spreading, trailing shoe or trailing hose apply the slurry in bands or lines directly onto the soil. This reduces the surface area of slurry in contact with air and consequently reduces ammonia emissions. Dribble bar is expected to deliver up to a 30% reduction, trailing shoe a 60% reduction and injection up to a 70% reduction in ammonia loss.

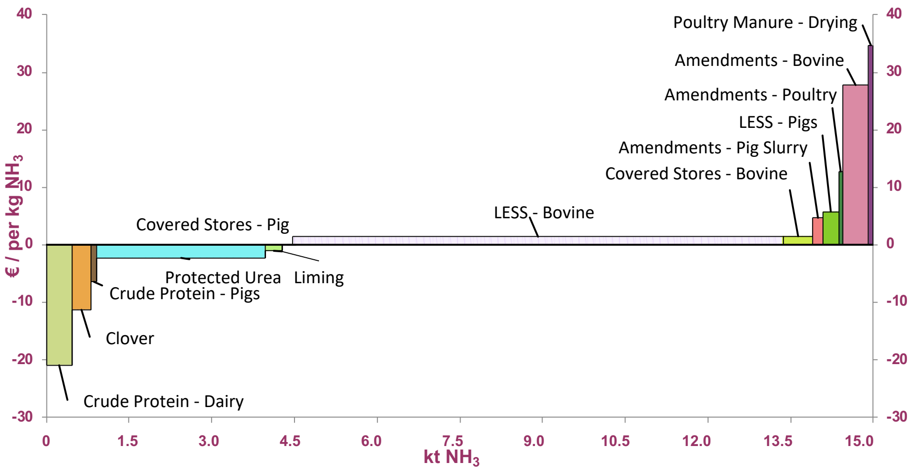


Figure 1. *Ammonia marginal abatement cost curve graph*

Conclusions

Out of the thirteen mitigation measures analysed, 80% of the mitigation potential can be obtained by implementing the mitigation pathways for protected urea and low emission slurry spreading techniques for bovines. In addition, it is estimated that full implementation of the mitigation measures examined will allow Ireland to abate appreciable amount of ammonia to comply with the EU NECD limits under the business as usual scenario. However, it is important to note that achieving the maximum abatement potential will be highly challenging in practice. Any increase in agricultural activity beyond the baseline scenario will increase absolute emissions and additional abatement strategies will be required.

Forests for water – protecting water, promoting sustainability

Eimear Connery[1] and John Casey[2]

[1]Teagasc, ASSAP, Midleton Advisory Office, Knockgriffin, Midleton, Co. Cork; [2]Teagasc, Forestry Advisory Office, Sandfield, Mallow, Co. Cork

Summary

- Publicly available EPA maps can assist farmers in identifying high-risk areas on their farm for potential nutrient loss and put suitable mitigation measures in place.
- Potentially every farm has an area that would be suitable for native tree planting.
- Under the proposed Forestry Programme 2023-2027, there will be a range of establishment options and tree species available to landowners.

Introduction

March 2023 saw the establishment of almost three hectares (ha) of new native woodland and undisturbed water setbacks at Teagasc's Animal & Grassland Research and Innovation Centre in Moorepark, Co. Cork. Teagasc's Forestry & Agricultural Sustainability Support and Advisory Programme (ASSAP) programmes have been encouraging the planting of such woodlands on farms, where appropriate. In the future, this exciting development will deliver a wide range of significant water-related ecosystem services, including:

- Reduction in sediment mobilisation and runoff into the adjacent river
- Interception of nutrient runoff into the watercourse
- River bank stabilisation
- Food input into the aquatic ecosystem
- Shading / cooling
- Regulation of floodwater
- Riparian restoration

These benefits are in addition to other ecosystem services such as increased native woodland biodiversity, habitat linkage within the wider landscape, carbon sequestration and increased amenity value.

Why plant trees in Moorepark?

The decision to plant native woodland in Teagasc Moorepark was based on the EPA's Pollution Impact Potential Phosphate Maps (PIP P maps) which identify areas that have a higher risk of Phosphate (P) loss. The farm at Moorepark is predominantly nitrate risky but the fields along by the Funshion River (i.e. the river floodplain) also have a high risk of phosphate loss. The 3 ha area planted in Moorepark accounts for approximately 33% of the P risky soil type within the farm. The P flow pathway identified within the area for planting, along with the P Index 4 soils, make the area an ideal location for native woodland planting. The water setback, an integral part of the woodland project, follows specifications set out in the *Environmental Requirements for Afforestation* (DAFM, 2016), and forms a strip of undisturbed ground vegetation positioned alongside the river bank.

New Forest Types (FTs)

Under the Department of Agriculture Food and Marine's (DAFM) proposed Forestry Programme 2023-2027, there will be a range of establishment options and tree species available to landowners, depending on site suitability and the landowners' objectives. Teagasc will be using the new woodland in Moorepark to highlight three options to farmers considering forestry, with a special focus on the protection of aquatic zones.

- **Forest Type 1 - Native Forests** - Creation of intimately mixed forest, comprised entirely of native species & prioritised native provenance (alder, oak, willow).
- **Forest Type 2 - Forests for Water** - Creation of native forest in targeted area, with the specific objective of protecting water from significant pressure.
- **Native Tree Area (NTA) 2** - Creation of native forest for water protection.

Moorepark Woodland - inputs & future management

Figure 1. *Woodland layout in Moorepark; Key: A - river; B - permanent undisturbed water setbacks; C - the new native woodland area; D - surrounding farmland*

The woodland was established with the minimal amount of site inputs (e.g. fertilisers) and disturbance (e.g. cultivation). The focus was on retaining natural site conditions and facilitating the emergence of a native woodland type that would occur naturally in time. Ground preparation was limited to inverted mounding and a small amount of pit planting. The control of competing vegetation such as grasses, herbaceous plants, bramble and bracken will be vital for the rapid establishment and growth of young trees on such a fertile location. While non-herbicide control (e.g. trampling, grass cutting, etc.) is only realistic on a small scale, any necessary post-planting spot spraying herbicide application will be kept to the minimum required to ensure success. Herbicide application will not be carried out within the water setback or within 20 metres of the aquatic zone.

Water Setback

The water setback was designed to create an intact and permanent buffer of natural vegetation alongside the aquatic zone, in order to protect water quality and aquatic ecosystems. In effect, the water setback breaks the 'pathway' between sources of possible pollution and the receiving watercourse. Appropriate tree planting within the water setback will deliver direct in-stream benefits such as bank stabilisation, cooling/shading, and food drop into the aquatic ecosystem.

Conclusion

Publicly available maps on www.catchments.ie are a very useful resource for all farmers to identify any high-risk areas on their farm for potential nutrient loss and put suitable mitigation measures in place. Potentially every farm has an area that would be suitable for native tree planting, particularly if it can be incorporated with a phosphate flow pathway to help break the pathway of overland flow. The aim is to slow the flow, allow the deposition of sediment and associated nutrients and also to encourage the uptake of nutrients by growing vegetation.

ASSAP – providing advice on measures to minimise nitrate losses from farms in high-risk catchments

Pat Murphy[1] and Noel Meehan[2]

[1]Teagasc, Head of Environment KT, Johnstown Castle, Wexford, Co. Wexford; [2]ASSAP Manager, Teagasc, Deerpark, Ballinasloe, Co. Galway

Summary

- The agricultural sustainability support and advisory programme (ASSAP) and the local authority waters programme (LAWPRO) work in collaboration to identify pressures from agriculture on water quality.
- Recent EPA water quality reports highlight deteriorating water quality due to increasing nutrient levels including nitrate in waters.
- Targeted action is required to help minimise diffuse nitrate losses to water from agriculture.

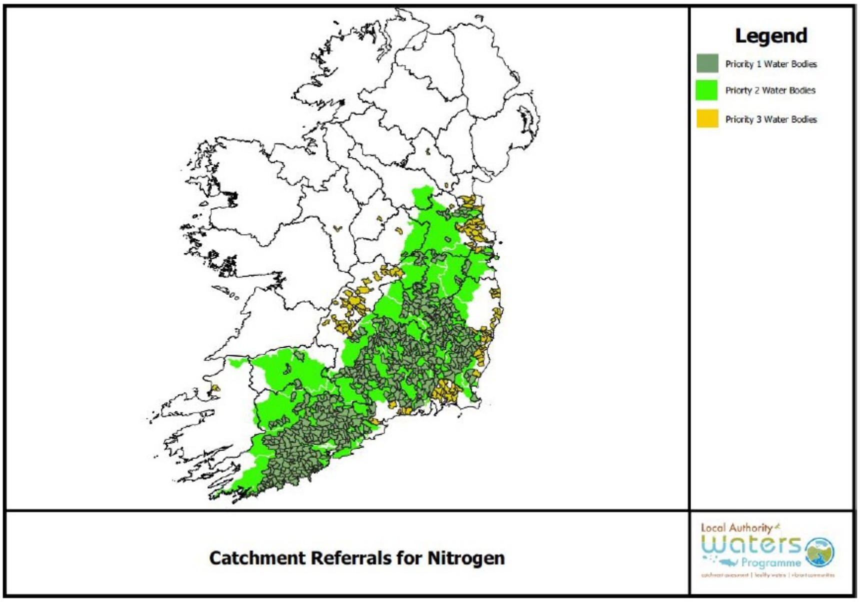
Introduction

ASSAP – The Agricultural Sustainability Support and Advisory Programme works in collaboration with LAWPRO (Local Authority Water Programme) to improve water quality. This is done by carrying out science-based catchment assessments on the pressures impacting waterbodies. This information is then utilised to provide detailed advice to farmers to mitigate agriculture pressures on water quality. The majority of the nitrogen lost to water is from agricultural sources.

In 2022, ASSAP and LAWPRO developed a catchment referral process for nitrogen. This identified over 1,200 waterbodies within the catchments of concern identified with elevated nitrogen concentrations as published in an EPA report in June 2021 (EPA, 2021). The purpose of the nitrogen referrals was to facilitate farmer interaction in these catchments. The waterbodies were categorised as shown in Table 1 and are located as shown in Figure 1. Using the information provided in the referrals, ASSAP advisers, particularly those employed by the dairy co-ops have begun to focus their efforts in the areas identified. This involves the prioritisation of farm visits at waterbody scale based on the concentration of nitrogen. Farms are selected for assessment based on risk of nitrate loss to water. The process involves identifying practices contributing to the loss of nitrogen and recommending mitigation actions.

Table 1. *Priority categories for catchment referrals for nitrogen*

Priority category description	No. of water bodies	
1.	Water bodies contributing high nitrogen within catchments of concern	404
2.	High pollution impact potential nitrogen areas in catchments of concern (not included above)	733
3.	Water bodies with elevated nitrogen (outside of catchments of concern)	94



Source: *LAWPRO*

Figure 1. *Map indicating catchments where reduction in nitrogen losses is required*

ASSAP – providing advice to maximise nitrogen use efficiency

Advice provided by ASSAP advisors is focused on optimising nitrogen use efficiency at farm level by promoting a series of practices including:

- Application of nutrients in optimal conditions for uptake particularly during times of restricted growth (early spring, late autumn and in drought conditions).
- Ensuring adequate slurry storage to facilitate matching application to crop requirement.
- Valuing and accounting for the nitrogen content of organic manures.
- Matching application to soil temperature, soil moisture content and growth rates.
- Taking account of current and forecasted weather when applying nutrient.
- Promoting good soil fertility (pH, phosphorous, potassium).
- Encouraging the increased use of sulphur with nitrogen applications.
- Increased use of clover and multi-species swards (MSS).

Conclusion

Urgent action to minimise diffuse nitrate losses to water is required and all advisors and farmers have a role to play in achieving this. It is particularly crucial in the catchments of concern identified by the EPA.

The seasonality of nitrate loss to rivers

Edward Burgess
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Summary

- Changes to nitrates regulation have targeted total annual load of nitrogen applied.
- Nitrate loss to water is very seasonal, half of it leaving in one quarter of the year.
- Soil type and weather have a major effect on nitrate loss.
- To minimise nitrate loss actions must be undertaken at the right time of the year.

Introduction

Recent changes to Nitrates regulations under the National Action Plan (NAP) have reduced the amount of chemical nitrogen (N) allowed on grassland, and "banding" of dairy cows has reduced stocking rates allowed on many farms. These changes are a consequence of observations by the EPA, highlighting increased amounts of nitrate entering estuaries each year along the east and south coast. When discussing this issue terms like "load of nitrogen", "stocking rate" and "nitrogen use efficiency" are used. However, all of these usually refer to an annual figure which can be, and often is, misleading when trying to decide on what to do to reduce nitrate losses. There is no doubt that, everything else being equal, the greater the amount of N applied to land (by fertiliser application, increased stocking rate, or both), the greater the risk of N loss to water. However, there are many other factors that influence nitrate loss. Soil type is extremely important, with light, free draining soils being much riskier than heavy soil, where rainfall is more likely to flow over the surface. The weather also has a big impact, with the drought in 2018 being of note. This resulted with higher than average nitrate losses in 2019 for most rivers in the country.

Monitoring when nitrate loss occurs

The Agricultural Catchments Programme (ACP) has measured nitrate losses in six contrasting catchments every ten minutes for the last 14 years, which has given an insight into the complexities of this issue. There are times of the year when we lose a lot more nitrate, and other times very little. Nitrate dissolves easily in water, and as water moves down through the soil it can bring with it nitrate that has not been taken up by a growing crop. This dissolved nitrate can then be carried to the ground water table and will eventually emerge in springs, field drains and ditches, all of which feed rivers and lakes and eventually the sea. This can happen in a couple of hours, days, or over many years. In order for this loss of nitrate to happen two things are required:

- Available nitrate in the soil that is surplus to crop requirement
- Water moving down through the soil

There are significant times during the year when water is not moving down through the soil. We can get plenty of rain at any time of the year. However, each year about half a meter (18 inches) of moisture leaves the land through 'evapotranspiration'. Daily amounts vary from zero during dull short days in the winter to 4 or 5 mm in June and July. Usually evapotranspiration exceeds rainfall during the summer months, soils dry out and the water table falls. The result is that not much water is moving down through soils, and even if there was nitrate surplus to crop requirements it wouldn't be carried. See Figure 1 'Soil Water Balance'.

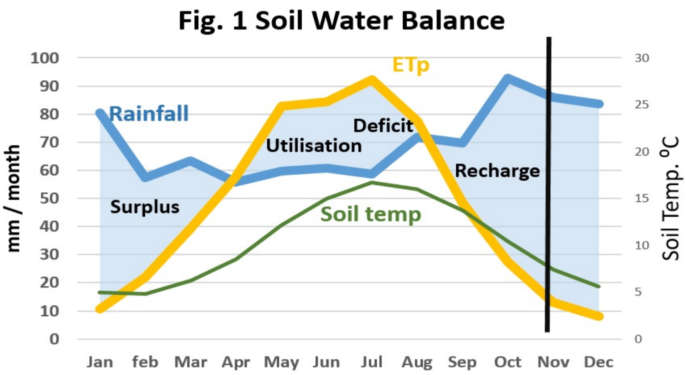

Figure 1. *Soil water balance (ET_p = evapotranspiration)*

Crop growth also varies during the year, with grass growth rates ranging from zero in mid-winter, to over 100 kg of DM/hectare (ha) per day in May and June. During the peak growing season, grass is an extremely efficient crop for utilising N. In addition, in Ireland, we also have a very long grass growing season, over 300 days in many parts of the country. Nitrate uptake can also be impacted by farm practice, consider how much nitrate is taken up by crop growth immediately after ploughing for example.

Conclusions

The total amount of nitrate-N leaving catchments in the ACP vary from 2.5 kg/ha/year in Ballinrobe to 15 kg/ha per year in Ballycanew to 35 kg/ha per year in Castledockrell and Timoleague. Half of this N leaves the stream during the 'closed period' for spreading slurry, which lasts for one quarter of the year. The seasonality of nitrate-N concentration is shown in the Figure 2. Each year the highest concentrations (peaks in the red line) occur during the winter months, from November to February, and the lowest concentrations occur at the end of the summer, usually around September.

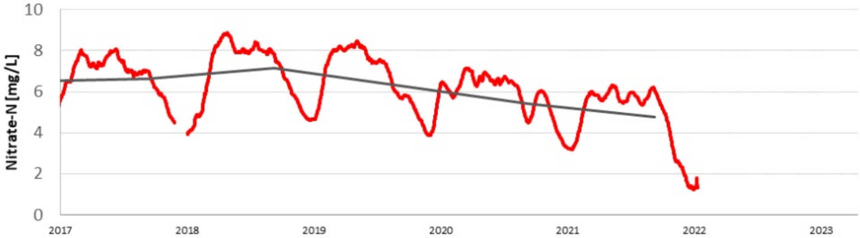

Figure 2. *The average annual N (black line) and monthly concentration (red line) for the Timoleague catchment since 2017*

There are many sources of nitrate in the soil, clover, chemical fertiliser, urine patches and mineralisation of soil organic matter to name a few. For anyone considering how to minimise nitrate losses to water, it is very important to consider the timing of whatever action they are going to do, and not focus just on the overall average annual stocking or application rate. Avoiding an N surplus to expected crop requirements in the soil at times of the year when water is moving down through the soil is key.

Agricultural catchments programme – key findings from over a decade of agricultural catchment research

Bridget Lynch, Edward Burgess and Per-Erik Mellander
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Summary

- The Agricultural Catchments Programme is building a robust scientific understanding of the factors affecting nutrient loss.
- Weather and soil type have a significant influence on nutrient losses to water and can override source pressures (farming intensity).
- Measures need time to be implemented on farms to deliver a positive impact on water quality.

Introduction

European member states are required to monitor their Nitrates Regulations, and in Irelands case through the Nitrates Action Programme (NAP). In Ireland the Department of Agriculture, Food and the Marine (DAFM) monitors the implementation of NAP through the Good Agricultural Practice (GAP) regulations. The DAFM has funded the Agricultural Catchments Programme (ACP) to monitor the effectiveness of GAP measures since 2008. In addition, catchment monitoring is required to support Ireland's derogation. The ACP provides the science for policy review of the NAP, its derogation across soil types and land use. The ACP is a combined research and advisory programme working with 300+ farmers across six small agricultural catchments.

Experimental design

The ACP monitor and research six meso-scale catchments (3 – 31 km^2). These were selected by a multi-criteria analysis to represent intensively managed agricultural land on different physical settings and dominating land use, therefore different types of riskiness for nitrogen (N) and Phosphorous (P) loss in terms of vertical drainage or lateral runoff risk. The catchment scale was chosen to include monitoring of both surface and groundwater as well as farming activity and surveys of soil, bedrock and topography.

Key findings

Over the whole 12-year period (Figure 1), the nitrate-N concentration and Total Reactive Phosphorus (TRP) were below the Environmental Quality Standards (EQS) in Corduff and Cregduff. Timoleague and Dunleer had an elevated TRP and nitrate-N concentration (above the EQS). The concentration was just below the EQS in Ballycanew for nitrate – N, it was above the EQS for TRP, in addition it was above the EQS for nitrate-N in Castledockerell. However, over the last 4-year rolling periods (2019 to 2022) there is a decreasing trend in nitrate-N concentrations in the Timoleague and Castledockerell catchment, stable in the Dunleer, Cregduff and Corduff and no trend in Ballycanew.

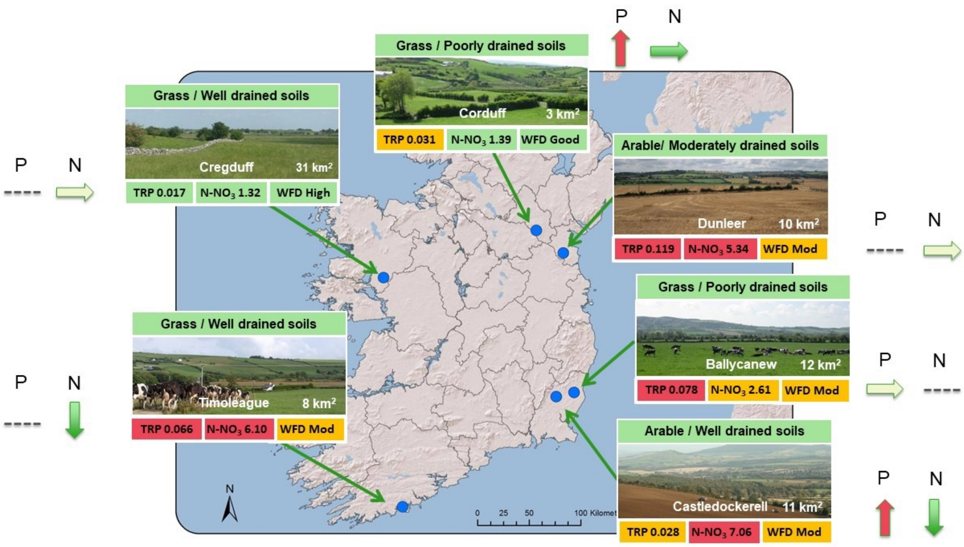

Figure 1. *12-year annual average Total Reactive Phosphorus (TRP) (Target <0.035) and nitrate-N (N03-N) (Target <2.6 mg/L) and the four-year inter annual trend for 2019 to 2022 indicated with symbols: ↑ increase; ↓ decrease; → stable; --- no trend*

Current research activities

High resolution monitoring (every 10 minutes) of water quality and quantity continues. Quantification of N and P loss on derogation and non-derogation farms through in field lysimeter and ceramic cup instrumentation is underway. The programme has expanded to include greenhouse gas and ammonia emissions and soil carbon sequestration. Development of models to represent the hydrologic, sediment, and nutrient dynamics in the ACP catchments is under way. The socio economic research is investigating farmer attitudes towards adoption of mitigation and management practices.

Conclusion

There is no clear, straightforward link between nutrient concentrations in the streams and source pressures (farming intensity) at the catchment scale – physical landscape, soil type and weather can override source pressures. There are time lags between agricultural pressures and water quality state. There are no “one-size-fits-all” solutions for mitigation strategies. An integrated approach to water quality research and knowledge transfer is key to sustainable agriculture.

Acknowledgements

The ACP would like to acknowledge our funders, the Department of Agriculture, Food and Marine, and the co-operation of the 300+ farmers that manage land in the six catchments.

Plant diversity enhances soil biodiversity in grasslands

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Summary

- Healthy soils are critically important for agricultural production.
- Soils are living ecosystems, and the life within soils is essential for soil functions.
- How we manage our soils strongly impacts belowground biodiversity.
- More diverse grassland swards can have positive effects on soil biology and soil functions.

Introduction

Soil life is essential to the health and productivity of our farming systems including: being intrinsic to plant establishment; recycling, transforming and scavenging nutrients for plant growth; providing essential plant vitamins and hormones; suppressing pests, pathogens and disease; protecting against plant stress; regulating climate; and maintaining soil structure. The abundance, diversity and functioning of soil organisms are strongly impacted by how we manage our soils. Low diversity grassland swards can result in a reduction in the availability and diversity of food sources accessible to soil organisms, potentially resulting in a loss of soil biodiversity and impacts on belowground food webs. More diverse grassland swards (such as multi-species mixtures) can increase the complexity of the soil habitat belowground and diversify carbon inputs through exudates into the ground, which feeds soil life (Figure 1). We measured nematode communities and microbial diversity and function in monocultures of perennial ryegrass, timothy, red clover, white clover, plantain and chicory, and in a mixture of the six species.

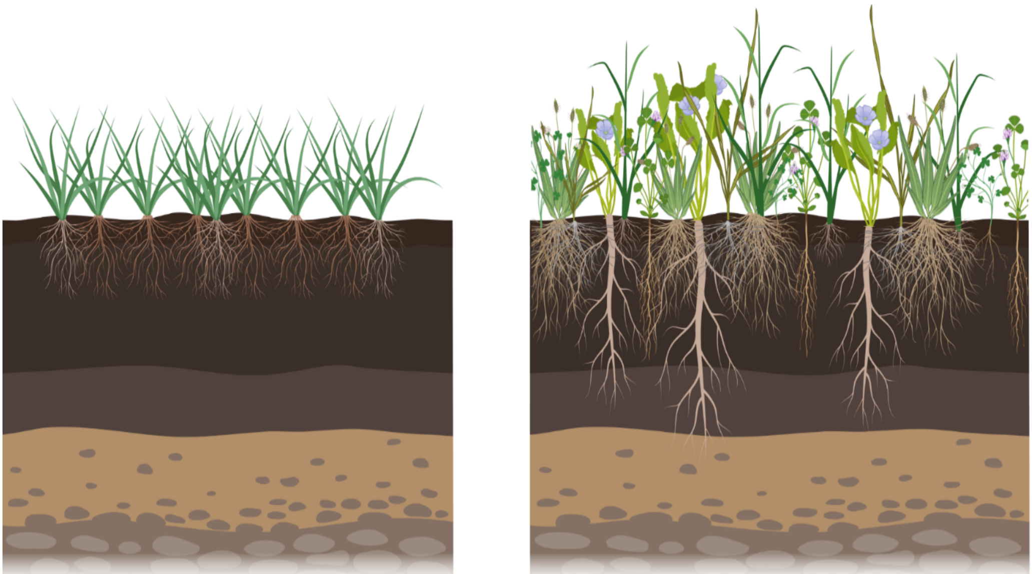

Figure 1. *In comparison to low diversity swards (left) more diverse grassland swards (right) can increase the complexity of root architecture, penetrating deeper into the soil profile and releasing a more diverse range of carbon sources that feeds a more diverse soil biology*

Results

The main findings from this research were:

- Positive effects on soil nematodes were associated with the more diverse multi-species mixture (e.g. Figure 2). There was higher diversity, maturity and structure indexes of nematodes in the mixture, as well as the occurrence of more sensitive nematode groups (predators and omnivores).
- A lower proportion of herbivorous nematodes (that feed on plant roots) and a higher proportion of predatory nematodes (that may have a role in biocontrol of plant pests) occurred in the more diverse multi-species mixture. This indicates a more stable soil food web.
- Different microbial communities were associated with different grassland plant species, indicating increased soil diversity should manifest in plant mixtures.
- There was greater microbial activity related to carbon cycling deeper in the soil profile when deeper-rooting plant species were present.

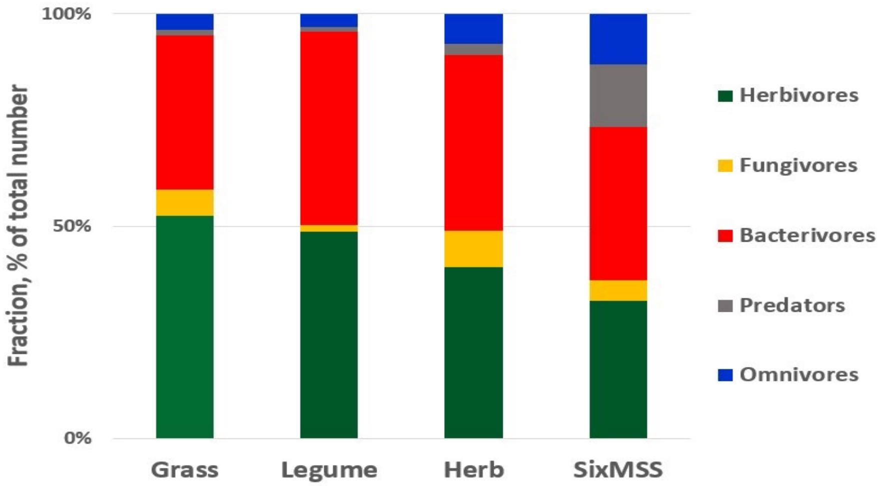

Figure 2. *Breakdown of different soil nematode types (based on nematode feeding type) in grass, legume, herb and six-species swards. There was a higher proportion of predatory nematodes (that typically feed on plant pests) in the six-species sward*

Conclusions

Experimental results indicate that, under more diverse grasslands swards soil biology can be positively impacted with implications for soil function.

Acknowledgements

We acknowledge funding from the EU Horizon research and innovation programme under the MASTER project (Grant agreement No. 818368) and the Teagasc Walsh Scholarship scheme.

Teagasc biodiversity management practices self-assessment tool: linear habitats for dairy farms

Catherine Keena[1], Jim Kinsella[2] and Aoife Leader[2]

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Summary

- The Teagasc Biodiversity Management Practices Self-Assessment Tool: Linear Habitats shows how well the linear habitats on a farm are managed to deliver biodiversity side by side with productive agriculture. The four element are:

  - » Hedges
  - » Farming platform structure
  - » Field margins
  - » Watercourses

Introduction

This paper draws on existing evidence and literature to inform the development of an innovative, affordable, repeatable and rapid assessment tool that measures biodiversity management practice on farms and gives clear messages on Best Practice Biodiversity Management. The tool combines four elements of intensively managed livestock farms, which are of high relevance to biodiversity management. (Figure 1).

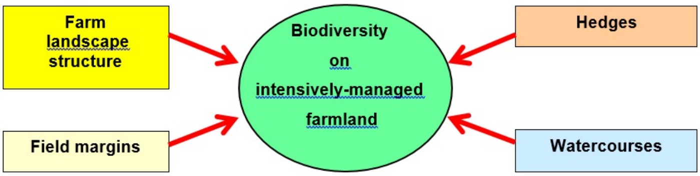


Figure 1. *Diagrammatic representation of the characteristics of farms that combine to reflect biodiversity on intensively managed Irish farmlands*

Results

Farm advisors were identified as the key source of environmental information, and along with other farmers and family members, were key influencers of farming decisions.

Hedges

Hedgerow structure is important for biodiversity. There are two distinct hedge types in Ireland. Both types are good, but each requires very different management. A lack of understanding of each hedge type leads to inappropriate management and damage to hedges. Ideally, each farm should have both types of hedges present to maximise biodiversity benefits.

- Escaped (never-topped) hedge or treeline: Do NOT top. Side trim only.
- Topped hedges: Top to maintain as a hedge – a little above the previous years cut. Aim to grow up to at least 1.5 m and retain a new thorn tree in every hedge.

Figure 2. *Do not top an 'Escaped hedge' and do not let a 'Topped hedge' escape*

Farmed landscape structure

Agricultural landscapes can be viewed as a mosaic of habitats, many linear in nature, within agricultural land. Average field size has the strongest overall effect on biodiversity on intensively managed farmland. The positive effect of decreasing average field size is not due to an increase in cover of natural and semi-natural areas in landscapes with smaller fields. Rather for a given amount of natural or semi-natural cover, farmlands with smaller fields have higher biodiversity. Linear habitats are networks or corridors for nature through the countryside. Their greater edge: area increases habitat diversity.

Field margins

Field margins are a rough grass habitat, which is absent from a lot of intensively managed farmland in Ireland. Uncultivated and unsprayed field margins allows the rough grass margin to continue undisturbed, protecting the soil biodiversity. Their presence allows grasses and wildflowers to flower and seed, providing habitat for associated invertebrates, birds and small mammals. Birds such as linnet feed on grass seed. There is a high biodiversity value in native plants growing wild naturally.

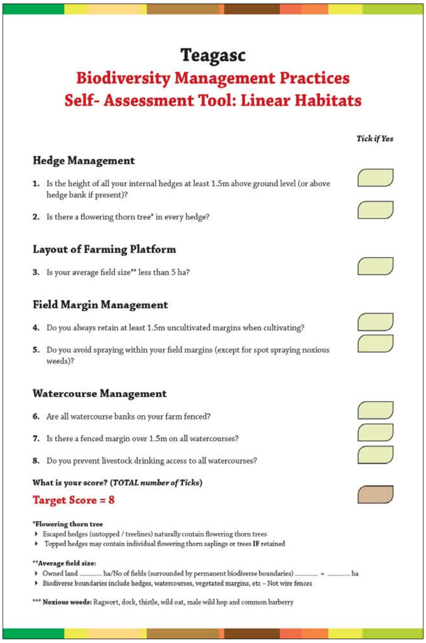
Watercourses

All watercourses are important for biodiversity, including small watercourses and drains which are important in their own right, and also important for their influence on larger watercourses. Fenced watercourse banks prevent siltation from eroded banks allow natural bankside vegetation to flourish. Watercourse margins provide further protection for watercourses and allows space for native wildflowers and grasses to grow, providing habitat for associated fauna. Prevention of livestock drinking access to watercourses prevents siltation of watercourses, and protects the habitat for instream biodiversity

Conclusions

Linear habitats comprising hedges, field margins and watercourses are valuable habitats for biodiversity within the farming platform, alongside land managed for agricultural production. Best biodiversity management practices on these linear habitats are important. A communication strategy to support farmers in implementing these best biodiversity management practices is currently being developed and piloted within dairy discussion groups.

Complete the Teagasc Biodiversity Management Practices Self-Assessment Tool: Linear Habitats for your farm to see how you score (see Appendix 1).



Teagasc

Biodiversity Management Practices

Self- Assessment Tool: Linear Habitats

Tick if Yes

Hedge Management

1. Is the height of all your internal hedges at least 1.5m above ground level (or above hedge bank if present)?
2. Is there a flowering thorn tree* in every hedge?

Layout of Farming Platform

3. Is your average field size** less than 5 ha?

Field Margin Management

4. Do you always retain at least 1.5m uncultivated margins when cultivating?
5. Do you avoid spraying within your field margins (except for spot spraying noxious weeds)?

Watercourse Management

6. Are all watercourse banks on your farm fenced?
7. Is there a fenced margin over 1.5m on all watercourses?
8. Do you prevent livestock drinking access to all watercourses?

What is your score? (*TOTAL number of Ticks*)

Target Score = 8

***Flowering thorn tree**
- Escaped hedges (untopped / treelines) naturally contain flowering thorn trees
- Topped hedges may contain individual flowering thorn saplings or trees **IF** retained

****Average field size:**
- Owned land .... ha/No of fields (surrounded by permanent biodiverse boundaries) .... = ... ha
- Biodiverse boundaries include hedges, watercourses, vegetated margins, etc – Not wire fences

*** **Noxious weeds:** Ragwort, dock, thistle, wild oat, male wild hop and common barberry

Appendix 1

Shinagh dairy farm update and Farm Zero Carbon project

John McNamara[1], Padraig French[2], Kevin Ahern[3] and Gavin Hunt[4]

[1]*Teagasc, Cork West Advisory Unit;* [2]*Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork;* [3] *Farm Manager, Shinagh Dairy Farm;* [4]*Biorbic, O'Brien Centre for Science, UCD, Belfield, Dublin*

Summary

- To date the technical focuses of Shinagh dairy farm have been to maximise the amount of grass grown and utilised per hectare and to optimise the proportion of the cows' diet coming from grazed grass. The future technical focuses will include reducing carbon, nitrogen and ammonia losses from the farm and improving labour efficiency while optimising animal welfare.
- The farm is also focusing on the challenges of environmental and social sustainability through the **Farm Zero Carbon** project which is funded by Science Foundation Ireland and is guided by its stakeholders including Carbery, Teagasc, UCD, TCD and MTU.
- All of the cows and heifers on Shinagh dairy farm are bred to sexed dairy semen or high DBI beef semen and all the non-replacement calves are taken to beef through the Ballyvadin dairy beef demonstration farm.

Introduction

Shinagh dairy farm, located near Bandon in West Cork, is a Teagasc-led project demonstrating efficient spring-milk production from grass, on a farm that was converted from a beef farm in 2010. The milking platform of 84 ha (5 ha leased), is owned by the four west Cork Co-Ops, is stocked at 2.95 cows/ha and winter feed is supplied from a separate leased outblock of 17 ha.

Farm performance

The focus of the farm has been to maximise grass production and utilisation and to breed a high EBI crossbred herd that could calve compactly at the start of the grass growing season and efficiently convert grass into milk solids (Table 1). The farm has successfully exceeded all of the performance targets that were established at the outset of the project and this has led to very significant cash surpluses and accumulated profits (Figure 1). While there has been inter-year variation in cash surpluses and profit, due primarily to milk price volatility, the farm is now very resilient due to a very low breakeven milk price.

Table 1. *Performance of Shinagh dairy farm from 2011-2022*

	2011	2012 to 2021 average	2022
Cows milked	195	227	247
Stocking rate (LU/ha)	3.12	2.91	2.58
Grass grown (t DM/ha)	12.25	13.62	11.78
Grass utilised (t DM/ha)	10	11.31	10.0
Six-week calving rate (%)	58	84	82
Empty rate (%)	13	8.3	9.2
Mean calving date	28 Feb	20 Feb	26 Feb
kg MS/ha	817	1,057	1,034

Current focus and Farm Zero Carbon (FarmZeroC)

The original objectives of Shinagh dairy farm were to identify and manage the economic risks and challenges associated with a dairy farm conversion in a volatile milk price environment. Currently, the farm is focused on some of the additional challenges that the industry faces around environmental and social sustainability. Strategies to combat these issues, which are being pursued through the FarmZeroC project include: reducing the carbon footprint of the milk produced, reducing the total ammonia emissions from the farm and increasing the nitrogen efficiency and the biodiversity of the farm. This project, which aims to make Shinagh farm carbon neutral, is funded by Science Foundation Ireland (SFI). Most of the funding will be used for trial work on products and methods that may reduce the overall emissions from a dairy farm. The items on the Teagasc MACC curve that reduce the carbon footprint will be implemented on the farm.

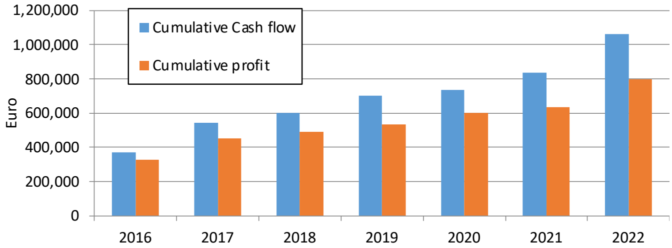


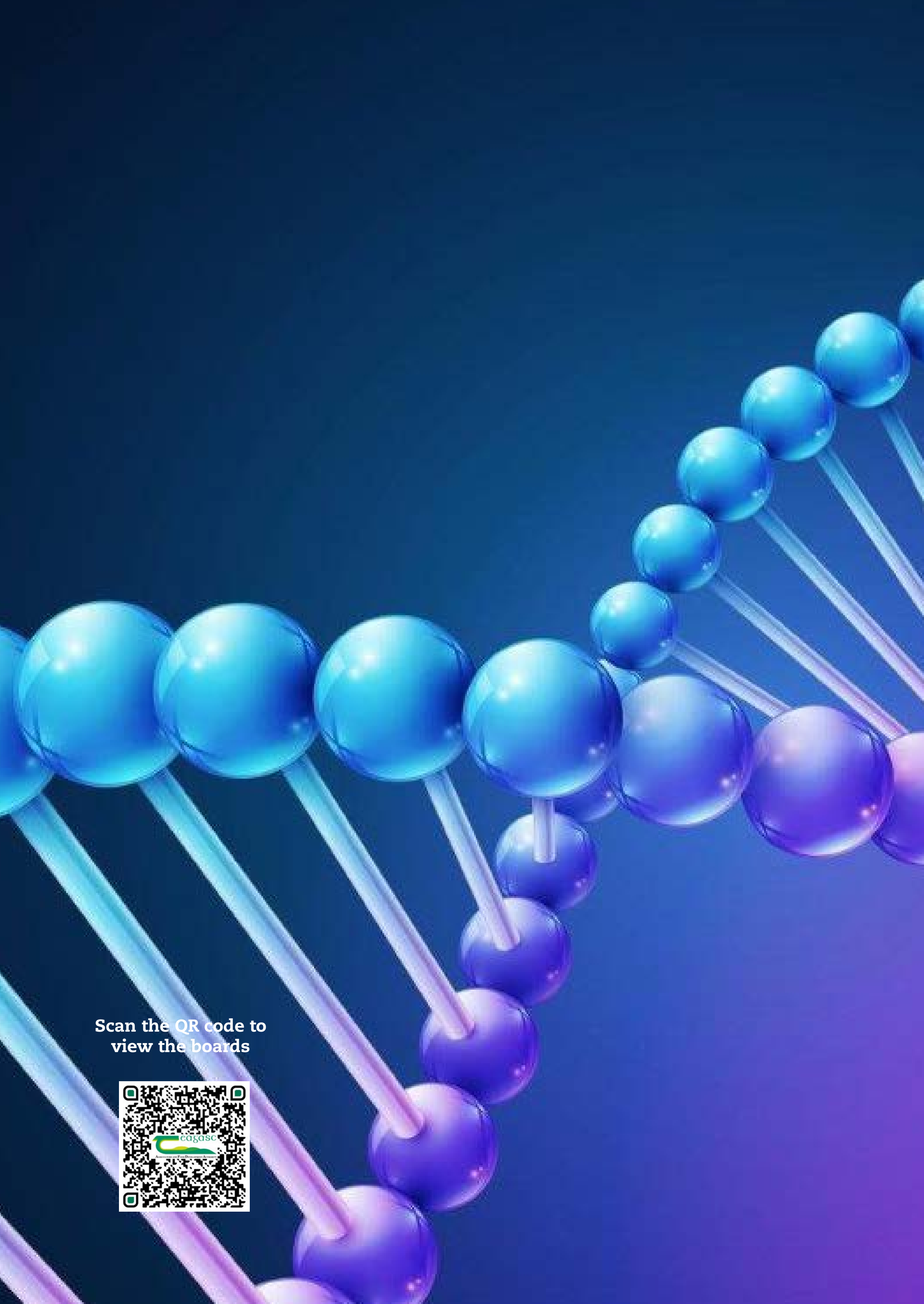
Figure 1. *Cumulative cash flow and profitability from Shinagh dairy farm from 2011 to 2022*

Current farm improvement initiatives

- The farm has been using sexed AI dairy straws on both the cows and replacement heifers since 2021. The conception rate to the sexed straws has been on a par with conventional AI at 60%.
- Movement monitors were put on the cows in 2022 prior to breeding and have proved very successful at heat detection.
- The heifers have been on a programme of synchronisation and fixed time AI and the conception rate to sexed straws has been disappointing at just 40%. In 2023 the heifers are being bred to natural heats.
- Using sexed AI straws has allowed the use of better beef AI bulls to increase the beef merit of all the remaining calves. All of the beef calves are transferred to the Ballyvadin dairy beef demonstration farm.
- All nitrogen fertiliser used on the farm is in the form of protected urea and all slurry spread on the farm is by low emission slurry equipment.
- Every paddock being reseeded includes 5 kg/ha of clover seed. Shinagh has reduced its total artificial nitrogen fertiliser to 152 kg of nitrogen per ha in 2022.
- The farm has been surveyed and 7.2% of the total area is biodiverse. The target is to achieve 10%. This has been increased to 8.6% to date by moving the fence wires out from a number of south facing ditches, by fencing off a wet portion of a paddock and by planting new hedges. Achieving 10% will involve replacing an existing sitka plantation with native woodland and planting a further 1 ha of woodland.
- The farm has set a paddock of multi-species pasture consisting of grass, clover, plantain and chicory each year since 2020. These have been part of the grazing cycle and they have each produced as well as their comrade paddocks. The chicory in particular has reduced in the 2020 paddock at this stage. The clover content of each of these paddocks is above 20%.
- A plate cooler and variable speed drives on the vacuum and milk pumps have been installed which will reduce the electricity demand. Solar panels and battery storage have been installed on the roof of the milking parlour and have reduced energy consumption from the grid by 30% from July to Dec 2022.

Conclusion

Shinagh dairy farm will continue to provide leadership to Irish dairy farmers by demonstrating the operation and management of an environmentally and economically efficient farm, while at the same time demonstrating how a dairy farm can reduce its climate effect potentially to zero. The Carbon footprint has dropped significantly since 2018 and in 2022 was 0.66 kg CO_2 eq./kg FPCM, which is a 21% reduction since 2018.



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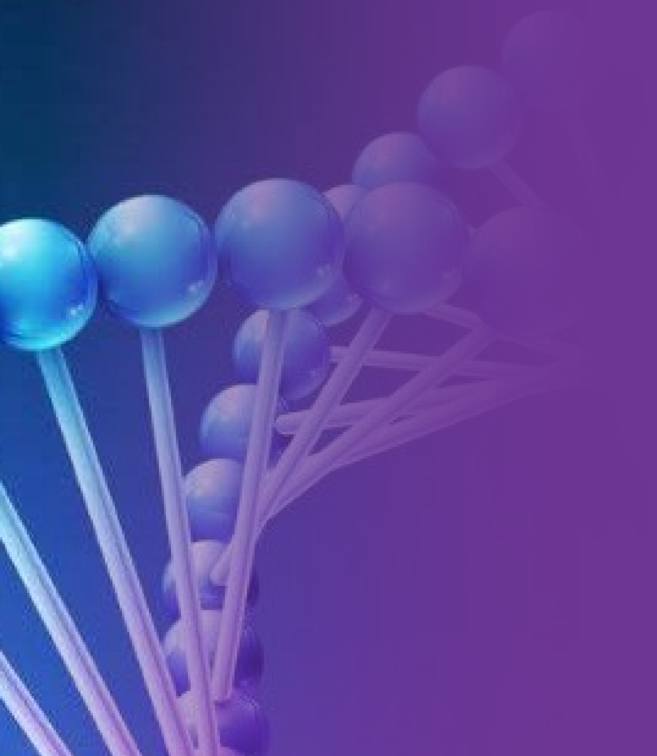
Breeding and Reproduction Village



Impact of breeding for dairy traits on beef production

Shauna Mulhall[1], Alan Twomey[1] and Ross Evans[2]
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[2]*Irish Cattle Breeding Federation, Bandon, Co. Cork*

Summary

- Recent genetic trends indicate a decline in beef merit in the offspring of dairy cows.
- Inclusion of beef merit in the EBI is required to ensure sustainable and profitable beef markets for animals coming from the dairy herd.
- With careful selection of traits and appropriate breeding strategies, it is possible to optimise beef production while also optimising desirable dairy cow traits.

Introduction

Irish dairy herds have made considerable genetic progress for both milk production and fertility traits, as well as breeding cows with lower maintenance requirements. However, focusing on these traits can have unintended consequences, such as a decline in beef merit. Although beef production may not be a key component for many dairy herds, it is important to at least maintain beef merit in dairy cows, as their calves now account for a large component of the beef industry.

Trends in beef traits of progeny in dairy herds

Over the last 10 years, breeding values for carcass weight have reduced by 4.7 kg, while conformation (i.e. muscle development) has reduced by 0.2 units in offspring with a dairy dam and a dairy sire. Similarly, over the same period, there has been a decrease in breeding values for carcass weight and conformation in animals from dairy dams and beef sires, with a reduction of 1.4kg and 0.4 units, respectively (Figure 1).

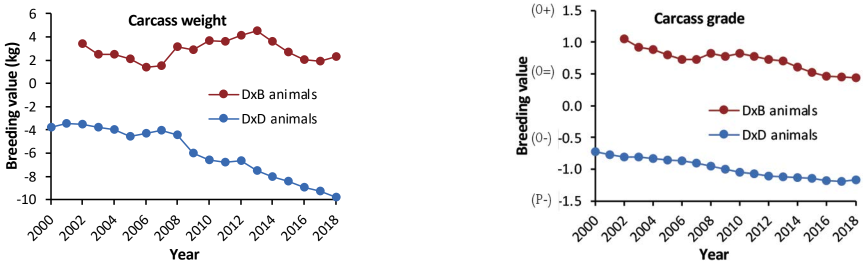

Figure 1. *Genetic trends in beef merit by year of birth for the offspring of a dairy dam and a dairy sire (blue line), as well as the offspring of a dairy dam and a beef sire (red line)*

Why is beef merit of dairy cows declining?

The aim of this study was to investigate the genetic relationships that milk production traits, fertility traits and cow maintenance traits (i.e. live weight) have with carcass traits. Genetic correlations were used to describe this relationship, which shows to what extent the two traits are influenced by the same genes. For instance, when the genetic correlation between two traits is high, as in the case of cow live weight and cull cow carcass weight (which has a genetic correlation of 0.81), it means that many of the same genes affect both traits. Correlation values range between -1 (negative relationship) and +1 (positive relationship); the larger the magnitude (i.e. the further from 0), the stronger the relationship between the two traits.

The increase in genetic merit for milk solid percentage traits is a potential reason for the decline in beef merit. Cows that are genetically good for milk solid percentages will on average have progeny genetically poorer for carcass traits, but the negative relationship is relatively weak (i.e. correlations ranging from -0.18 to -0.28). This weak relationship is good for animal breeders as selection for outliers is relatively easy in animals with good genetic merit for both carcass traits and milk solid production traits.

A more complex breeding relationship exists between cow maintenance and beef production. The dairy breeding goal is to breed smaller, lower maintenance cows as these animals are lower cost and require less expensive concentrate feed. There is a belief that it not possible to breed for a smaller cow and increase carcass weight of progeny. Recent research indicated a strong unfavourable relationship between the two traits (i.e. a genetic correlation of 0.71 between cow live weight and carcass weight of progeny). Therefore, selecting solely to improve cow maintenance (i.e. lighter cows) will negatively impact the carcass weight of progeny from dairy cows. Breeding for lower maintenance cows also has a strong unfavourable impact on age at slaughter. The strong genetic linkage makes it more difficult to find outliers. A similar unfavourable genetic link exists between milk production traits and fertility traits. Through the use of the EBI and a well-designed breeding program, outliers were identified that were good for both milk production traits and fertility traits. In Figure 2, sires highlighted in red have daughters with low maintenance (i.e. low live weight) but these daughters also produce progeny with good carcass weight. In terms of carcass conformation (i.e. muscling), there is a weak positive genetic correlation (0.25) with dairy cow live weight, meaning that low live weight cows have progeny with poorer carcass conformation. We can counteract this negative relationship by also breeding for conformation.

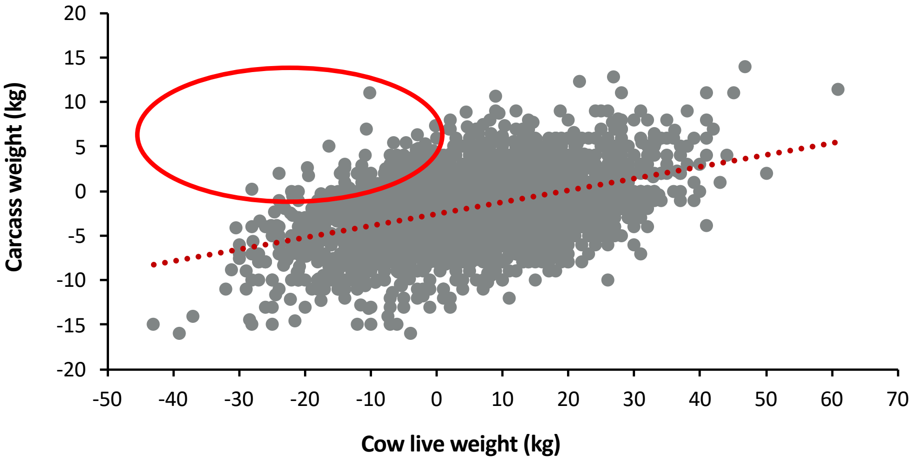

Figure 2. *Plot of breeding values for carcass weight and cow live weight for Holstein-Friesian sires. Sires highlighted in the area outlined in red are positive for carcass weight and have a low cow maintenance breeding value*

Conclusions

Recent genetic trends indicate a decline in carcass weight and conformation in the dairy herd due to high selection pressure for both milk production and fertility traits. However, with appropriate breeding strategies, it is possible to optimise beef production while still maintaining other desirable traits in dairy cows. Recent updates to the EBI have changed the beef sub-index, which now penalises animals that do not meet carcass specifications and animals which take longer to finish, this will help improve the genetic trends for beef traits. In addition, using the Dairy Beef Index to select beef sires to use on dairy cows will improve the resulting progeny beef merit.

Breeding animals that have younger age at slaughter

Alan Twomey

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Summary

- Age at slaughter is a key trait for beef herds to reduce costs and improve environmental efficiency.
- Significant differences exist in genetic potential to reduce age at slaughter within and across breeds.
- Ireland is the first in the world to include age at slaughter in national breeding objectives.

Improvements in beef breeding

Beef breeding has traditionally focused on selecting fast growing, heavy and well-muscled animals. These traits are important drivers of performance. One trait missing until now was age at slaughter, with younger age (i.e. easily fleshed) being desirable. Cattle that can be slaughtered at a younger age are more efficient as these animals incur less cost (i.e. reduced feed, labour, housing, etc.). Not only is reducing age at slaughter economically beneficial it is also environmentally beneficial.

Breeding for age at slaughter

Breeding decisions in dairy herds create the genetic products (i.e. calf offspring) that have economic and environmental consequences for the viability of the beef herds that rear and finish the non-replacement dairy herd offspring. Reducing the age at slaughter on beef herds has been identified as a key trait to improve the sustainability of beef herds. Although on-farm decisions and management play a large role in the age cattle are slaughtered at, 30% of the inter-animal variability in age at slaughter is under genetic control. For example, almost 40 days variation in age at slaughter exists between active beef sires that are easy calving (i.e. <4% dairy cow calving difficulty).

The economic value for age at slaughter is estimated across the year to be €1.35 per day. This includes costs such as maintenance for an additional day, labour, facilities, capital, depreciation and veterinary costs. The difference between selecting the best and worst sire for age at slaughter (difference of 40 days) is worth €54 per animal to the beef finisher on average across the whole year. Nevertheless, these costs vary greatly throughout the year, with costs during winter of approximately €5 per day. At a cost of €5 per day, progeny from the best sire would cost €200 less to slaughter compare to progeny of the worst sire.

Breed differences

There is a large difference between breeds in age at slaughter. Early maturing breeds (i.e. Angus and Hereford) are, on average, younger at slaughter compared with continental and dairy breeds. Nevertheless, the difference between breeds managed similarly on farm was less than expected. For example, progeny of Belgian Blue sires are expected to be only 13 days older, on average, compared with progeny of Angus sires. There is as much variation within breed as across breed. The progeny of the top 5% of Angus sires for age at slaughter were 16 days younger than the progeny of the bottom 5% of Angus sires. The difference in age at slaughter between the progeny of the top and bottom 5% with the Belgian Blue sires is 10 days. Some continental breed sires produced progeny with younger age at slaughter compared with early maturing sires. These genetic differences are based on the cattle performance on average beef herds. In well managed beef herds, the difference between sires divergent in age at slaughter is much greater.

Will this reduce carcass weight?

A potential concern with breeding for animals that are younger at slaughter is the possible reduction in carcass weight. In fact, the relationship between age at slaughter and carcass weight is very weak (Figure 1). This weak association means that both traits can be selected for independently of each other. This means age at slaughter and carcass weight traits can be selected for within for breeding objective, and improvements in both traits can be achieved at the same time.

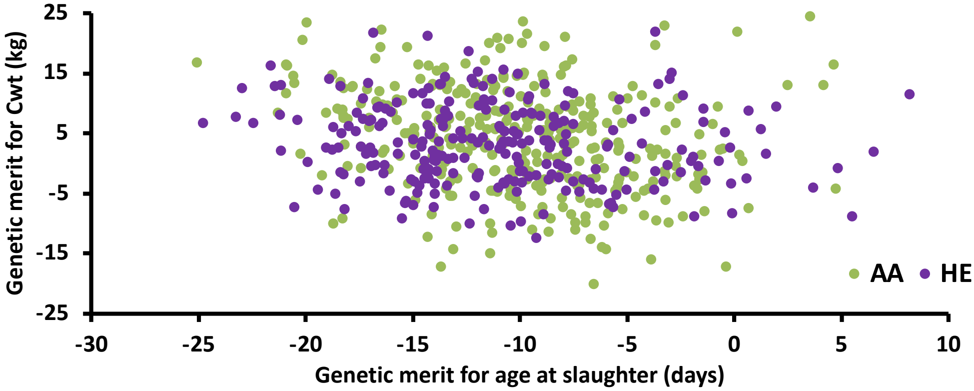

Figure 1. *The relationship between breeding values for carcass weight (Cwt) and age at slaughter for Angus and Hereford Sires*

How can you breed for age at slaughter?

The Irish Cattle Breeding Federation (ICBF) recently launched age at slaughter breeding values for all animals. These breeding values have been incorporated in to our national breeding objectives: the Economic Breeding Index (EBI) and the Dairy Beef Index (DBI). These are the first breeding objectives in the world to include age at slaughter as a goal trait. The breeding advice for dairy farms is to select dairy sires based on the EBI and DBI, which will both select for genetic improvement in age at slaughter as well as other economically important traits.

Conclusion

Age a slaughter is increasing in importance due to economic and environmental challenges facing beef herds. Dairy farmers now have the tools to be able to select sires that produce replacement dairy heifers to suit their herd while also producing non-replacement beef calves that are suitable for the beef herd. Selecting sires based on the DBI to generate all non-replacement calves will generate offspring with good carcass potential with early finishing ability, as well as ensuring calving ease for the dairy farmer.

Breeding for improved product quality

David Kelly and Maria Frizzarin
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Summary

- Considerable genetic variability exists within and across breeds for both milk quality and meat eating quality.
- Publicly available sire genetic evaluations now exist for offspring meat eating quality.

Introduction

Consumer desires for safe, nutritious, healthy, and tasty products are intensifying. While management techniques such as grass-fed versus total mixed ration diets can influence milk quality and composition, and some post-mortem treatments of animal carcasses can influence the quality of meat products, breeding is a technology proven to deliver year-on-year cumulative and permanent gains for a range of performance traits. Accurate measurement of product quality, however, is resource intensive contributing to a large associated cost and generally slow throughput. Hence, identifying tools that can predict product quality has benefits, especially if that technology can provide additional insights into other features of the product or the animal itself.

Milk quality metrics

The Irish national Economic Breeding Index (EBI) has enabled genetic selection for economically important milk quality parameters (fat, protein and somatic cell count), but far more granular measures of milk quality exist. These can relate to properties affecting milk processing characteristics, nutritive value (amino acid concentration), and appearance (colour) of milk. Genetic differences exist among cows in the type of milk they produce. In fact, some milk quality attributes are attributable to only a single or a few DNA variants, which are now routinely genotyped in Irish cows. The proportion of variation in milk protein fractions due to differences in genetics range from 0.05 (β-casein) to 0.69 (β-lactoglobulin B); the equivalent metric for free amino acids range from 0.08 for Glycine to 0.29 for Aspartic Acid. Variability in milk colour traits due to genetics varies from 0.07 to 0.35. Regarding milk processing attributes, the proportion of variation due to genetics ranges from 0.16 (heat coagulation time) to 0.43 (curd firming time). Many of these traits can be predicted using a technology called mid-infrared spectroscopy (MIR), which is already used globally to predict the fat, protein and lactose concentrations in milk. Previous Moorepark research has demonstrated that MIR can also predict the energy status of the cow, potentially how much methane she is producing, and even differentiate the milk of cows fed grazed pasture versus a total mixed ration. Because MIR data are already being generated for each milk sample collected for milk recording purposes in Ireland, it is possible to generate genetic evaluations for these metrics.

The DNA information now available has also been used to quantify the incidence of different variants of milk proteins like β-casein; the most common β-Casein variants of interest are A1 and A2. These variants have different properties, which can influence milk processing, and are often perceived to influence human health. The majority of Holstein-Friesian cows in Ireland carry one copy of each of the A1 and A2 variants, and these cows produce a mixture of A1 and A2 milk. Conversely, 42.4% of Holstein-Friesian cows have two copies of the A2 variant, and thus produce only pure A2 milk (Table 1). Furthermore, a greater proportion of Jersey cows produce pure A2 milk (64.5%) compared with Holstein-Friesian cows (Table 1).

Table 1. *The frequency (%) of A1 and A2 β-casein type genotypes in different dairy breeds using recent Irish data*

Genotype	Holstein-Friesian	Jersey	Montbeliarde
A1A1	12.9	4.5	16.1
A1A2	44.7	31.1	46.2
A2A2	42.4	64.5	37.8

Potential to breed for better meat eating quality

Ireland boasts one of the largest meat sensory databases globally, with tenderness, juiciness, and flavour information recorded for beef steaks from over 7,100 Irish prime cattle, and all animals also have DNA genotype information. Through research conducted using this large database, the Irish Cattle Breeding Federation (ICBF) launched the world's first multi-breed genomic evaluations for meat eating quality in September 2020. The proportion of the observed differences between individuals attributed to genetics is 0.16 for tenderness, 0.14 for juiciness, and 0.11 for flavour. Significant variation exists in these quality attributes both within and across breeds (Figure 1). For example, the meat from Angus-sired progeny is expected, on average, to be of superior quality (higher breeding value) than the meat from Charolais-sired progeny (lower breeding value). On the other hand, some Charolais sires produced progeny with meat of superior eating quality than some (poor) Angus sires. Research is ongoing on the incorporation of genetic merit for meat eating quality into the national breeding indexes.

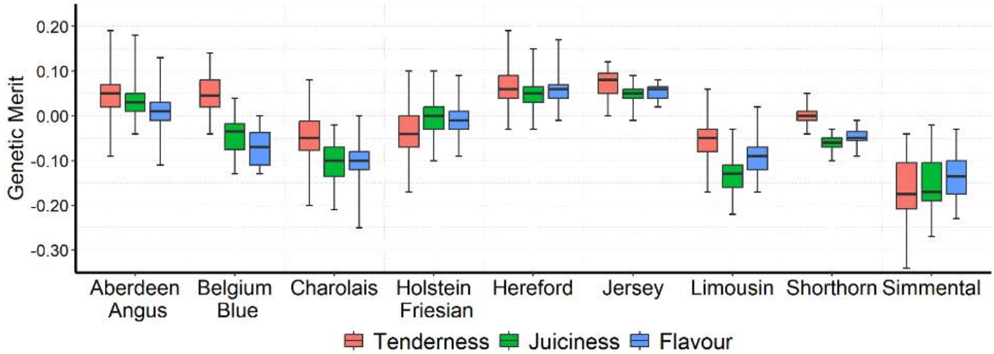

Figure 1. *Box and whisker plots of genetic merit for tenderness (red), juiciness (green), and flavour (blue) for different sire breeds. For each trait within breed, 50% of sires values are inside the box, the horizontal line indicates the median value, and the whiskers outside the box indicate the top and bottom 25% of sire values*

Conclusions

Maintaining excellent product quality is essential to retain customer loyalty, and for gaining a foothold in future markets for Irish produce. The necessary tools and information now exist to make permanent and cumulative gains in milk and meat quality through breeding.

Dairy-beef trilogy toolkit: Dairy-Beef Index, sire advice and commercial beef value

Nóirín McHugh[1], Donagh Berry[1], Siobhán Ring[2] and Alan Twomey[1]
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[2]Irish Cattle Breeding Federation, Link Road, Ballincollig, Co. Cork

Summary

- A trilogy of tools are now available to farmers to aid in the breeding, mating and trading of dairy-beef animals:
    - » The Dairy-Beef Index (DBI) ranks the most suitable beef bulls for mating to dairy females
    - » Dairy-on-beef sire advice in Herdplus recommends optimal individual matings between beef bulls and dairy females
    - » The Commercial Beef Value (CBV) forecasts the likely profit from a calf destined for beef production.

Introduction

The expansion of the national dairy herd, improved dairy cow fertility, and the rapid growth in the use of sexed semen to generate dairy replacements will contribute to a greater quantity of Irish beef originating from dairy herds. New beef-on-dairy breeding strategies are therefore required to increase the value of non-replacement calves by capitalising on the superior carcass credentials of beef × dairy cross calves compared with purebred dairy cattle. A trilogy of tools are now available for the breeding, mating and trading of dairy-beef animals: 1) an index to select the most suitable beef bulls for breeding to dairy females; 2) a web-based service to recommend optimal individual male-female matings; and 3) an index to forecast the likely eventual profit from a calf destined for beef production.

The Dairy-Beef breeding index

The Dairy-Beef index (DBI) was launched in 2019 with the goal of ranking beef bulls for suitability to both dairy and beef producers. The index comprises traits of importance to dairy producers (calving difficulty, gestation length and calf mortality), but also includes traits of interest to beef producers (carcass growth and value, feed efficiency, age at slaughter, and temperament). The dairy and beef components of the index are unfavourably correlated. A similar unfavourable correlation exists between milk production and fertility, but clear evidence from dairy cow breeding (i.e. the EBI) has demonstrated the ability to breed for both traits in a favourable direction. Selecting beef bulls on the DBI rather than on a specific beef breed or on calving characteristics produces more balanced and valuable progeny. This helps to meet the requirements of the dairy farmer, and also generate additional profit for the beef finisher.

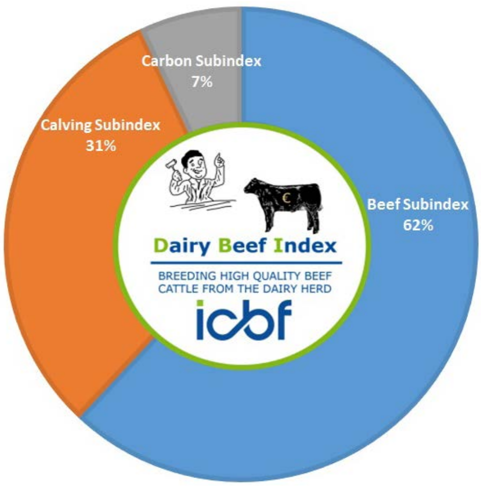

Figure 1. *Traits and their relative emphasis included in the DBI*

Dairy-Beef mating advice

Once the dairy producer selects an appropriate team of beef bulls based on the DBI, the next stage is to decide which bulls should be mated to which dams (cows and heifers) using the sire mating advice. In the sire advice system, the females' likely predisposition to calving difficulty (based on genetic merit and age) is considered, and the genetic capacity of the offspring generated to achieve the carcass weight and conformation specifications is also factored in. Dairy females with a genetic predisposition to require assistance at calving (i.e., a more positive direct and maternal calving difficulty figure) should be mated to a proven beef bull that has a genetic proof for low(er) direct calving difficulty. The sire advice tool only recommends matings using the bulls the farmer selects. Therefore, farmers should invest time in appropriately selecting a suitable beef bull team. The outcome from the web-based sire advice is a list of dairy females in the herd with the beef bull recommended to mate to each female.

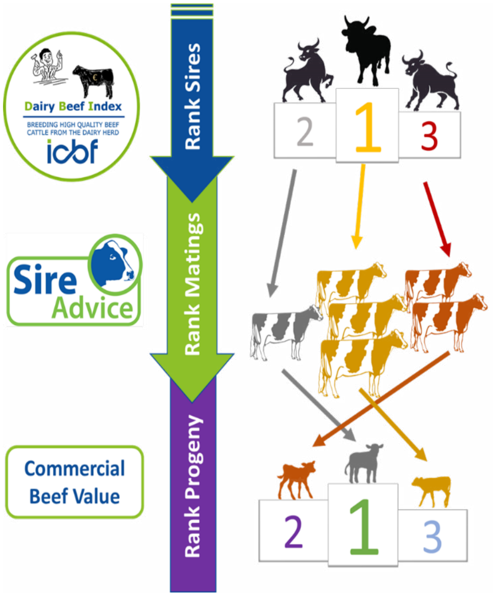

Figure 2. *The trilogy of Dairy-beef tools available: DairyBeef Index, sire advice and commercial breeding value*

Dairy-Beef trading tool – the commercial beef value

Carcass value is the main factor that determines the revenue received for dairy-beef progeny, but predicting potential carcass value is not easy in 2-3 week old calves. Carcass value is highly heritable, however, meaning that the genetic merit of an animal translates very well to the actual observed performance. The Commercial Beef Value (CBV) is a new tool, which assigns a value to calves based on their expected profit until slaughter. It comprises estimated genetic merit for five traits from the dairy-beef index: carcass weight, conformation and fat, as well as docility and feed intake. Therefore, it links very well to the DBI (and associated sire advice). The CBV is presented within three main breed categories: suckler, dairy-beef and dairy-dairy. The CBV is now available for all genotyped cattle and displayed at livestock marts.

Conclusions

Three interlinked dairy-beef tools are now available to Irish farmers. The Dairy-Beef index aids dairy farmers to select the most appropriate beef bulls, the beef-on-dairy sire advice system recommends beef-on-dairy matings using the components of the dairy beef index, and the Commercial Beef Value (CBV) trading tool assigns a monetary value to a calf based on its estimated genetic merit for the traits in the DBI. All data underpinning the three tools are housed within a single national database, which will enable the tools to be updated as more data becomes available on beef bulls, dairy cows and beef-cross calves.

Everycalf – profitable dairy calf to beef systems on commercial rearing farms

Brendan Horan[1], Alan Twomey[1], Nicky Byrne[2], Anthony Mulligan[3] and Tom Coll[4]

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Summary

- The Everycalf project has demonstrated that high-quality pasture management on commercial farms can deliver good animal performance in dairy calf-to-beef systems.
- The slaughter data collected to-date indicate that calf Commercial Beef Value has a significant impact on carcass value within pasture-based dairy-beef production systems.

Introduction

Consumer concerns about where their food comes from is growing, and the welfare of farmed animals is a particular focus. In dairy farming, one such concern has focused on the management of surplus calves. Increased cow numbers on Irish dairy farms, and compact calving patterns have resulted in large numbers of surplus male dairy calves born on dairy farms each spring. During the peak calving period, dairy farmers face many challenges: provision of adequate feed for the herd; sourcing skilled help to assist with additional workloads; and having access to adequate calf rearing facilities. As a result, more dairy farmers are looking to contract rearing of both replacement female calves and non-replacement calves to reduce both workload and requirements for facilities on farm. Teagasc has recently undertaken a project looking at the performance of male dairy and dairy-beef cross calves in contract rearing partnerships on commercial farms.

Everycalf Project – Dairy Calf-to-Beef with commercial rearers

The objective of the Everycalf Project is to evaluate the potential for profitable dairy calf-to-beef systems in collaboration with commercial farmers operating a contract rearing service. In the programme, Teagasc and 10 dry stock farmers entered a collaborative arrangement where the dry stock farmers contract rear the entire population of approximately 300 male progeny from Teagasc dairy farms each year from three weeks of age to slaughter at 22-23 months. The breed composition of the calves born was 60% dairy (with equal parts Holstein-Friesian, Holstein-Friesian crossbred and Jersey Holstein-Friesian cross) and 40% beef cross (primarily Aberdeen Angus but also Limousin, Hereford, Charolais, Belgian Blue and Aubrac). The proportion of beef crossbred calves increased from 34% in 2020 to 46% and 41% during 2021 and 2022, respectively, due to increased use of sexed semen to generate replacement heifers on all farms.

Results to-date

The average birth weight of the calves during the first two years was 37 kg and these were moved on average at 35 days of age [56 kg live weight (LW)] to the rearing farms. All calves were weaned at 63 days of age when eating in excess of 1 kg of concentrate per day. On average, all calves achieved 0.6 kg LW/head/d average daily gain (ADG) from birth to weaning and 0.7 kg/d during the first grazing season and during the first winter period, and 0.9 kg for second grazing season. Following a short (80 day) intensive indoor finishing period on a high concentrate and silage diet, average live weight at slaughter was 585 kg, resulting in an average carcass weight of 281 kg and an average carcass value of €1,291 (€4.60/kg) at 23 months of age. The overall ADG from birth to slaughter was 0.78 kg. Both sire and dam genetic merit had a significant impact on carcass weight and conformation with each additional €10 increase in the Commercial Beef Value (CBV, €) of the calf corresponding to a 2.8 kg increase in carcass weight at slaughter while also improving confirmation (Figure 1).

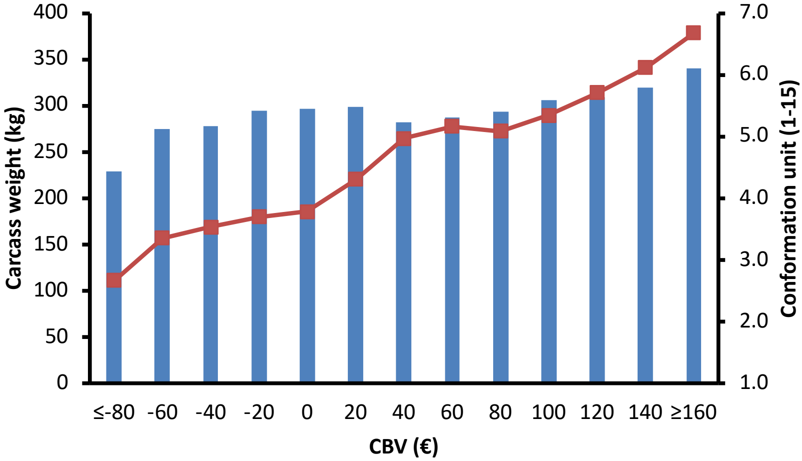

Figure 1. *Association between carcass traits (weight (kg) = blue bars; conformation units (1-15) = red line) and animal Commercial Beef Value (CBV)*

The average cost of contract rearing the cattle to slaughter was €1,225 over the two years leaving a residual value of €66 to cover the cost of the calf incurred before movement and initial vaccination costs (€10/calf). On that basis, the preliminary results are indicative of the potential of high quality pasture management on commercial farms to deliver excellent animal performance in dairy calf to beef systems. The data presented corresponds to a census population of calves that were predominantly dairy breed (66%) rather than dairy-beef crosses, and with poor genetic merit for beef traits. These results also indicate that substantial increases in profitability can be achieved by increasing the proportion of beef-cross calves and associated CBV of surplus calves in the future.

Conclusion

The preliminary results from the project highlight the potential of high-quality pasture management on commercial farms to deliver excellent animal performance in dairy calf-to-beef systems and provide a strong basis for the development of such operations into the future.

Acknowledgements

The authors wish to acknowledge the essential contribution of the 10 rearers to the project.

Reward for producing higher beef merit calves

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[2]*Irish Cattle Breeding Federation, Link Road, Ballincollig, Co. Cork*

Summary

- The Commercial Beef Value (CBV) is a tool to facilitate the buying and selling of cattle destined for slaughter.
- Dairy farmers can generate higher value and more saleable calves by using Beef bulls with a high Dairy-Beef beef sub-index value (>€80).
- Calves with higher CBV subsequently have greater carcass value.

What is the commercial beef value?

The Commercial Beef Value (CBV) is a decision-support tool to aid in the buying and selling of cattle that are destined for slaughter. The tool allows farmers to easily identify highly profitable animals, irrespective of colour or breed, at the time of sale. This information allows the buyer and seller to have a better understanding of the lifetime value of the animals on sale. Without this tool, dairy farmers have no opportunity to reap the benefits of using more favourable beef merit sires since it is impossible to visually see the carcass potential differences between animals as calves. Historically, the market value of calves was determined by a combination of breed, weight and age. Within a breed, however, variability for carcass weight and quality traits is large, and just because an animal is sired by a continental breed (e.g. BB, CH) it does not mean that calf will outperform the traditional breeds (e.g. AA, HE) at slaughter and vice versa. The large variation in CBV within breeds is illustrated in Figure 1, and therefore it is important to choose an elite beef bull with desirable beef genetic merit. The CBV is displayed as an economic value, similar to the EBI whereby higher euro values are more desirable. The CBV is also presented with stars to represent its rank within the genotype group (i.e. Dairy×dairy, Beef×dairy and Beef×beef), whereby 1-star is considered very poor within the genotype, whereas 5-stars is considered excellent within the genotype.

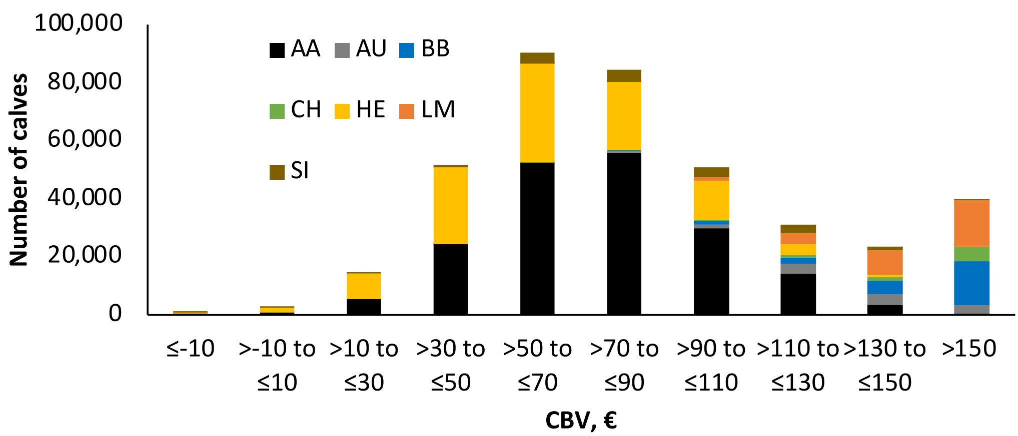

Figure 1. *Commercial Beef Value (CBV) of calves born to a dairy cow and sired by a beef bull. Higher CBV values are more desirable*

How can I breed a high CBV calf?

Breeding decisions in dairy herds determine the quality of beef calves available to beef farmers. Beef farmers can now identify and seek out only high genetic merit calves for slaughter characteristics by using the CBV. Hence, it will be important that dairy farmers generate beef calves with high CBV, which will be in demand in the market. The beef merit (and the CBV) of calves is determined by the genetic merit of both the dam the sire. It is important to note that poor beef merit cows can still produce high value CBV calves if a very high beef merit bull is used. The average herd needs to use a beef bull with a Beef SI of at least €75 to obtain a 4-star CBV calf (i.e., a calf in the top 40% for the CBV); to achieve a 5-star calf, a Beef SI of at least €118 is required. Dairy herds with poorer beef genetic merit need to use bulls with a higher Beef SI (Table 1). The advice for all herds is to maximise Beef SI of the bulls used, while also ensuring that calving difficulty thresholds are appropriate for your herd.

Table 1. *Minimum DBI Beef SI required for beef bulls to achieve a 4* or 5* CBV dairy-beef calf categorized by dairy herd ranking on EBI Beef SI*

Dairy herd Beef SI ranking[1]	Dairy herd Beef SI	Beef Bull Beef SI (DBI) to achieve	
		€80 [4*CBV]	€123 [5*CBV]
1* herds	-€13	€86	€129
2* herds	-€5	€78	€121
3* herds	-€2	€75	€118
4* herds	€0	€73	€116
5* herds	+€4	€72	€112

[1]*available on EBI report scorecard*

Do higher CBV calves perform for beef farmers?

A validation study of CBV was conducted using slaughter data collected in 2022. This indicated that animals with higher CBV outperformed lower CBV animals at slaughter. Beef×dairy cross calves that had a four star CBV were 11 kg heavier, were three days younger and had a higher conformation score at slaughter compared with the three star calves (i.e. average beef×dairy calf; Table 2). The calves with a five star CBV produced superior carcasses, although they were slightly older at slaughter (Table 2).

Table 2. *Slaughter performance of beef X dairy steers ranked stars for CBV*

Star rating	CBV (€)	Carcass weight (kg)	Conformation score, 1-15 (EUROP)	Age at slaughter (d)	Percentage ≥O= for conformation
1	35	315	4.6 (O=)	824	56%
2	55	326	4.8 (O=)	818	64%
3	72	334	5.1 (O=)	814	73%
4	98	345	5.4 (O=)	811	81%
5	152	361	6.4 (O+)	820	91%

Conclusion

Breeding higher beef merit calves will become more important in future years. The introduction of the CBV will enable beef farmers to purchase calves based on beef potential and not just breed. This in turn will reward dairy farmers in the marketplace that use high beef merit sires and consequently produce high CBV calves.

Teagasc DairyBeef500 demonstration farm profitability performance

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Summary

- Profitability of DairyBeef500 farms decreased from €650/ha to €516/ha from 2021 to 2022.
- Beef prices rose by 18% but feed and fertilizer costs increased by 36% and 64%, respectively.
- Farms with high levels of output from a diet based primarily on grazed grass maintained or increased profits.
- Fixed costs have begun to increase on farms and will need to be monitored.

Introduction

The Teagasc DairyBeef500 campaign was launched in 2022 and consists of a series of 15 demonstration farms located nationwide, a knowledge transfer programme, a standalone calf-to-beef demonstration farm, a new entrant calf-to-beef course and a dairy calf-to-beef manual. The majority of the demonstration farms have been involved in Teagasc programmes since the Teagasc Green Acres programme. The demonstration farms receive intensive one-to-one advice from dedicated programme advisors on grassland management, financial management and herd health. The target net profit for the farms is €500/ha excluding all subsidies. The demonstration farmers in the programme range in size from 24 hectares to 92 hectares and are made up of part-time and full-time farmers. All demonstration farms run a calf-to-beef system as their main enterprise with some farms running additional enterprises on a smaller scale such as store-to-beef, sheep or tillage.

Cost increases in 2022

Fertilizer prices increased by 2.5-3 times the price paid in 2021 for products such as 18-6-12, protected urea and 10-10-20. Concentrate feed prices from the middle of the year onwards increased by 30% and remained very high into 2023. Other inputs such as diesel, polythene, sprays and contractor costs also markedly increased, but the concentrate feed and fertilizer costs experienced the greatest increases.

Earlier age of slaughter

Many of the monitor farms have moved to a more efficient early slaughter system. Slaughter age has reduced by 76 days relative to the previous three years, and hence a large proportion of cattle on these farms were slaughtered between October 2021 and early February 2022. The slaughter of these animals preceded the beef price increase that occurred in late spring 2022.

Physical and financial performance of DairyBeef500 farms in 2021-2022

Profitability of DairyBeef500 farms reduced from €650/ha net profit excluding all subsidies in 2021 to €516/ha in 2022 (Table 1). Some farmers experienced very large increases in concentrate costs, with a large proportion of this increase occurring in the August to December period when weanlings entered sheds and cattle were fed to target a 21-22 month age at slaughter. The 21% reduction in profitability could have been much greater had beef prices not increased to the level they did in 2022. Data from Bord Bia indicates that average beef prices increased 18% from €4.05/kg in 2021 to €4.78/kg in 2022. The

DairyBeef500 demonstration farmers have a key issue to manage for 2023: while beef prices are currently strong, inputs costs have markedly increased. For example, relative to the same period last year, concentrate costs have increased over €100/tonne, milk replacer increased by €5-10 per bag (to €55-60) while fertilizer started at higher prices than last year but appear to have eased again. A notable increase occurred in fixed costs in 2022. This occurred in part, because farmers invested extra cash in areas that had been neglected over the previous years with low beef prices, such as fencing, roadways, machinery repairs and labour saving equipment such as handling units and calf feeders. A number of the farms had fixed costs close to or in excess of €1,000/ha, meaning they need a gross margin of close to €2,000/ha to achieve an industrial wage of €40,000 from 40 hectares.

Table 1. *Physical and financial performance of DairyBeef500 farms in 2021-2022*

	2021	2022	Change %
Grassland stocking rate	2.31	2.30	0
Grassland organic N kg/ha	183	183	0
Gross output kg/ha	1,427	1,358	-5%
Gross output kg/LU	606	583	-4%
Gross output €/ha	2,882	3,236	+12%
Gross output €/kg LW	2.02	2.35	+16%
Variable costs €/ha	1,541	1,953	+27%
Gross margin €/ha	1,341	1,284	-5%
Fixed costs €/ha	692	768	+11%
Net margin €/ha	650	516	-21%
Average Irish beef price €/kg	4.05	4.78	+18%

Average stocking rates on the DairyBeef500 farms are high at 2.3 LU/ha (Table 1). In any beef system, a high level of beef output is required to leave a large enough gross margin to cover fixed costs and leave a substantial net margin for farmers before subsidies. The demonstration farms in this programme are consistently achieving 1,300-1,400 kg of live weight per ha, which can deliver net margins of at least €500/ha. Efficient farms that are stocked at 1-1.3 LU/ha typically generate enough of a gross margin to cover fixed costs only, meaning that the only revenue that the farmer keeps is from direct payments.

Conclusions

The DairyBeef500 farmers that generated profits of at least €500/ha provided the animals with a diet consisting primarily of grazed grass and grass silage, had good herd health plans including vaccination policies against pneumonia, and placed attention to detail in the rearing phase, which included the transition phase from milk to grass.

Johnstown Castle dairy calf-to-beef update

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Summary

- Early maturing dairy-beef heifers have the ability to finish from pasture during the second grazing season, resulting in lower slaughter ages, concentrate inputs and housing requirements, than steer systems.
- Dairy-beef heifers consuming perennial ryegrass (PRG)-only, PRG + Clover, and multispecies swards (MSS) achieved carcass weights of 250, 258, and 255 kg, at 20, 19.7, and 19.1 months, respectively.
- Additional research is required to identify the potential of pasture type, animal maturity, and age of slaughter in improving the economic and environmental efficiency of heifer based dairy-beef production.

Introduction

With improved use of animal genotypes, pasture composition, and improved grassland management, dairy-beef heifer systems have the opportunity to save on input and housing costs by slaughtering animals from pasture, during the second grazing season. Dairy-beef systems which can minimise inputs (fertiliser and feed), slaughter animals younger, and that maintain high levels of carcass output have improved economic and carbon efficiency. Heifer systems, using high carcass merit animals, legume rich swards and improved grassland management practices have the potential for high levels of physical, financial and environmental performance.

Results from 2022 study on the slaughter performance of dairy-beef heifers

In 2021, 120 reared dairy × beef heifer calves were purchased at approximately 16 weeks of age, and were assigned to one of three pasture treatments 1) PRG-only, receiving 150 kg N/ha, 2) PRG + clovers (red and white), receiving 75 kg N/ha, and 3) MSS (PRG, red and white clover, plantain, and chicory) swards receiving 75 kg N/ha. The calves were balanced across treatments based on breed, date of birth, and weight on arrival. The calves were housed in November when the grazing conditions began to deteriorate. During the first winter period, the calves were fed silage offered ad libitum along with 2 kg/head of concentrate. The yearlings were turned out to pasture in March, and were drafted for slaughter when they reached a target carcass fat score of 3+. Those not slaughtered off grass were housed in October and commenced their finishing diet of 4 kg/head of concentrate and ad libitum grass silage until slaughter (Table 1).

All groups achieved a similar carcass performance, despite differences in slaughter age and the level of concentrate fed to achieve adequate carcass fatness. The PRG + CLOVER and MSS treatments resulted in 20 and 4%, respectively, more heifers being drafted for slaughter by the end of the second grazing season compared with PRG-only treatment. This was likely due to greater dry matter intake and superior sward nutritive quality. Thus, the finishing concentrate requirement was lower for the PRG + CLOVER and MSS treatments, which represents a significant saving in costs associated with feed and housing. During the first grazing season, heifers consuming the PRG-only, PRG + CLOVER, and MSS herbage achieved an average daily gain (ADG) of 0.82, 0.79, and 0.84 kg, respectively. Correspondingly, during the second grazing season, ADG values were 1.10, 1.22 and 1.15 kg, respectively. On average, during the 2022 grazing season, a 227-day grazing season was achieved.

Table 1. *2022 Slaughter performance of dairy-beef heifers managed on perennial ryegrass (PRG)-only swards, PRG plus red and white clover swards, and multispecies (MSS) swards*

Slaughter Performance	PRG-only	PRG + CLOVER	MSS
Age at slaughter (months)	20.0	19.7	19.1
Drafted off grass	74%	89%	77%
Finishing concentrate (kg)	56.2	25.6	43.0
Carcass weight (kg)	250	258	255
Carcass conformation	O=	O=/+	O=
Fat score	3+	3+	3+

Current dairy-beef research at Teagasc Johnstown Castle

Clover-based swards have shown benefits in terms of animal intake and performance, sward nutritive value, and increased biological nitrogen fixation in both dairy and beef systems. Similarly, multi-species swards have shown potential to increase sward dry matter production under reduced chemical nitrogen application rates. Traditionally, early maturing animals can be finished from pasture while late maturing animals generally require an indoor finishing period. The maturity of beef cattle can also influence their suitability to a particular finishing system. Hence, specific research is required to explore the differences between grass, grass-clover and multi-species swards for dairy-beef heifers.

A new study was designed in 2023 to investigate the interactions between animal maturity and pasture type at different slaughter ages, which was motivated by the policy ambition to reduce the national slaughter age by three months. In this study, female calves from HF cows mated to Early (Hereford and Angus) and Late (Belgium Blue and Limousin) maturing sires, were bought from dairy farms at approximately three weeks of age. All calves are being reared on milk replacer (0.5 kg/hd/day, from 30 days of age) and have ad-lib access to concentrates up to weaning, at a targeted weaning weight of 90 kg. Post weaning, calves will be assigned to one of three pasture treatments 1) PRG-only, receiving 150 kg N/ha, 2) PRG + clovers (red and white), receiving 75 kg N/ha, and 3) MSS (PRG, red and white clover, plantain, and chicory) swards receiving 75 kg N/ha. The calves assigned to each pasture treatment will be balanced for live weight, age, maturity, breed and sire. The system will be stocked moderately at 2.4 LU/ha. All animals will be finished in a serial slaughter arrangement at 16, 19 or 21 months (Table 2).

Table 2. *Preliminary 2023 data from the early (Hereford and Angus) and late (Belgium Blue and Limousin) maturing dairy-beef heifer calves*

Breed	Early maturing		Late maturing	
	Hereford	Angus	Belgium blue	Limousin
Date of birth	18/02/23	28/02/23	24/02/23	18/02/23
Age at arrival (days)	21	23	20	29
Weight on arrival (kg)	55.9	53.4	53.6	55.4

Conclusions

Although all treatments achieved a similar carcass performance in 2022. The incorporation of legumes and herbs into PRG swards resulted in a greater proportion (+ 20% for the PRG + CLOVER treatment and + 4% for the MSS treatment) of heifers being drafted by the end of the second grazing season compared with the PRG-only treatment, avoiding the need for an indoor finishing period.

Grange dairy calf-to-beef system evaluation

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Summary

- Dairy-beef progeny from beef sires with high-genetic merit for carcass traits have greater carcass, economic and environmental efficiency.
- Performance, profitability, greenhouse gas emissions, and human-edible protein efficiency improved with increasing carcass merit.
- Increased conformation and reduced feed costs were key profit drivers.

Introduction

Due to the expansion of the national dairy herd, the number of dairy-beef animals has increased in recent years, and now accounts for 63% of the cattle processed in Irish meat plants. Concurrently, there has been a decrease in carcass conformation score in the progeny from dairy dams bred using both beef and dairy sires. The selection criteria for beef sires used on the dairy herd (calving ease, gestation length and breed) places insufficient emphasis on genetic merit for carcass traits to counteract the poor and declining beef traits in Irish dairy cow genetics. Improved reproductive efficiency, greater usage of sexed semen and reduced heifer replacement rates have facilitated greater use of high genetic merit beef sires. These superior dairy-beef genetics, coupled with good management practices at farm level, can create more profitable grass-based dairy-beef systems with reduced slaughter age and environmental impact.

Grange dairy calf-to-beef study

The objective of the study was to compare the physical and financial performance of male progeny from three dairy-beef genetic groups, within an efficient grass-based production system. The sire genetic groups were Holstein-Friesian (HF) and two Angus (AAX) groups representing the main calf breeds born in the dairy herd. The HF group were the progeny of the top four sires on the Economic Breeding Index (EBI) active bull list in the previous breeding season. The two AAX groups were the progeny of AA sires that were ranked high (HIGH AAX; +8.1 kg carcass, 0.83 conformation) or low (LOW AAX; -3.7 kg carcass, 0.53 conformation) for carcass weight and conformation score, but both AAX groups had similar breeding values for calving ease and were used extensively across the national dairy herd. All progeny were from HF dams and sired by AI bulls.

In both spring 2018 and 2019, 120 male calves were purchased from 33 dairy farms throughout the country at approximately 21 days of age. The effect of early-life calf nutrition (indoors) on lifetime performance was evaluated, whereby half of the calves in each of the three 'genetic' groups received either four or eight litres of milk replacer/day from 30 days of age until weaning. Subsequently, each of the three genetic groups were grazed separately but were managed identically. An intensive grass-based system of production was implemented based on 48-hour grass allocations and grazing to a post-grazing sward height of 4 cm. When housed for the first winter and finishing period, steers were offered high dry matter digestibility (DMD 75%) grass silage ad-libitum and 1.5 kg and 5 kg concentrates/day, respectively. Steers were body condition scored (BCS) fortnightly during the finishing phase, and were drafted for slaughter at a BCS of 3.75 (scale 1-5), equating to a target carcass fat score of between 3= and 4-. All inputs and outputs were measured and used to model the economic and environmental efficiency of the genetic groups.

Results

There were no differences in lifetime growth or carcass performance for calves reared on four or eight litre of milk/day. Despite the four litre treatment consuming 25 kg more concentrate (fresh weight basis) than the eight litre treatment, there was a saving of €33 per head during the calf-rearing phase as a result of feeding 20 kg less milk replacer. The HIGH and LOW AAX steers had the same slaughter age and finishing period (63 days), which was one month shorter than HF steers (Table 1).

Table 1. *The effect of sire carcass merit on animal, system and environmental efficiency within a grass-based dairy-beef system*

	HF	HIGH AAX	LOW AAX
Animal			
Age at slaughter (days)	686 (22.8 months)	656 (21.8 months)	657 (21.8 months)
Carcass weight (kg)	300	305	300
Carcass conformation (1-15)	3.8 (O-)	5.3 (O=)	5.1 (O=)
Carcass fat (1-15)	8.4 (3=)	8.9 (3+)	9.2 (3+)
Lifetime concentrate use (kg)	695	552	545
System			
Stocking rate (LU/ha)	2.9	2.7	2.7
Carcass output/ha (kg)	960	976	960
Net margin (€/ha)*	462	728	607
Net margin (€/kg carcass)	0.48	0.75	0.63
Cost of production, (€/kg carcass)	3.07	3.04	3.11
Environmental			
GHG emissions (kg CO_2e/kg carcass)	14.2	12.9	13.2
Human edible protein ratio (kg/kg)	0.75	1.05	1.02

Base price of €3.70/kg on the QPS grid; €0.20/kg QA payment and €0.10/kg AA breed bonus. Calf and finishing concentrate price €420 and €300/t, respectively. Protected urea price €387/t. *Net margin excludes land & labour charge and assumes a calf purchase price of €60 and €180 per head for HF and AAX sired bull calves, respectively.

There were small differences in carcass weight and conformation score between the AAX groups (numerically in favour of HIGH AAX). The HF steers had a similar carcass weight but were leaner and had poorer conformation than the AAX groups, which resulted in a lower carcass value. The percentage of the lifetime diet dry matter consumed as forage (grazed and conserved grass) was 87% for both AAX groups and 85% for HF. Over their lifetime, the AAX groups consumed a total of 549 kg of concentrate (fresh weight) compared with 695 kg consumed by the HF steers.

HIGH AAX steers achieved the highest net margin (Table 1), due to better carcass weight, conformation and value/kg carcass; both AAX groups performed better than HF steers due to better carcass performance and a shorter finishing period. The HIGH AAX steers had the lowest 'carbon footprint', producing 9% less CO_2 eq per kg carcass than HF steers. Both AAX groups were net producers of human edible protein, whereas HF steers produced 25% less protein at slaughter than they consumed in their lifetime, meaning that for every 1 kg of human edible protein fed to cattle only 0.75 kg of human edible protein was produced in the form of meat.

Conclusions

In summary, all groups achieved similar carcass weight, but the AAX groups produced a carcass with better conformation and higher value. As AAX steers were slaughtered at a younger age, they had lower variable costs (fewer inputs) than HF. The use of high carcass merit beef genetics on the dairy herd will play an important role in improving the sustainability of both the dairy and the beef sectors. Large scope exists to improve the carcass characteristics of beef-cross calves derived from the dairy herd by choosing bulls ranked highly on the Dairy Beef Index for carcass traits (page 164).

Demonstrating best practice in dairy Calf-to-Beef: Tipperary beef farm update

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Summary

- The Tipperary beef farm is a new 105 ha dairy calf-to-beef demonstration farm in Fethard, Co. Tipperary, which was established by Teagasc with Dawn Meats and Shinagh Estates Dairy farm to demonstrate the best technologies for profitable and sustainable production of beef calves from the dairy herd.
- The farm uses a range of key technologies:
  - » Closer collaboration between a dairy farmer and a beef farmer in the breeding, management and transfer of calves.
  - » Excellent pasture management to ensure animals always have high quality grass and grass silage.
  - » Minimal concentrate supplementation, with a focus on maximising animal performance from forage.
  - » Maximising animal performance at all stages of the life cycle to reduce age at slaughter.
  - » Herd health planning to minimise morbidity and use of antibiotics and anthelmintics.

Background

The recent expansion of the national dairy herd has resulted in an increasing number of calves that are destined for beef production coming from the dairy herd annually. These calves include both dairy breed calves (male calves with a dairy dam and a dairy sire) and beef-cross calves (male and female calves with a dairy dam and a beef sire). Currently, a sustainable outlet for these calves includes live exports to mainland Europe; however, this may not be possible in the future. Building a sustainable outlet for the population of dairy breed and beef-cross calves coming from the dairy industry is essential. In addition, the slaughter of un-weaned calves will not be socially acceptable in the future. The most socially sustainable outlet for non-replacement calves from Irish dairy herds is a thriving dairy calf-to-beef industry. Teagasc has engaged with dairy and beef stakeholders to develop a new demonstration farm to highlight the key technologies that drive profitability on a dairy calf-to-beef farm.

Shinagh Estates Limited is owned by four West Cork dairy Co-Ops (Bandon, Barryroe, Lisavaird and Drinagh), and Shinagh Dairy Farm is a demonstration dairy farm operated in conjunction with Teagasc and Shinagh Estates. The dairy calf-to-beef demonstration farm in Fethard is a joint venture between Teagasc, Dawn Meats and Shinagh Estates Limited, and operates under the name “Tipperary Beef Farm Ltd.” as a standalone commercial unit that began in April 2022.

Farm system

Dairy calf-to-beef production is exposed to significant financial risk in terms of animal performance, input prices and beef carcass prices. Nationally, performance at farm level is significantly poorer than what is achievable with best practice. Tipperary Beef Farm will demonstrate a model that can provide a competitive return on the capital and labour employed. Tipperary Beef Farm is 105 ha of relatively free-draining clay loams, and was converted from cereals to a perennial ryegrass/white clover sward in 2022. The farm will receive approximately 125 kg N/ha per year. In 2023, the farm is stocked with 320 calves and 240 yearlings. The farm plan is to match the stocking rate on the farm with the potential of the farm to grow grass. All animals will be slaughtered when they reach adequate fat cover. The age at slaughter will determine the feed demand and the number of animals reared will be adjusted based on forage supply and demand. A key technology that the farm will demonstrate is reducing the age at slaughter. The objective is to maximise the number of animals slaughtered at the end of the second grazing season, having been fed a diet primarily based on grazed pasture and high quality grass silage.

Animal selection

Closer collaboration between dairy and beef farmers in the management and transfer of calves will lead to significant benefits for both parties. The dairy farmer will have a secure outlet for non-replacement calves and the beef farmer will have a supply of calves that he or she has had an influence on the selection of the sires used, as well as having input into calf nutrition and health management before the calves arrive on the beef farm.

A supply contract is in operation between Tipperary Beef Farm and Shinagh Dairy Farm and other dairy farms; this contract will be published for all farmers to use. The calf purchase specification protocol from the selected source dairy farmers includes key criteria related to the genetics, health, movement and value of the calves:

Calves must be ranked in the top 40% of beef-cross animals (i.e. four or five star) based on the Commercial Beef Value (CBV). Based on the January 2022 evaluation, the threshold for a four star animal is €79.

- Calves must weigh at least 30 kg (measured using a weigh band).
- Calves have no signs of ill-health.
- All suitable calves are made available to the rearer to purchase.
- Calf PI3 intranasal vaccine to be administered by dairy farmers a minimum of five days before transport.
- Dairy farmer to allow pre-movement examinations of the calves.
- Transport of the calf to the beef farm is the responsibility of the dairy farmer.
- Calf value is calculated based on the average value of calves from that breed at mart sales corrected for age and weight.

Reducing environmental impact

Key technologies will be demonstrated at Tipperary Beef Farm to reduce the environmental impact of beef production without reducing farm profitability:

- Use of high DBI beef genetics.
- Inclusion of white clover in swards to reduce chemical N requirements.
- All slurry applied using low emissions slurry spreading (LESS) methods.
- All chemical N applied as protected urea.
- Use of low crude protein concentrate feeds.
- Reaching target slaughter weights earlier to reduce lifetime methane emissions.
- Maintain and manage existing habitats appropriately and improve the quality of existing hedgerows.

Improving nitrogen use efficiency through breeding

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Summary

- Genetic differences explain 8% of the variability in the efficiency of how nitrogen is used and 10% of the variability in the quantity of nitrogen excreted.
- A dairy cow in the top 10% of the most nitrogen-efficient cows nationally would be expected to excrete 8.5 kg less nitrogen over a 305-day lactation than an average dairy cow for nitrogen efficiency.

Introduction

Both nitrates in drinking water and nitrous oxide, a powerful greenhouse gas, are of growing concern. Management strategies can be used to reduce the use of nitrogen on farms (e.g. clover) and also increase the efficiency of its use (e.g. targeted use of Low Emission Slurry Spreading). Animal breeding is a proven technology that has clearly demonstrated its ability to deliver sustainable gains in performance. A study was undertaken to examine if genetic differences existed between cows for nitrogen use efficiency, the first undertaken in grazing dairy cows globally.

Nitrogen sources and uses

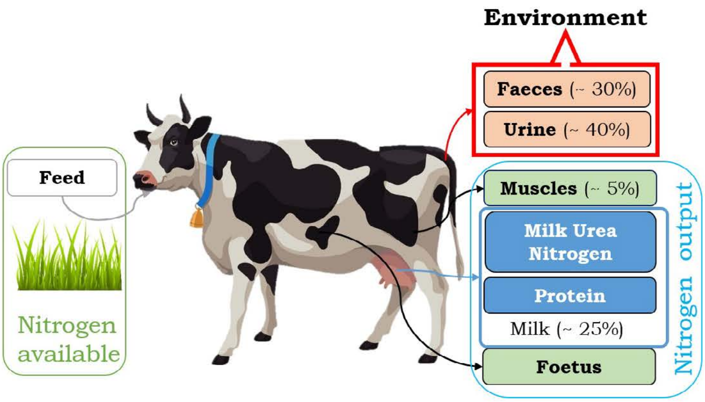

Figure 1. *Different nitrogen sources and sinks for a grazing dairy cow*

The quantity of nitrogen ingested by Irish dairy cows is almost exclusively a function of how much the cow eats and the crude protein (of which nitrogen is a component) of that diet. A small portion of the nitrogen available to the cow can also come from the mobilisation of body muscle reserves. Dairy cows use nitrogen to produce milk protein, milk urea nitrogen, and the protein in the meat (Figure 1). How the nitrogen ingested is portioned into the nitrogen sinks are represented in Figure 2.

Two definitions of nitrogen use efficiency were defined for this study, each on an individual cow basis for different points of the lactation:

- The nitrogen excreted, which was calculated as the nitrogen available to the cow minus the total nitrogen partitioned into the different products, and
- The traditionally used nitrogen use efficiency metric, which was defined as simply all of the nitrogen output into the different products divided by the total nitrogen available to the animal.

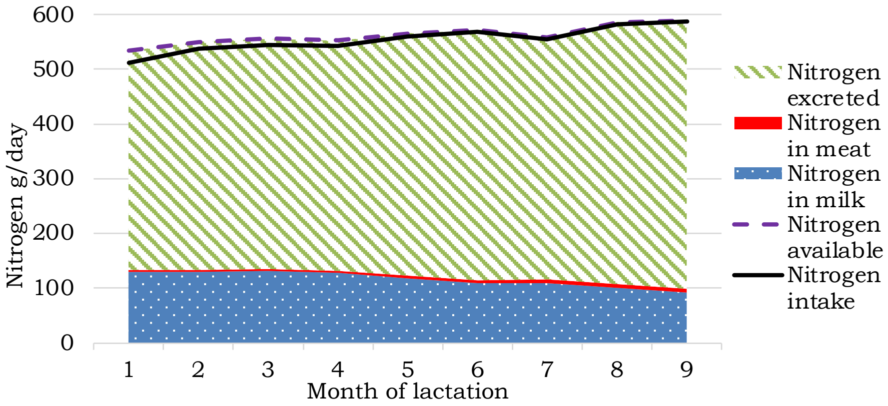

Figure 2. *Nitrogen intake, available and used in product depending on the month of lactation*

Data were available on 1,291 dairy cows from four research farms at the Teagasc, Animal & Grassland Research Centre, Moorepark, Fermoy, Co. Cork. Milk production and composition, body weight, dry matter intake, and crude protein content of the diet were recorded for 2,241 lactations recorded between the years 2008 and 2018.

Potential improvement from breeding

Genetic differences among cows are responsible for 8% and 10% of the variability in nitrogen use efficiency and the quantity of nitrogen excreted, respectively; these values are referred to as the heritability. The best 10% of dairy cows used 1.1% more of their nitrogen intake for milk and meat, and excreted 28 grams less of nitrogen per day than the average cow. Assuming an average herd size of 83 dairy cows, where all dairy cows are in the top 10% for nitrogen-efficiency, that herd would be expected to excrete 709 kg less nitrogen over a 305-day lactation than a herd of cows that are average for nitrogen efficiency.

Relationship between milk production and nitrogen efficiency

The genetic relationship between two traits is a measure of how much one trait might change if the other trait was selected for. For example, the genetic relationship between nitrogen excretion and nitrogen use efficiency was moderately negative; this means that selecting cows with high nitrogen use efficiency could result in lower nitrogen excretion. Nitrogen use efficiency was positively associated with the milk yield, meaning that selecting for high milk production alone could increase nitrogen use efficiency. There was no relationship between either of the definitions of nitrogen use efficiency and milk urea nitrogen, so selecting for high or low milk urea nitrogen concentration would not influence nitrogen use efficiency.

Conclusions

Genetic differences among animals contribute to actual differences in both the amount of nitrogen excreted and also the efficiency by which nitrogen is used. This genetic diversity is a cornerstone to successful breeding programs, however, meaning that, breeding for improved nitrogen use efficiency is possible. This will require measures of nitrogen use efficiency in individual cows, which are difficult to capture.

Sustainable dairying with efficient and effective breeding programs for improved health and fertility

Siobhan Ring[1], Donagh Berry[2] and Margaret Kelleher[1]

[1]*Irish Cattle Breeding Federation, Shinagh House, Bandon, Co. Cork;* [2]*Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork*

Summary

- Genetics creates the potential, management realises the potential, reproductive failure and disease destroys the potential.
- Breeding for improved reproductive performance has delivered, but more has yet to be achieved.
- Breeding for improved health status will, like the successes in fertility, deliver improved national health status.

Understanding genetic evaluations

Genetic evaluations for fertility have been available on all dairy cattle since 2001; genetic evaluations for somatic cell count and later mastitis and lameness have also been available for over 10 years. Genetic evaluations for TB and liver-fluke are now available. Each bull and cow receive a genetic proof (often referred to as a predicted transmitting ability; PTA) for calving interval as a measure of fertility. The more negative the calving interval PTA the more desirable it is; a calving interval PTA of -6 days implies that the female progeny of that animal, when producing in the average Irish herd, are expected to have a calving interval six days shorter than an average historical cow (referred to as the base population); the base population calving interval is currently 400 days.

1. EBI Herd Summary

Average EBI for all dairy cows with; (i) a known sire (or milk recorded progeny with a known sire) and (ii) are currently on your farm.

Group	Num of Cows	M Kg F Kg P Kg	F% P%	Surv % CI Days	Milk Solids % Contrib	Fertility % Contrib	Calving % Contrib	Beef % Contrib	Health % Contrib	EBI €
Overall Cows	607	143 8.6 7.4	 0.06 0.05	 1.4 -2.0	€49.4 44.1%	€39.4 35.1%	€16.1 14.4%	€-5.9 -5.3%	€-1.3 -1.2%	**€98**
1st Lactation	196	169 10.1 8.4	 0.07 0.05	 1.3 -2.0	€55.7 45.4%	€38.9 31.7%	€19.9 16.2%	€-6.6 -5.4%	€-1.7 -1.4%	**€106**

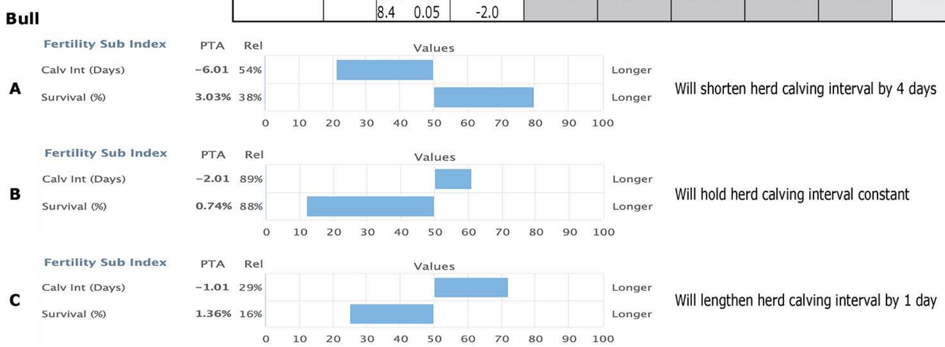

Figure 1. *Expected impact of using bull A, B, or C on the calving interval of the herd*

Every herd is different, however, and the best way to determine if a team of bulls will improve the fertility in your herd is to compare the average calving interval PTAs of the cows in your herd with the average of the team of bulls. If the average calving interval of the team of bulls is more negative than your herd, then the resulting progeny are expected to be genetically more fertile that the current herd of cows. This is clearly depicted in Figure 1; the calving interval PTA of the herd is -2 days. Hence a bull that is more negative than -2 (i.e. bull A) will reduce the calving interval; the number of days the bull is expected to reduce the calving interval by is the difference between the mean of the herd and that of the bull (i.e. -6-(-2)= a four day shortening in calving interval).

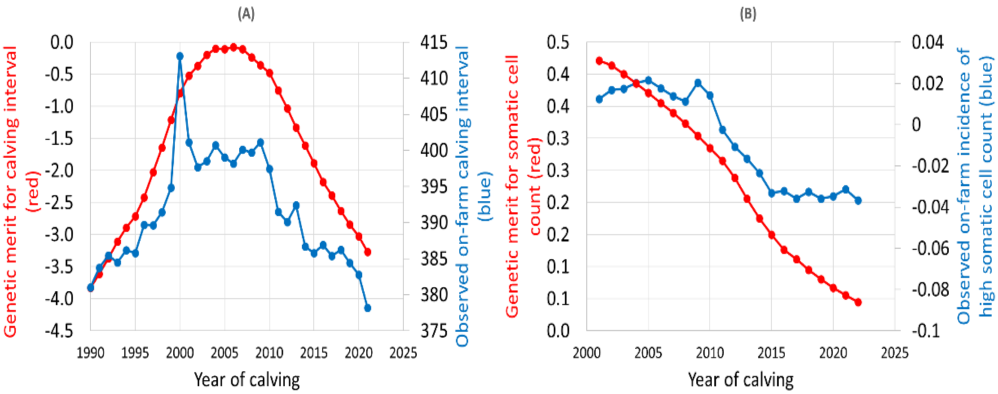

Figure 2. *Genetic and observed trends for (A) calving interval and (B) somatic cell count for Irish cows*

A lot done…

Breeding programs for improved calving interval have clearly delivered. Figure 2 demonstrates how the observed calving interval on farm closely tracks the genetic merit of the same cows for calving interval; the same is true for somatic cell count (Figure 2). This, therefore, clearly illustrates how using bull teams with good genetic merit will deliver a more fertile and healthy herd.

… a lot more to do

A new fertility genetic evaluation model is currently being researched. While the current fertility genetic evaluations have delivered (Figure 2), a greater proportion of herds are calving cows in a more strictly seasonal pattern. Historically accounting for the voluntary waiting period post-calving was not necessary, but now cows calving earlier in the calving season are currently being disadvantaged, as their calving interval record are longer, due to management rather than fertility. Furthermore, some of the improvement in calving interval was due to shortening of gestation length, which does not reflect conception. The new research model proposes to improve the calving interval and survival genetic evaluation model by accounting for voluntary waiting period but also by supplementing these with a 6-week in-calf trait.

Conclusion

Cow fertility continues to improve, albeit room for improvement still exists for many herds; therefore, selection pressure on using high fertility bulls needs to continue. Genetic evaluations for a range of health traits now exist; the improvements observed in fertility performance over the last few decades can also be realised for animal health.

Environmental research in the Next Generation Herd

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Summary

- The *Next Generation Herd* continues to be a valuable resource to future proof the direction of the national breeding programme.
- The EBI can be used as a tool to reduce greenhouse gas emissions per unit of milk solids output on-farm.
- The methane output of Elite EBI animals may be overestimated using current models.
- Direct selection for lower methane emissions in the EBI may also be possible in the future.

Introduction

The economic breeding index (EBI) was developed in 2001 to deliver genetics that increase profitability in Irish pasture-based dairy systems. The Teagasc *Next Generation Herd* was established to validate genetic gain and ensure compatibility between high EBI genetics and pasture-based systems of milk production. The results from the initial phase of the study demonstrated favourable responses in terms of milk solids yield, intake capacity, fertility and economic performance via selection based on the EBI. New environmental pressures facing the dairy industry, however, also requires milk to be produced in a sustainable manner. In recent years, the *Next Generation Herd* has been used to evaluate the environmental impact of continued selection for the EBI.

Modelled greenhouse gas emissions

Greenhouse gas emissions of both the high (Elite; EBI = €181) and national average (Nat Av; EBI = €82) EBI dairy cows were modelled through a lifecycle assessment analysis using biological data from the *Next Generation Herd*. This analysis was based on a 40-ha dairy farm milking 110 cows and modelled all greenhouse gas emissions (methane, nitrous oxide and carbon dioxide) up to the farm gate. The results are presented in Table 1. The Elite cows produced more milk solids (fat and protein yield) compared with the Nat Av cows. This increase in productivity led to the Elite cows producing more methane per cow. The Elite cows also had superior fertility, however, and therefore had lower emissions from rearing fewer replacement heifers compared with the Nat Av cows, which resulted in no overall difference in greenhouse gas emissions on an area basis between the two groups. The net effect was 11% less greenhouse gas emissions per kg of milk solids. The analysis showed that each €10 increase in EBI between the Nat Av and Elite cows led a 1% reduction in greenhouse gas emissions per kg of milk solids.

Table 1. *Modelled greenhouse gas emissions of the Elite and Nat Av dairy cows*

Item	Elite	Nat Av
Milk solids (kg/cow)	484	434
Greenhouse gas emissions (tonnes/ha)	16.3	16.2
Greenhouse gas emissions per unit milk solids (kg/kg)	12.2	13.7

Direct measurements of methane

Direct measurements of daily methane emissions were also conducted on the Elite (EBI = €233) and Nat Av (EBI = €133) cows in the *Next Generation Herd* using GreenFeed technology between March and October 2021. The results are presented in Table 2. As expected, Elite cows had greater milk solids yield compared with Nat Av cows. The increase in productivity of Elite cows resulted in greater daily methane output when calculated using models similar to that used within the national greenhouse gas inventory. Despite this, there was no difference in the measured methane output between Elite and Nat Av cows. This finding suggests that a proportion of the increased methane output used in national greenhouse gas inventories for elite dairy cows may not exist in practise. The greater milk solids yield and similar daily methane output of Elite cows translated to a dilution of their methane emissions on a unit of output basis, resulting in less methane per unit of milk solids.

Table 2. *Methane emissions of Elite and Nat Av dairy cows*

Trait	Elite	Nat Av
Milk solids (kg)	1.93	1.78
Measured methane (g)	305	301
Calculated methane (g)	370	351
Methane per unit milk solids (g/kg)	158	169

The results also demonstrated there was substantial variation in methane output between individual dairy cows within both Elite and Nat Av groups of cows. This suggests it may be possible to directly select dairy cows for reduced methane emissions in the future. To achieve this objective, the key challenge is to develop technologies capable of generating a large number of methane emission phenotypes, which would allow breeding values for the trait to be calculated. Caution is also required to ensure that other economically important traits such as fertility, feed intake capacity or milk production are not adversely impacted through selection for reduced methane emissions.

Conclusion

The *Next Generation Herd* continues to be a valuable tool for the Irish dairy industry, providing confidence that the EBI is capable of identifying more profitable and sustainable genetics for pasture-based dairy systems in Ireland. The EBI in its current form is selecting for more profitable and environmentally efficient dairy cows.

C.O.W. (Cow's Own Worth): Culling the right cows for you

Margaret Kelleher[1] and Donagh Berry[2]

[1]Irish Cattle Breeding Federation, Link Road, Ballincollig, Co. Cork; [2]Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

Summary

- Identifying candidate cows to cull is made easy using C.O.W.
- The C.O.W. index is freely available on HerdPlus.

Introduction

The opportunity to voluntary cull cows has markedly increased in recent years due to improved reproductive performance. Since the removal of quotas, 6-week calving rate has improved by nine percentage units to 66% in 2022, reducing the need to involuntary cull empty or late calving cows. Almost half of all dairy herds have expanded by more than 5% in the last two years, with over 1,300 of these herds expanding by >25% during this period. Because of either physical or regulatory limitations on stocking rates, many herds are likely to cease expansion or even contract in the years ahead. Interestingly, 23% of herds have reduced in size by >5% between the years 2020 and 2022.

The C.O.W. Index

There has also been a significant increase in the number of herds milk recording in recent years; up 38% in 2022 compared with 2020. As a result, more herds can get access to their Cow's Own Worth (C.O.W.) decision support tool, available on HerdPlus (www.icbf.com), to make more informed culling decisions. C.O.W. ranks dairy females, within a given herd, based on each cow's excepted remaining lifetime profitability considering factors such as milk production, age, level of heterosis (i.e., crossbreeding effect), and calving date as well as the genetic merit of both the female herself and her future expected female progeny.

How C.O.W. works

Milk-recorded, spring-calving herds can access C.O.W. on their HerdPlus profile. The application instantaneously gathers all information to rank cows from expected most profitable to least profitable. The profit potential is calculated as 1) expected profit from the current lactation, 2) expected profit from future lactations, and 3) net profit from culling (including the replacement cost) for each dairy cow (see Figure 1).

Current lactation profit

This is estimated as the expected profit of the cow until the end of the current lactation. The current lactation module of the C.O.W. includes five attributes: i) the cow's expected milk production (under the prevailing A+B-C milk pricing system); ii) the calving date (actual or expected depending on most recent source of information); iii) expected health issue costs; iv) maintenance cost; and v) management costs. Both additive and non-additive (e.g., heterosis) genetic merit, as well as cow-centric effects (e.g. milk yield records) are used.

Future lactations

This module considers the expected profit generated by a cow in future lactations. The module includes the same animal attributes as the current lactation module as well as three additional components considering future profit from calving performance, progeny beef performance and future replacement merit accounting for the transmission of genetics to future generations. One of the key strengths of the C.O.W. is the inclusion of predicted probabilities of the expected future number of lactations, future calving patterns and likelihood of udder health issues in subsequent lactations.

Net profit from culling

This component deducts the average cost of a replacement heifer from the expected value of the cow to be culled based on her genetic merit for carcass weight.

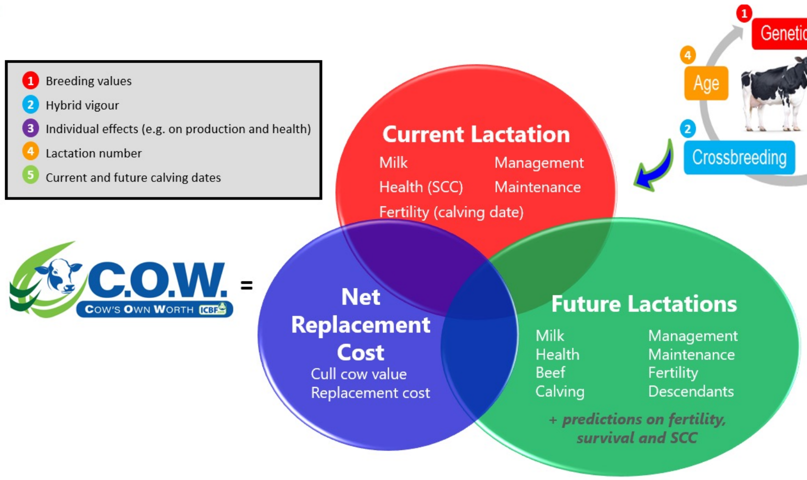

Figure 1. *C.O.W. components – expected profit for remaining lifetime*

When to use C.O.W.

C.O.W. uses live data directly extracted from the ICBF database; therefore, keeping herd and cow records up to date is essential to generate accurate C.O.W. values for the herd. The C.O.W. can be run at any time of the year; most farmers run the decision support tool in late autumn (i.e. before drying off) and again before breeding. For the former, ensure all breeding records (such as inseminations and pregnancy diagnoses) and health events are up to date before making culling decisions. The advantage of running the C.O.W. before breeding is that cows identified for culling removes additional costs of breeding. It is still important to use the EBI to make all breeding decisions for the herd. Use sire advice to assist in mating decisions; cows marked for culling using C.O.W. will appear in sire advice as marked as a cull candidate.

Conclusions

The ability to identify cows with the greatest predicted future profit potential has a substantial impact on herd profitability. C.O.W. provides a decision support service to herdowners to assist in their routine culling management and is particularly useful where voluntary culling options have increased on farms. Farmers might also need to consider reducing cow numbers to comply with stocking rate regulation changes introduced this year. Removing obvious candidates for culling as well as the more difficult to identify "passenger" cows can improve herd profitability while assisting in compliance.

Use of DNA in animal breeding

Cliona Ryan
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Summary

- DNA technology has a range of uses in animal breeding and management.
- Genomic evaluations use DNA to supplement parentage and own performance information, enabling identification of genetically elite heifers and cows.
- DNA calf registration uses genomic information to verify or assign parentage, thus providing more reliable estimates of the value of animals.
- DNA influences performance, with some individual genes like myostatin having a large effect on performance traits like calving difficulty and carcass value.

Introduction

The genotype of an animal (i.e. its DNA profile) impacts performance not just of the animal itself but also its progeny. Therefore, knowing the DNA profile of the calf at birth, and knowing how the DNA profile affects performance, enables prediction of the performance of that animal and its progeny. DNA information currently exits for almost three million Irish cattle and has been incorporated into the national genomic evaluations. The outcome is not only more reliable genetic evaluations at birth but also the ability to screen more animals for traits of economic interest, thereby increasing the intensity of selection and thus genetic gain. In addition to its use in genomic evaluations, the DNA of an animal has many other uses (Figure 1).

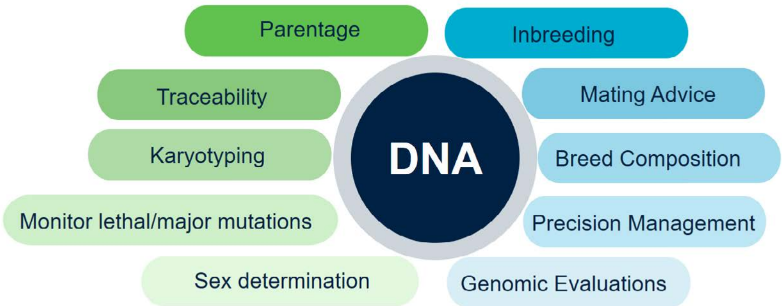

Figure 1. *Potential uses of DNA information in cattle*

Advances in genomic selection

Genomic selection uses DNA information to supplement ancestry information and own performance data to generate a more accurate estimate of the genetic potential of an animal (and thus also its offspring). All calves receive half their DNA from their sire, but it is a random half, and thus the animal has to be genotyped to determine what half it received and how that half affects a wide range of performance traits; the same is true for the dam. Predictions of an animal's genetic merit from DNA are still only predictions; to overcome the uncertainty that still exists, teams of animals should be used. This includes teams of bulls for breeding, but also when selecting genotyped heifers, the team of heifers should be the focus and not individual heifers. The number of bulls per team currently recommended for different herd sizes is indicated Table 1. The ICBF sire advice system calculates the reliability of the team of bulls selected; aim for a target bull team reliability >90%. Using a team of bulls also minimises the risk of an individual bull (or even straws from an individual ejaculate) having compromised fertilising capacity, especially when using sexed semen.

Table 1. *The number of bulls required for different herd sizes*

Herd size	Minimum number of bulls
1-50	7
51-100	7
101-150	8
151-200	10
201-250	11
251-300	12
301-350	13
351-400	14

DNA calf registration

The incidence of incorrect sire recording in Irish dairy herds is approximately 14%. This not only affects genetic gain, but can also result in mating events between animals that were thought to be unrelated. DNA can be used to verify or refute assumed parentage, and if incorrect, it can be used to assign parentage. This is because each individual receives half its DNA from each parent and the DNA is unique to each individual (except for identical twins). Hence, this can be useful if a mob of natural mating bulls is used, where sire assignment is not possible or cumbersome. DNA can also be used to assign breed composition to an individual; the breed composition of the progeny from a crossbred parent cannot be known unless the progeny itself is genotyped.

Genetic defects and chromosomal abnormalities

DNA information is a valuable tool for monitoring the incidence of genetic defects in livestock and identifying carriers. Most genetic defects only materialise when an animal has two bad copies of the gene; animals with one copy are called carriers and generally have no noticeable effect. If two carriers are mated, however, then there is a 25% chance (i.e. one in every four calves born) that the resulting calf will have two copies of the bad gene and express the defect. Genotyping can be used to screen for carriers thereby informing an appropriate mating plan and downstream culling decisions.

Major genes

Major genes, as the name suggests, are genes with a major effect on performance; myostatin is a major gene that causes extra muscle with or without a concomitant increase in calving difficulty. There are 21 known mutations in the myostatin gene, all of which are now tested when animals are genotyped. The F94L mutation (often called the Limousin mutation) is one such mutation that increases carcass weight and conformation, but without any increase in calving difficulty.

Conclusions

Incorporation of DNA information into the national genetic evaluations increases the accuracy of predictions of an animal's genetic potential at birth, aiding identification of the most genetically elite replacement heifers and cows. DNA information is also used to verify parentage, assign breed composition, screen for carriers of genetic defects, and identify carriers of major genes that have a significant impact on performance.

Optimal use of sex-sorted semen

Stephen Moore and Stephen Butler
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Summary
- Delay timing of AI with sex-sorted semen to improve fertility.
- Avoid using sex-sorted semen on low fertility potential cows.
- Timed AI at mating start date mitigates against reduced fertility.

Introduction

Heifers should be bred with dairy AI because they are the most fertile animals in the herd and they generally have the best EBI. Good fertility with sexed semen can also be achieved in young, healthy cows that are at least 50 days in milk. Sex-sorted semen use on the most fertile heifers and cows allows faster genetic gain, reduces calving difficulty, increases the proportion of replacement heifers born at the start of the calving period, and facilitates greater AI use with high DBI sires on the remaining dairy cows. Having all heifer calves born at the start of calving insures a uniform group of heifers for easier management.

Heifer timed AI sex-sorted semen study

Sexed semen has a shorter duration of viability in the female reproductive tract (12–16 hours) compared with conventional semen (>24 hours) and may benefit from AI closer to the time of ovulation. In 2021 and 2022, a sexed semen trial was conducted on 11 herds to compare the reproductive performance of altering the timing of AI in 816 heifers. Heifers received the same sequence of hormone treatments outlined in Figure 1. Half the heifers received AI and an injection of GnRH 48 hours after the second PG injection and progesterone device removal (TAI_0). For the other half of the heifers, the hormone treatments were identical and the only change was that AI was delayed until 8 hours after the injection of GnRH (TAI_8). The pregnancy per AI was 50% and 59% for TAI_0 and TAI_8 heifers, respectively (Figure 2A).

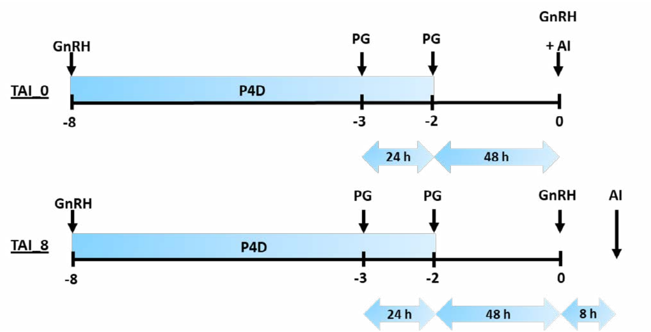

Figure 1. *Synchronisation protocols for TAI of heifers*

Factors affecting the success of sex-sorted semen

Heifers selected for sex-sorted semen must have reached target liveweight, be cycling regularly, and be in good body condition score (≥3.25). Cows selected for sex-sorted semen should be parity 1-4, ≥50 days in milk, BCS ≥3.0, cycling regularly, and free of any health issues. Correct timing of AI is critical and should occur 14-20 hours after the onset of standing heat. Sex-sorted semen is more sensitive to environmental conditions and has a shorter life-span compared with conventional semen. It is important that sex-sorted semen is thawed and inseminated within five minutes of its removal from the AI tank.

In 2018, a trial was undertaken on 142 Irish dairy herds to evaluate the reproductive performance of cows inseminated with conventional and sex-sorted semen. Of the 7,246 cows enrolled on the study, a subset of cows with either high fertility potential (n=813; ≥70 days in milk, first or second lactation, > €60 fertility subindex) or low fertility potential (n=718; <70 days in milk, third or greater lactation, <€60 fertility subindex) were evaluated. Pregnancy per AI was greater in the cows with the high fertility potential compared with the low fertility potential cows inseminated with conventional (65 vs. 52%) or sex-sorted (50 vs. 30%) semen (Figure 2B).

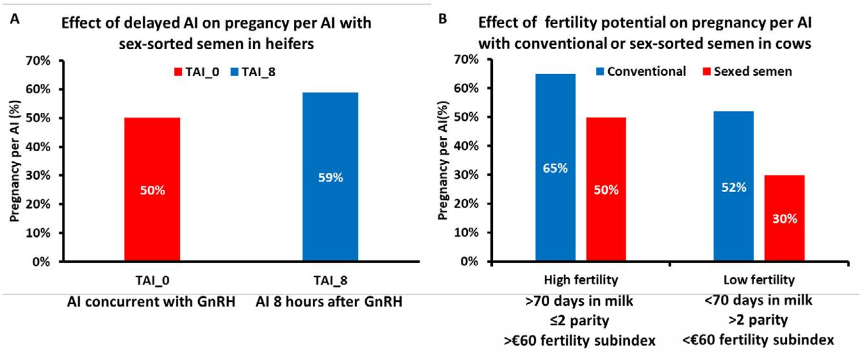

Figure 2. *Pregnancy rate in heifers (A) and cows (B)*

Conclusions

These studies indicate a considerable benefit to delaying timed AI in heifers by 8 h after the final GnRH (18% increase) and highlight the importance of targeting sex-sorted semen in cows with high fertility potential. The use of timed AI synchronisation protocols with sex-sorted semen at mating start date mean that the majority of the repeat heats occur three weeks later, thereby mitigating any reduced pregnancy rate to the first service. Generating more heifer replacements from maiden heifers and high fertility cows accelerates genetic gain, and facilitates greater use of high DBI sires on the remainder of cows in the herd.

Comparison of effect of artificial insemination and in vitro embryo production on gestation length, calf birth weight and calving difficulty

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Summary

- Increased usage of sexed semen will decrease the number of male dairy calves, thereby improving the sustainability credentials of the dairy sector. A new strategy to generate the next generation of elite genetic merit bulls will be required.
- In vitro embryo production can accelerate genetic gain by facilitating multiple matings between elite dams and sires.

Introduction

Every year, ≥60% of the calves born on Irish dairy farms are destined for beef production. Many of these are male offspring of dairy sires and are not genetically selected for beef production, resulting in low economic value. The usage of sexed semen from dairy bulls has rapidly increased in recent years. This has allowed dairy farmers to accelerate herd genetic gain by selecting the best genetic merit dams to breed replacements, and breeding all other dams to beef sires. There are two consequences of these changes to dairy breeding practices: (1) it will be necessary to generate elite genetic merit male dairy calves; and (2) more beef semen will be used than dairy semen, requiring greater efforts to generate beef bulls specifically suited for crossing with dairy dams. Assisted reproductive technologies, particularly in vitro embryo production (IVP) and embryo transfer (ET) can contribute to accelerating genetic gain in both dairy breeds and beef breeds suitable for mating with dairy cows by increasing number of offspring produced from genetically elite dams.

IVF-ET calves in Moorepark

The aim of this study was to determine the effect of embryo origin (artificial insemination, AI vs embryo transfer, ET), calf breed, and calf sex on gestation length (GL), birthweight (BW), and calving difficulty (CD) score. Lactating dairy cows were synchronised with a standard 10-day Progesterone-Ovsynch protocol and randomly assigned to receive timed AI (n =163; frozen-thawed conventional semen) or timed ET with fresh (ET-Fresh; n=291) or frozen (ET-Frozen; n=289) in vitro produced (IVP) embryos. Data were subsequently obtained from a subset (n = 273) of calves that were derived from these breeding events. Calves derived from the IVP embryos were either dairy (Holstein-Friesian, FR, n = 81 or Jersey, JE, n = 38) or beef breed (Angus, AA, n = 94). For all calves, weight was recorded immediately after birth and calving difficulty was scored on a scale of 1 to 4: 1 = unassisted calving (n =173), 2 = minor assistance (n = 52), 3 = considerable difficulty (n = 45) or 4 = veterinary assistance/ caesarean (n = 3). The effects of embryo origin (AI, ET-fresh, ET-Frozen), breed (FR, JE, AA) and calf sex on GL, BW and CD score were examined.

Results

There were positive correlations between GL and BW (r = 0.33) and between BW and CD score (r = 0.55). This means that as GL got longer, calf birthweight increased, and that as calf birthweight increased, CD score also increased. Overall, origin of the calf affected BW, GL and CD (Table 1). Amongst calves born from ET, AA calves were heavier, had longer GL and greater incidence of CD than FR or JE calves. When the analysis was restricted to FR calves only, calves born from ET (fresh or frozen) were slightly heavier than those born from AI (+3.7 kg). Overall, male calves were heavier than females (40.8 ± 8.2 kg vs. 37.2 ± 8.0 kg.

Table 1. *Mean ± SD gestation length (GL), birth weight (BW) and calving difficulty (CD) score following timed AI or ET with fresh or frozen IVP embryos*

Embryo origin	Breed	Number	GL (days)	BW (kg)	CD score
AI	FR	52	276.5 ± 4.2	35.7 ± 5.1	1.3 ± 0.5
	JE	8	277.8 ± 4.0	26.8 ± 3.7	1.0 ± 0.0
ET-fresh	AA	52	281.8 ± 4.9	46.9 ± 8.3	2.2 ± 1.0
	FR	47	278.9 ± 4.5	39.2 ± 5.5	1.4 ± 0.7
	JE	p	282.8 ± 4.7	29.9 ± 4.0	1.1 ± 0.3
ET-frozen	AA	42	281.0 ± 5.9	44.1 ± 6.8	1.6 ± 0.9
	FR	34	279.6 ± 4.4	39.6 ± 4.6	1.6 ± 0.8
	JE	16	280.6 ± 3.2	29.2 ± 4.3	1.3 ± 0.6

Conclusions

In conclusion, calves originating from IVP/ET were heavier at birth, had up to three days longer GL and had a slightly increased incidence of CD compared with calves derived from AI. Given the small numerical difference between the calves derived from the different embryo origins, however, the impact at farm level of these differences is likely to be minimal. The AA calves were, as expected, heavier than dairy breed calves, and hence careful selection of elite genetic merit DBI donors and sires for the production of beef embryos is necessary to ensure low BW, GL and CD of beef ET calves born from dairy dams. Furthermore, beef breed embryos should be transferred into mature cows with a large frame, whereas dairy breed embryos can be safely transferred into all cows.

Acknowledgements

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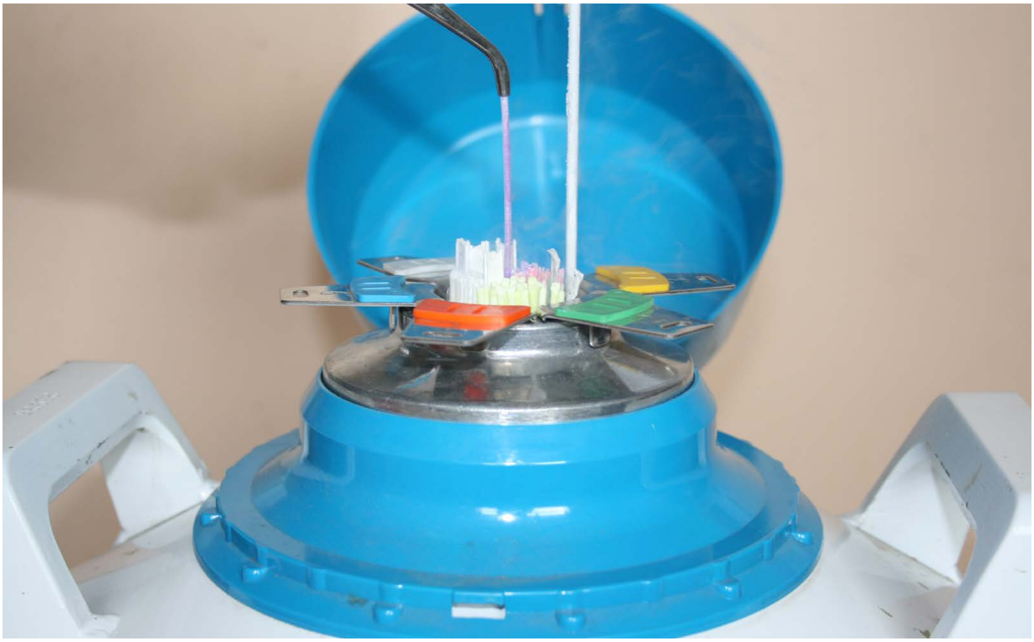

Effect of breed and animal genotype on dairy cow production efficiency based on commercial and research farm data

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Summary

- Total lactation kg of milk solids per kg bodyweight during mid-lactation (MS/BW) is a robust and accessible measurement to evaluate animal production efficiency on-farm.
- There is large variation between and within breeds for MS/BW on commercial dairy farms in Ireland.
- Farmers should routinely milk record throughout the year and weigh their herds in mid-lactation to identify the most efficient animals within their herd to increase performance and farm profitability and improve the environmental footprint for the herd in the future.

Introduction

Excellent grassland management and genetically elite animal genotypes form the basis of a successful and profitable pasture-based dairy system. Increasing the feed conversion efficiency of a herd, and therefore maximising milk output from a given amount of feed, is a key measure of both the efficiency and environmental impact on-farm. Worldwide, breeding programmes have started to include feed efficiency (FE) estimates in selection indices to accelerate improvements in productivity and sustainability. The evaluation of FE traits, however, is costly and has largely been based on individual animal intake data, mostly collected from animals in confinement systems fed Total Mixed Rations. The absence of a large database of feed intake records from individual cows within commercial grazing dairy herds is a barrier to the development of robust FE measures. Feed efficiency information is indeed valuable for both pasture-based animal breeding programs and on-farm selection intensity. Therefore, Teagasc evaluated the relationship of traditional FE measurements and a routine cost-effective production efficiency measurement using data collected from both research and commercial herds, and compared different breeds and genotypes during stages of lactation.

Commercial and research data

Individual animal intake data were collected during four years from 1,788 lactations from 407 Holstein-Friesian (HF) and Jersey × Holstein-Friesian (JFX) cows on two Teagasc research farms (Evers *et al.*, 2023). On these farms, data for total milk solids production (MS), bodyweight (BW), total dry matter intake (TDMI), TDMI per kg BW (TDMI/BW) and total kg MS per kg BW in mid-lactation (MS/BW) were available throughout the lactation. To validate the production efficiency measurement MS/BW, 27,951 records from 16,898 animals across 80 commercial dairy farms mostly located in the south of Ireland were compiled across four years (Evers *et al.*, 2021). Within each breed, cows were subsequently ranked as either top 25% (High Eff), or bottom 25% (Low Eff) for efficiency. We then identified the characteristics of the most efficient animals and compared MS/BW to other FE measurements.

Results

There was large variation in MS/BW between animals within commercial farms (0.42 to 1.47 kg MS per kg BW) and the average values between these herds (0.73 to 1.14 kg MS per kg BW). Despite considerable variation between animals within breed, JFX cows were consistently more efficient in terms of MS/BW than HF cows on both the research farms (Table 1) and commercial dairy farms. Moreover, JFX cows also reached a greater TDMI per kg BW (+0.25 kg/kg) and daily MS yield per kg TDMI (+0.005 kg/kg) compared with HF cows (3.26 kg/kg and 0.109 kg/kg, respectively). Within breed, High Eff cows (top 25%) were 20 kg lighter during mid-lactation and produced 15% more MS over the total lactation than Low Eff cows (bottom 25%). This finding was in accordance with High Eff cows having greater genetic merit (EBI) for both the Milk and Maintenance sub-indices. When comparing the High Eff and Low Eff cows, Low Eff cows exhibited a steady decline in daily milk and MS production after peaking at 2.06 kg MS in early lactation and did not have an increase in daily TDMI from early to mid-lactation (15.5 kg DM). In contrast, High Eff cows maintained high levels of milk production into mid-lactation, which was supported by an increase in TDMI (17.3 kg DM) compared with early lactation (15.7 kg DM). Indeed, High Eff cows achieved increased daily MS yield (+0.16 kg/cow) during the measurement periods. The top 25% of animals also reached a higher daily MS yield per TDMI in mid and late lactation, compared to Low Eff cows. The consistently positive correlations (0.33 and 0.52) between MS/BW and TDMI per kg BW and daily MS per TDMI, respectively, demonstrated that MS/BW is a robust measure that can be applied within commercial grazing dairy systems to increase the selection intensity for FE.

Table 1. *Production and efficiency parameters for HF and JFX animals*

	HF		JFX	
	Low Eff	High Eff	Low Eff	High Eff
MS/BW (kg/kg)	0.80	1.06	0.91	1.21
Milk SI (€)	35	54	46	70
Maintenance SI (€)	5	19	25	37
Total MS yield (kg)	460	533	473	543
BW (kg)	541	517	485	470
TDMI (kg DM)	17.1	17.5	16.6	17.2
TDMI/ BW (kg DM/100 kg)	3.18	3.40	3.43	3.66

[1]*Breed: HF = Holstein-Friesian where ≥75% of the breed proportion was Holstein-Friesian; JFX = Jersey × Holstein-Friesian crossbreds where ≥25% of the breed proportion was Jersey.*

Conclusion

The results of the present study highlight the potential to increase productive efficiency through both selecting for high genetic potential within breed and crossbreeding programs. Given the large variability in MS/BW within and between herds, this study validates the significant opportunity for farmers to increase the selection intensity within their herd. Incorporating a mid-lactation BW measurement to allow calculation of MS/BW will aid identification of the most efficient cows from which to breed replacement heifers. This robust breeding strategy will not only enhance animal productivity, but also develop a more resilient, profitable and environmentally sustainable national dairy herd for the future.

Acknowledgements

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Automated detection of oestrus

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Summary

- Automated activity monitoring systems can improve herd reproductive performance and decrease labour costs.
- Evaluating the cost-benefit of an automated activity monitoring system requires knowledge of current herd performance, technology cost and capabilities, and overall farm goals.

Introduction

In recent years, there has been an increased emphasis on maximizing the efficiency of dairy farms due to multiple challenges linked to labour constraints, market volatility, and sustainability. Therefore, developing strategies to optimise reproductive efficiency and management is critical for modern dairy farms. One potential approach is through the implementation of precision technologies on-farm. Depending on various factors such as herd size, labour cost, technology cost and accuracy, automated activity monitoring (AAM) technologies can improve the success of oestrus detection and decrease associated labour costs. The objective of this paper is to describe available data on the performance of AAM systems for oestrus detection of pasture-based dairy cows, discuss how AAM system data may be utilized on the farm to optimise reproductive performance, and summarize the key considerations to reflect on when considering investment.

Accuracy of AAM systems for oestrus detection

Oestrus detection efficiency is a key driver of submission rate, and thus critical for fertility performance and seasonal calving patterns. During oestrus, dairy cows display behaviours such as mounting and increased activity. Therefore, AAM systems are able to indirectly determine oestrus by monitoring individual cow activity and generating alerts when activity levels surpass a threshold indicative of oestrus. Automated technologies are commonly evaluated for their sensitivity (Se), Specificity (Sp), and positive predictive value (PPV). Sensitivity is proportion of the cows in oestrus correctly 'alerted' by the system, whereas Sp is the proportion of cows not in oestrus and correctly not 'alerted' by the system. Positive predictive value reflects the proportion of cows with an oestrus alert that truly are in oestrus. Based on data collected in a New Zealand pasture-based dairy system, AAM technology achieved 77%, 99%, and 82% for Se, Sp and PPV, respectively. In confinement TMR systems, AAM systems have been reported to have similar performance metrics. Overall, this is an acceptable performance given that data has shown skilled farm personnel conducting visual observations at 4-5 hour intervals fail to detect up to 10% of cows in oestrus. More research on accuracy of these technologies within a pasture-based system is necessary to gain a better understanding of the return on investment.

Utilizing AAM systems to optimize fertility

Reproductive efficiency is dependent on achieving high submission and conception rates. To achieve this, cows must resume ovarian activity, undergo normal uterine involution, and be detected in oestrus and inseminated at an optimum time. Several studies have demonstrated that oestrus expression and oestrus features are correlated with phenotypic fertility outcomes. Additionally, genetic merit for fertility traits (EBI Fertility sub-index) has been associated with many aspects of dairy cow reproductive physiology, including oestrus expression and overall reproductive performance. Cows that have a prompt resumption of oestrous cycles after calving and have multiple normal oestrous cycles before the farm mating start date have better fertility performance during the breeding season. Automatic identification of cows that have or have not cycled before the farm mating start date is valuable information that can be utilized in decision-making. For example, non-cyclic cows may benefit from hormonal synchronization to assure timely insemination. On the other hand, cows with at least one oestrus event before breeding are likely to have better fertility, and are therefore potential candidates for AI with sexed semen. Knowing the time when an oestrus alert was generated also informs decision making around timing of AI, which is also important for inseminations with sexed semen.

In 2022, the Teagasc dairy herd at Ballyhaise exclusively relied on an AAM system for detection of oestrus. The herd achieved a 21-day submission rate of 87%, a six week pregnancy rate of 72% and an empty rate of 12%. The farm also utilizes the system before mating start date to automatically identify non-cyclic cows for ultrasonography and, if required, hormonal intervention to aid cyclicity.

Considerations before investment

Investment in AAM technologies by Irish farmers has been increasing in recent years, driven by increased herd size and inadequate labour availability. The decision to invest in an AAM system is primarily influenced by the expected accuracy and reliability of the system, initial and on-going costs, and the need for new technology skills to effectively engage with the data generated. In order to determine if an AAM system is a good farm investment, careful consideration of costs and benefits is required. It is important to consider the following factors; 1) Farm financial position, 2) Farm current fertility performance and future fertility goals, 3) Labour availability, 4) Technology costs, capabilities and limitations. It is vital to know your herd's strengths, weaknesses and goals because the value of the investment is impacted by success of oestrus detection by the system relative to current management. It is also important to consider other areas of herd management that could be improved by investment. For example, many of the AAM systems also monitor rumination and eating, which can potentially improve health management through early detection of health events. Additionally, individual goals and values are important since smaller improvements in reproductive performance may be acceptable to the farmer if other benefits such as reduced labour requirements or improved work-life balance are achieved.

Conclusions

Depending on various factors such as herd size, labour cost, technology cost and capabilities, AAM systems can improve the success of oestrus detection and decrease associated labour costs. It is important, however, to consider factors such as current farm finances, herd performance, technology cost and capabilities, and overall farm goals before investment. Future studies will be aimed at evaluating the accuracy of AAM systems within an Irish pasture-based system, as well as the impact of incorporating AAM system into reproductive management on fertility and profitability.

The importance of linear type traits in Irish Holstein-Friesian cows

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Summary

- Some udder-related linear type traits are known to be associated with udder health, and will become more important determinants of survival as the Irish dairy cow population ages.
- Over the last 20 years, Holstein-Friesian cows have become shorter in stature with shallower, less angular bodies.

Introduction

Linear type traits are an assessment of an animal's physical characteristics. Linear type traits are assessed on a scale of 1-9 and can generally be categorised into three classes; 1) body size, 2) the mammary system, and 3) feet and leg conformation. One hypothesis is that cow conformation will become a more important determinant of longevity as the dairy cow population ages. Additionally, little is known about how the size and conformation of dairy cows has changed in recent decades.

Relationship between survival and linear type traits

Selecting for dairy cow longevity is challenging, as a cow's true longevity is not known until she is culled. Linear type traits are typically scored during the first lactation, and have frequently been proposed as potential early indicators of dairy cow survival. This could be particularly relevant for older cows and this is worth investigating in Ireland given the push to achieve 5.5 lactations per cow. An analysis of linear scores from 52,121 Irish dairy cows and survival data from 152,894 lactations on 52,447 dairy cows identified three linear type traits that become more important to the genetic merit of survival as cows age; these were udder depth, rear udder height, and teat length (Figure 1).

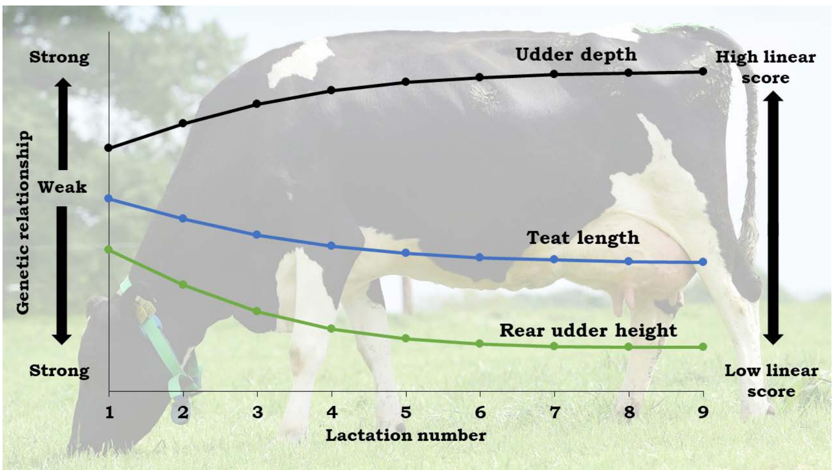

Figure 1. *The strength of the genetic relationship between survival in each lactation and rear udder height, teat length, and udder depth*

As cows get older, having shorter teats (lower teat length scores), a bigger distance between the vulva and udder (lower rear udder height scores), and a shallower udder (higher udder depth scores) become more important to survival. Each of these udder traits had previously been linked to somatic cell count and/or mastitis suggesting that traits associated with udder health become more important genetic determinants of survival as cows age.

How has the genetic merit for linear type traits changed?

Linear type traits from 246,870 Holstein-Friesian cows, born between 2000 and 2018, were used to quantify how the genetic merit for cow size and confirmation has changed in recent decades. On average, Holstein-Friesian cows are getting shorter with shallower, less angular bodies and better body condition (Figure 2).

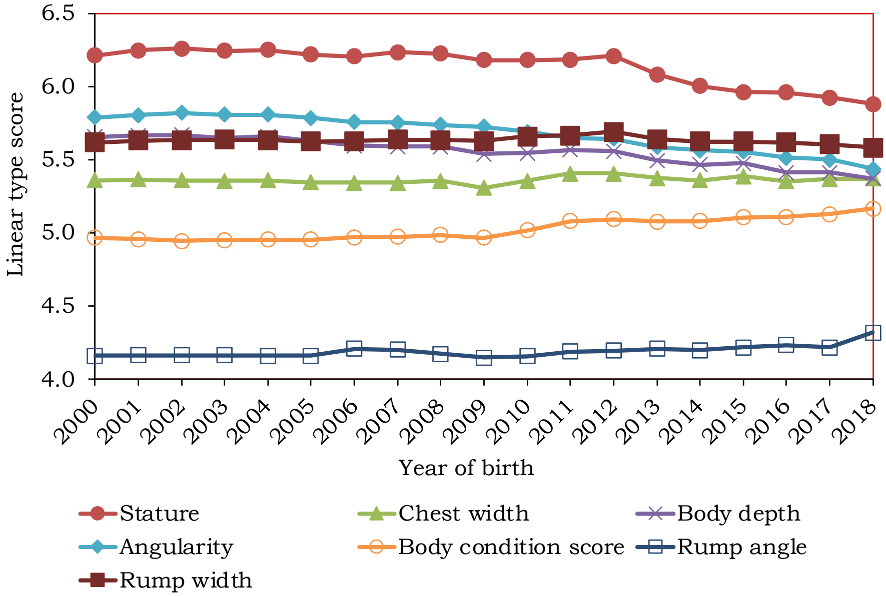

Figure 2. *Average linear score for stature, chest width, body depth, angularity, body condition score, rump angle, and rump width by year of birth for Holstein-Friesian cows born between 2000 and 2018*

The analysis also separated herdbook-registered cows from non-registered cows; the direction and speed of the trend varied between the two groups for some traits. For example, herdbook-registered cows were holding constant for height, and they were only becoming shallower and less angular at half the speed of the non-registered cows.

Conclusions

Traits associated with udder health become more important genetic determinants of survival as cows get older. Overall, Holstein-Friesian cows are getting shorter, shallower, and less angular, but herdbook-registered cows are taller, deeper, and more angular with less condition than their non-registered counterparts.


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Colostrum: A food for calves and humans

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Summary

- Consumption of high quality colostrum following birth is critical for calf health and survival.
- Colostrum management is a key factor in determining calf health and lifelong productivity.
- Excess colostrum may be utilised for nutritional purposes for the benefit of human health.

Introduction

Colostrum is the first milk produced following calving and accounts for approximately 0.5% of a cow's annual milk production. Irish dairy cows produce an average of 6.7 kg of colostrum but ranges from 0.1 – 24 kg. Cows have an epitheliochorial placenta which prevents the transfer of passive immunity to the foetus during gestation. As calves are born without an active immune system, they rely almost entirely on the absorption of immunoglobulin (antibodies) within colostrum to provide initial immunity. Therefore, it is critical that the calf receives an adequate supply of colostrum immediately after birth as the ability to absorb these antibodies decreases as the permeability of the gut diminishes rapidly over the first 24 h postpartum. Colostrum quality is determined by the concentration of IgG where high quality colostrum is defined as IgG levels of >50 g/L (>22% on Brix refractometer). Ensuring calves receive three litres of high quality colostrum within two hours of birth will encourage optimal absorption of these antibodies and therefore, provide immunity to disease over the initial days of life.

Colostrum management

Managing colostrum is the most important factor in determining calf health and survival. Failure to provide high quality colostrum, in a timely manner, to the neonate results in failure of passive transfer (FPT) of critical IgG which contributes to high pre-weaning mortality rates. Colostrum quality (IgG concentration) is the primary factor in ensuring transfer of immunity to the calf, however, a number of other factors affect colostrum quality. Colostrum must be collected as soon as possible following birth as its quality decreases as time postpartum increases (once cows are calved over nine hours, colostrum quality may be too poor to feed to calves as their first feed). If colostrum cannot be collected from the dam immediately following parturition, high quality colostrum obtained from another dam should be administered to the calf. Pooling colostrum from multiple dams has been shown to dilute the quality, with the absorption of IgG greater in calves fed single dam colostrum than pooled colostrum. Volume of colostrum is critical to ensure the calf receives an adequate feed, it is recommended that colostrum be fed at a rate of 8.5% of the birth body weight (3 L for a 35 kg calf). Highest absorption of antibodies occurs within the first two hours of birth, as the permeability of the calf gastrointestinal tract decreases following birth. Using the colostrum 1-2-3 rule (1st milking for the 1st feed, within 2 h of birth, at least 3 L of colostrum) is a simple tool for farmers to effectively provide adequate colostrum to the calf. Long term benefits have also been associated with good colostrum management, including improved average daily gain, improved feed efficiency, reduced age of first calving and improved first and second lactation performance.

Utilisation of excess colostrum for human consumption

In general, cows produce colostrum in excess of the volume required by the calf. Bovine colostrum has previously been classified as unmarketable for human consumption but with current processing technology this issue is resolved. Manufactures of functional foods and dietary supplements have recently taken a greater interest in colostrum given the array of beneficial bioactive ingredients available, as seen in Figure 1. Colostrum acts as a potential reservoir for the extraction of these valuable components, which are present at higher concentrations in colostrum compared to whole milk. Excess colostrum provides a potentially viable volume for processing on a seasonal basis within the Irish spring calving system. This market may act as a means by which farmers can add additional value to their excess colostrum in the future. In particular, the high contents of immunoglobulins and oligosaccharides could be nutritionally beneficial to infant and human nutritional formulations. Excess colostrum is used for humans in the US but not currently Irish colostrum.

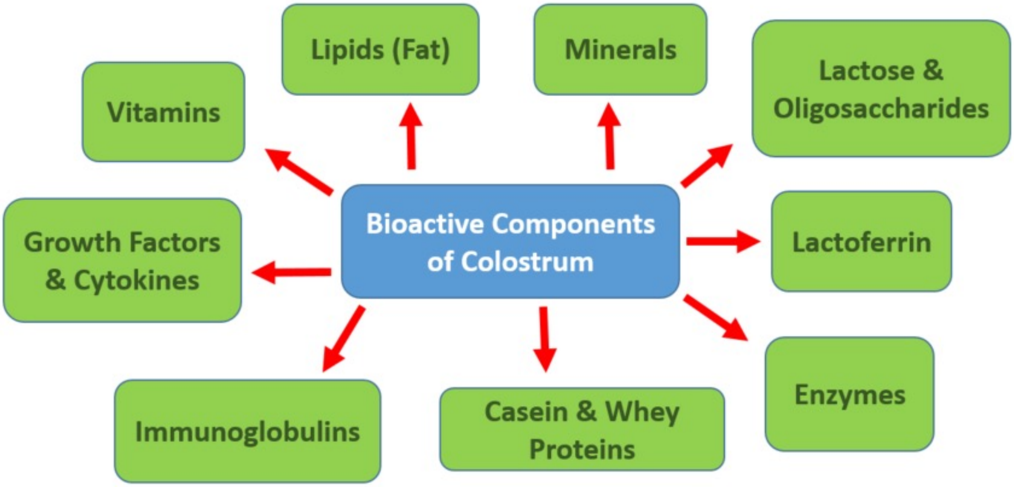

Figure 1. *The numerous bioactive ingredients available within colostrum*

Conclusions

Colostrum management is critical in determining calf health and survival. Simple steps ensuring high quality colostrum (>22% Brix) is provided within two hours of birth, at a rate of three litres/calf, will ensure that the immune system is supported over the initial days of life, a particularly vulnerable period for neonatal calves. Ensuring colostrum management is maintained to a high standard will optimise lifelong productivity within the herd. As colostrum is generally produced in excess of what is required by the calf, utilising the excess for the production of human health supplements and infant formulas may provide additional value to colostrum.

Importance of feeding high quality milk to calves

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Summary

- Waste milk is high in bacteria and can contain residues of antibiotics.
- Waste milk feeding leads to the emergence of antibiotic resistant bacteria in the calf's gastrointestinal tract, which poses a potential risk to human and animal health.
- Waste milk contributes to poorer calf health outcomes.

Introduction

Waste milk is milk from cows treated with antibiotics and those with high somatic cell counts. The practice of feeding this waste milk, containing antibiotic residues to pre-weaned calves is not recommended, as it has been associated with increased risk of diseases such as diarrhoea and leads to the emergence of antibiotic resistant bacteria. This resistance is concerning because many of the antibiotics used in animals are also required in human medicine. More worryingly, there is survey evidence showing that 50% of Irish dairy farmers still feed this non-saleable milk to their calves. Other studies have also shown that feeding milk containing low levels of antibiotics can interfere with the bacteria in the calf's gastrointestinal tract, potentially impairing the development of a healthy digestive system.

Study

In 2022, a study on 87 calves was undertaken at Teagasc Moorepark to investigate the long-term effects (from birth to 17 weeks of age) of feeding milk containing very low concentrations of antibiotics. The antibiotics included in the milk were Neomycin and Amoxicillin; the amount of antibiotics delivered was equivalent to waste milk from a cow on the second day of her withdrawal post intramammary antibiotic administration. The study was made up of three experimental treatments; calves fed milk replacer containing the antibiotics from three days of age until completion of weaning at 12 weeks of age (long-term treatment; LONG), calves fed milk replacer containing the antibiotics from 3-5 weeks of age (short-term treatment; SHORT) and calves fed milk replacer free from antibiotic residues (control group; CONT). Throughout the duration of the experiment the calves were health scored, blood sampled, and faecal samples were collected in addition to environmental swabs of the calves' pens, feeding equipment, and the gloves and boots of farm staff feeding the calves.

Results

A greater number of resistant bacteria were isolated from the faecal samples of calves from the LONG and SHORT treatments compared to the CONT (Figure 1). Calves in both the LONG and SHORT treatment groups were more likely to have higher faecal scores (a looser faecal matter consistency, and more faeces present under tail and on hocks) at 9-12 weeks of age (while weaning off milk) than they were at 13-17 weeks of age (post-weaning). In contrast no change was seen in the CONT's faecal scores between these two time periods. Additionally, the CONT's faecal scores were generally lower than both the LONG and SHORT treatments from 9-12 weeks of age. The higher faecal scores of calves in the LONG and SHORT treatments, compared to the CONT, during the weaning period from weeks 9-12 when milk volume was being reduced in the diet may be indicative of poorer digestive health in the LONG and SHORT treatments when calves were adapting from a milk based to a forage and concentrate based diet.

Further laboratory analysis of the bacterial composition of the faecal matter collected and the blood samples taken is ongoing. Once completed this data will reveal the variety of bacteria present in the digestive tracts of the calves, and the activity of the calves' immune cells during the pre-weaning period. This will allow for further insight into the calves' health status during the experiment.

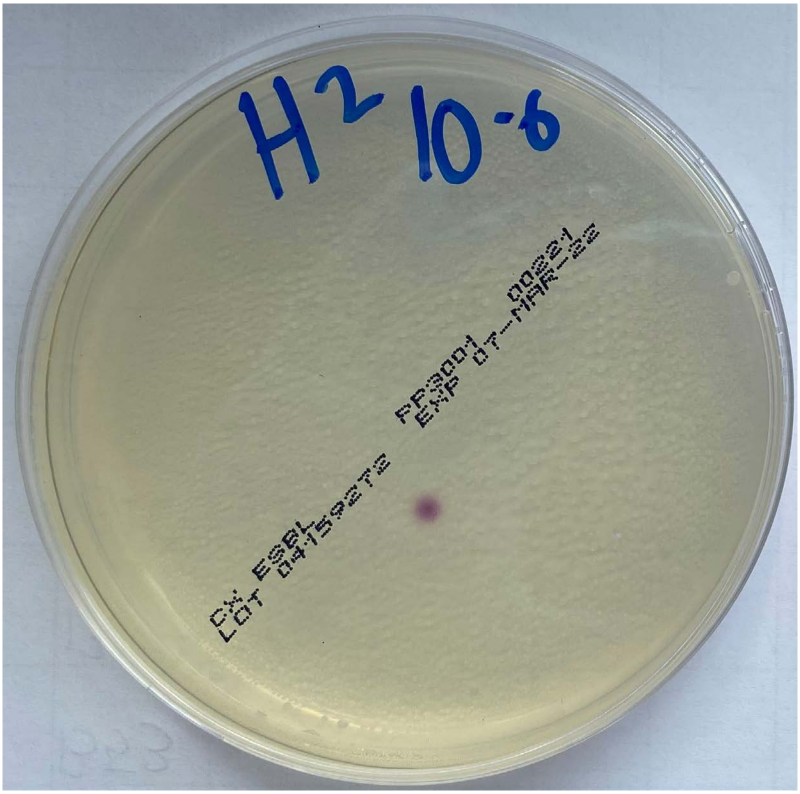

Figure 1. *Resistant isolate (seen as purple-bacterial colony on petri dish) were found in faecal samples from calves fed milk replacer containing trace amounts of Neomycin and Amoxicillin*

Conclusions

The feeding of waste milk is still common on Irish dairy farms but should be avoided as it is known to contribute to the emergence of antibiotic resistant bacteria, which poses risks to human and animal health.

Acknowledgements

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Cow-calf contact systems: an Irish perspective

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Summary

- Cow-calf contact (CCC) systems are dairy rearing systems that allow calves to have contact with either their dam or a foster cow for a prolonged period of time (>24 h) after birth.
- Calves reared in the CCC systems had increased growth pre-weaning, but were in poorer health than the control calves.
- Even though cow SCC was not affected, cow-calf contact had a negative effect on cow production over the full lactation.
- Cow-calf contact systems reduce labour around calving; however, daily labour increased thereafter.

Introduction

In current dairy calf rearing systems, cows and calves are separated soon after birth. Early separation is done so that cows can be managed with the rest of the milking herd and calves can be artificially reared by the farmer, ensuring proper colostrum intake and reduced risk of disease exposure. Historically, early separation was thought to be a more welfare-positive experience for the pair as it prevents the formation of the maternal bond between cow and calf; however, this view has come under scrutiny by researchers and consumers alike. Surveys have shown that in Ireland and around the world, consumers have become increasingly concerned about cow-calf separation at birth.

Teagasc Moorepark cow-calf contact study

A study was carried out in Teagasc, Moorepark to investigate the impact of two different CCC rearing systems compared to the conventional Irish calf rearing system on dairy cow and calf production, health, and welfare, as well as the differences in labour between the different systems. Fifty-four cow-calf pairs (18 pairs/system) were balanced across the three systems: full-time access (FT), part-time access (PT), and no access (control). The FT pairs had constant access to each other; after three days of bonding indoors cows and calves were turned out to pasture fulltime. The PT pairs had contact by night: calves were kept indoors in a straw bedded pen, their dams grazed from 8am to 3pm, cows were then housed in a cubicle area adjoining the calves, to allow calf access. The PT cows were milked once a day (OAD) in the morning (8am). The FT and control cows were milked twice a day (TAD). The control pairs were separated immediately after birth, after which the calf was artificially reared and the cow joined a conventional herd of cows at grass. All calves were weaned at eight weeks; control calves were gradually weaned by the automatic feeder, while the FT and PT calves were weaned and separated from their dams in a 7-day gradual process, where PT cows switched to TAD milking. From birth to three weeks post-weaning, calf health and labour were evaluated twice-weekly, and calf weight and behaviour were recorded weekly (behaviour: daily during weaning). Cow production (milk yield, milk solids, and somatic cell count (SCC)) was measured weekly for the duration of their lactation. Cow weight and BCS were evaluated weekly during the first 12 weeks of lactation and at week 35 (end of lactation).

Calf results: health, behaviour, growth, and labour

Four FT calves (4/18; 26%) were removed from the system due to illness. The FT and PT calves were more likely to require antibiotic treatment than the controls. Faecal and eye issues were more common in PT calves than both control and FT calves. Abnormal behaviours (e.g. cross suckling) were seen most often in the PT group, which can indicate challenged welfare. Calf growth was similar for FT and PT calves; control calves weighed less than both groups at 28 (49.0 vs 55.5 kg), 56 (69.0 vs 82.1 kg) and 77 (81.8 vs 90.8 kg) days.

Calving labour was 90% greater for the control system than the FT and PT systems. Weekly labour input was 51% greater for the FT system than control and PT systems. It should also be noted that separating cows and calves daily poses a health and safety risk to farmers. Weaning labour was negligible for control calves (due to automatic feeder), but considerably higher for both FT and PT systems (including cow-calf separation and movement). Consequently, labour was highest for the FT treatment.

Cow results: production and health

During the CCC period, the FT and PT cows had lower parlour milk yields than the controls, due to calf intake and OAD milking of the PT cows. After weaning and separation, the FT and PT cows' milk yields increased, but never reached the level of the controls (Figure 1). Cumulative 35-week milk yield for the FT and PT cows were 24 and 32%, respectively, less than the controls (5,034 kg). Cumulative milk solids yield was similarly affected; the controls (449 kg) produced the most, followed by the FT cows (332 kg) and then the PT cows (291 kg). Neither mastitis incidence nor SCC differed between systems throughout the entire 35-week lactation.

After eight weeks of lactation, the PT cows (519 kg) were heavier and in better BCS (3.16) than control and FT cows which were similar weight (481 kg) but BCS of FT was greater than the controls (3.03 and 2.94, respectively). The PT cows (535 kg) remained heavier than the FT (502 kg), but not the control cows (523 kg), at the end of the lactation, and were in better condition (3.20) to the similar control and FT cows (3.02).

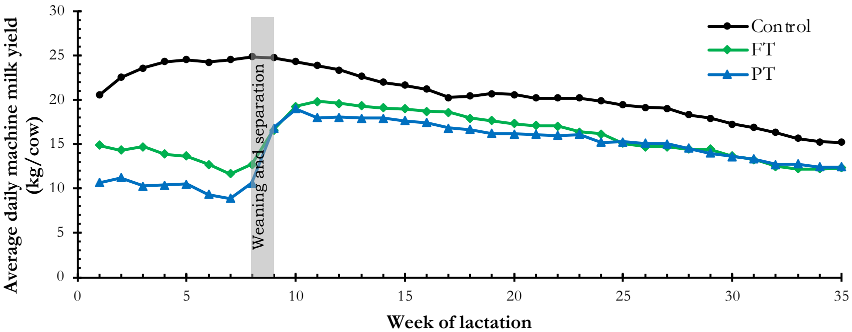

Figure 1. *Effect of cow-calf contact systems (control (C; ●); full-time access (FT; ♦), part-time access (PT; ▲)) on average daily parlour milk yield (kg/d) across the first 35-weeks of lactation*

Conclusions

Calves reared in the two CCC systems had contact with their dam, increased growth pre-weaning, and lower calving labour, but poorer health, behaviour, and post-weaning growth. Daily labour required for the two CCC systems was higher than the control system. Cows in the CCC systems had contact with their calves without an increase in SCC or mastitis incidence; however, milk yield and milk solids yield were substantially reduced for FT and PT cows during and after the CCC period, leading to lower cumulative 35-week lactation yields.

Acknowledgements

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HoloRuminant – Understanding the rumen microbial colonisation of calves and its impact on performance

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Summary

- The microbiome refers to any organisms such as viruses, bacteria and fungi that live within or on a living host. Examples of microbiome habitats include the skin, body cavities, and mucosal surfaces of respiratory, gastrointestinal, and urogenital tracts.
- Microbes within the rumen play a key role in the conversion of ingested feed into a source of energy and protein for ruminants. However, enteric methane is produced as a by-product of the microbial fermentation in the rumen.
- Understanding the temporal development and colonisation of the rumen of young calves, poses a potential avenue for the development of targeted probiotic and additive treatments aimed at increasing the productivity and sustainability of livestock production.

HoloRuminant

HoloRuminant, an EU Horizons 2020-funded project, is a consortium of 25 organisations from 17 countries. As part of the project, Teagasc is working to uncover the development of microbiomes across various body sites of dairy cattle and apply that information towards more sustainable dairy production. Research is focused on the development of the microbiomes from early life through to first lactation. This aims to highlight the complexities and factors influencing colonization and maintenance of microbiomes, with relation to animal health, welfare and performance. Thus far, a comprehensive set of samples has been collected from spring-born Holstein-Friesian (HO) and Jersey (JE) 2022 and 2023 heifer calves at the Moorepark research farm. The samples collected will be analysed by meta-Taxonomics, exploring the bacteria, protozoa, fungi, and viruses present, to identify potential variation of microbiomes. This information can then be applied to enhance animal breeding and probiotic-based strategies, aimed at supporting the development of a healthier, more effective microbiome.

Benchmark database of ruminant-associated microbes

Commensal microbes (these supply the host with essential nutrients and defend the host against opportunistic pathogens) have a positive contribution to the health and performance of cattle. In contrast, when microbial dysbiosis (disruption to the microbiome, causing an imbalance to the microbial community) occurs, pathogenic microbes can colonise the ruminant, and have adverse effects on animal health and contribute to the development of various diseases. An in-depth understanding of the temporal microbial establishment of the bovine neonatal gastro intestinal tract (GIT) is lacking. Overcoming this data void, and establishing the timing of the microbial colonisation of the calf, and sources where key microbes originate from, is crucial in the development of early life preventative measures. These measures aim to decrease the prevalence of pathogenic microbes and promote the establishment of a fully functional commensal microbiome.

Enhancing dairy calf sustainability via early life manipulation of the rumen microbiome

The digestion of plant matter consumed by ruminant livestock is facilitated by members of a microbial ecosystem residing in the rumen (forestomach). The rumen, which is a specialised fermentation chamber, contains anaerobic bacteria, fungi and ciliate protozoa, all of which contribute to the efficient conversion of lignocellulolytic plant matter, into a source of energy and protein for the host (cow), which is subsequently utilised to produce high quality sources of dairy protein for human consumption. However, an additional group of rumen microbes, known as methanogens, are solely responsible for the production of enteric methane as a by-product of microbial fermentation. Indeed, enteric methane, which is recognised by the UN's International Panel on Climate Change (IPCC) as being 28-times more damaging to the environment than carbon dioxide, is responsible for 63.1% of Irish agricultural GHG emissions (EPA report, 2023). Due to its environmental potency, reducing the volume of methane produced by ruminant livestock is key to achieving a 25% reduction in agricultural GHG emissions, by 2030, in line with the national Climate Action Plan 2030.

Ruminal methanogenesis (methane producing process) is primarily influenced by host genetics and the diet, with previous work by Teagasc having identified the key rumen microbes associated with a high and low methane emissions phenotype. As part of previous work conducted by the EU funded projects Rumen-Predict and MASTER, low methane-emitting beef cattle were shown to have an increased abundance of bacteria associated with the production of lactic acid, and its subsequent conversion into the volatile fatty acid, propionate. More recently, early life manipulation of the rumen microbiome has been promoted as a promising strategy to reduce the abundance of microbes associated with a high methane emissions output. Further work conducted by researchers at Teagasc has identified that ruminant bacterial and archaeal communities stabilise by the third week of life. This research suggests this period is a good time to intervene and manipulate the microbiome. HoloRuminant aims to identify the sources where microbes originate from. This will allow for the identification of methods that could alter farm practices to reduce the prevalence and sources of pathogenic microbes, as well as those associated methane production and reduced animal productivity, on the farm and in the environment. This will allow for a preventative course of action, such as the administration of additives/probiotics to young calves, to be adopted in farm management to reduce potential disease incidence and promote more sustainable ruminant production.

Conclusion

HoloRuminant aims to identify measures that could be applied to farm management practices in order to reduce the prevalence of pathogenic microbes on the farm. Through the administration of probiotics at identified time points a preventative approach could be adopted in order to reduce disease incidence and methanogenesis.

Acknowledgements

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Calf diarrhoea – prevention and the role of microbes

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Summary

- Diarrhoea or scour is the most common disease in calves under one month of age.
- Calf diarrhoea has many causes and it may be non-infectious (mainly due to nutrition) or infectious.
- Optimal colostrum management is essential for the development of the calf's immune system and supports calf gut health.
- A microbiome is a community of microorganisms in a particular environment.
- The "Holoruminant" EU-funded project is investigating the role of microbiomes in developing solutions to reduce early-life diseases including calf diarrhoea.

Introduction

The microbiome refers to the collection or community of microorganisms in a particular environment. Ruminants, have a complex microbiome consisting of bacteria, archaea, protozoa, fungi and viruses. The microorganisms that are present, for example bacteria, can either work with one another or compete with each other for a particular function. Diarrhoea is the most common cause of death in pre-ruminant calves (one month of age and younger). On-farm research by Teagasc Grange has shown an incident rate for diarrhoea of 8.7% in suckler calves and 25.5% in dairy calves. Non-infectious factors such as inadequate colostrum management, poor feeding environments and weaning stress can increase the risk of diarrhoea. *Cryptosporidium parvum*, rotavirus and coccidia are usually seen as the most common infectious causes of calf diarrhoea (Table 1). There is limited information on the contribution of the hindgut bacterial microbiota (community of microbes) to the incidence of diarrhoea in dairy calves. Therefore, the structure and functional roles of the microbiota in diarrheic calves requires further study.

Table 1. *Infectious causes of calf diarrhoea*

Type	Agent/disease	Calf age	Occurrence
Bacteria	*E. Coli* (ETEC)	1-5 days	Rare
	Salmonella spp.	4-28 days	Less common
Viruses	Rotavirus	5-14 days	Extremely common
	Coronavirus	5-30 days	Less common
Parasites (protozoa)	Cryptosporidiosis (*Cryptosporidium parvum*)	5-30 days	Extremely common
	Coccidiosis (*Eimeria* spp.)	Over 3 weeks	Common

Development of the lower gastrointestinal (GIT) microbiome and calf diarrhoea

During the neonatal period, calves are particularly susceptible to enteric disease due to immature immune function and naïve microbial communities that are not yet established. In turn, opportunistic pathogens can establish themselves and proliferate resulting in diarrhoea. Research conducted as part of the EU funded HoloRuminant project, found that during the first week of life, when microbial colonisation of the lower GIT is underway, pathogenic microbes, such as Escherichia-Shigella, are more prevalent. The abundance of Escherichia-Shigella was reduced by the 2^{nd} week of life with the overall microbiome of the young calf stabilising (i.e. all of the main microbes being present) within 3 weeks of life.

A recent study evaluated effect of colostrum source (CS) and calf breed (CB) on diarrhoea incidents in 51 spring born Holstein (HO; n=29, birth weight (BW) 34.7 kg) and Jersey (JE; n=22, BW 25.9 kg) heifer calves from birth (day (d) 0) to weaning (d83). Calves were fed 8.5% BW in colostrum, from either, the calf's dam (n=28) or a pooled source of colostrum (n=23) within 2 hours of birth. A modified Wisconsin-Madison calf health scoring system was used and rectal temperature (RT) measured for clinical assessment at d0, d7, d21, and day-of-diarrhoea incident, and day-of-weaning. Live weights were recorded at d0, d21, and weaning. Diarrhoea incident was assessed using faecal scores (0=normal, 1=semi-formed, 2=moderate, 3=severe diarrhoea), and health status was defined as calves having diarrhoea (n=27), or healthy (n=24). The mean day post-birth for diarrhoea was d23 and d22 for HO and JE calves, respectively; 53% of calves had a diarrhoea incident. On the day of diarrhoea detection, faecal scores were greater for diarrhoeic calves (median score 3) than healthy calves (0) while RT of diarrhoeic calves was elevated (+0.37°C). Health status had no effect on average daily gain from birth to weaning. Phases with high incidence of diarrhoea from birth to weaning, and the faecal microbiotas between healthy and diarrheic calves (pre-diarrhoea, diarrhoea and post-diarrhoea) were examined. Using next generation sequencing analysis, a significantly different bacterial community between healthy and diarrhoeic calves was detected. The results suggest that the dynamic changes of the calf gut microbiota and the interactions among some bacteria could influence diarrhoea onset and outcome.

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Coccidiosis – What's happening on Irish dairy farms?

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Summary

- Coccidiosis is a parasitic disease that causes scour and deaths in calves.
- A new research project is looking at farmers' current knowledge of the disease and trying to differentiate pathogenic from non-pathogenic cocci strains.
- The survey showed that the majority of farmers self-diagnose coccidiosis (63%) and believe that birds are the primary source of infection at grass (60%).
- For the first time in Ireland, PCR testing identified pathogenic coccidia.

Introduction

Coccidiosis is a disease caused by harmful strains of a parasite (coccidia) that damages the intestine lining (Figure 1), resulting in clinical signs of diarrhoea, that is frequently bloody. Currently, we have no data on how dairy farmers diagnose, prevent or treat coccidiosis in Ireland. In addition, little is known about what species of cocci occur in Ireland. Current routine lab techniques cannot differentiate between the disease causing and harmless strains of coccidia. Molecular techniques (Polymerase chain reaction, PCR) may be able to detect pathogenic strains and so improve routine diagnostics.

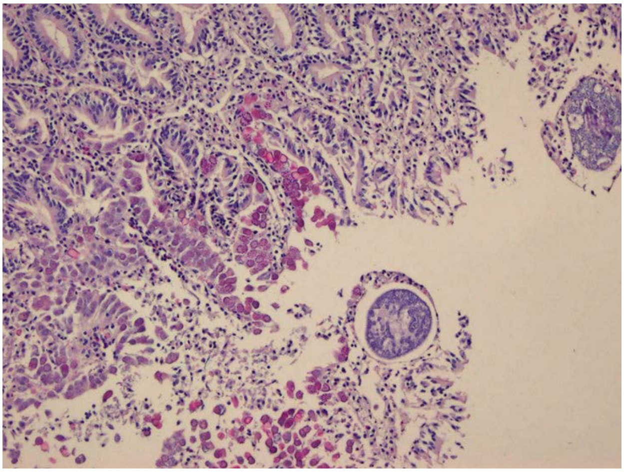

Figure 1. *Numerous coccidia invading and damaging the lining of the intestine*

Hence, the aims of this new research project were 1) survey farmers to ascertain their knowledge of cocci and their treatment, prevention and control practices and 2) develop a PCR method to identify pathogenic strains of coccidia.

Results

Farmer survey

Farmers were surveyed on SurveyMonkey using multiple sources: Teagasc advisory clients, social media (Agri-Land) and the agri-media (*Todays Farm, Irish Farmers Journal, Farming Independent*).

Preliminary results from 299 farmers are reported here. The majority (63%) of farmers diagnosed cocci in their calves themselves, not through vet diagnosis or lab testing. The majority of farmers reported having cocci in their calves either within the last year (42% of farmers) or within the previous three years (31%). The most common age groups calves were affected with cocci were at 3-5 weeks old (30% of farmers) and 3-5 months old (29%). Farmers believed that when calves are indoors the most common sources of cocci are birds (46% of farmers), the calf environment (44%) and feed or water troughs (35%). When calves are at grass, farmers believed that the most common sources of cocci are birds (60% of farmers), feed or water troughs (49%) and other calves in the group (19%). Of farmers who used *preventive* medication for cocci, the majority administered the products when calves were 3-5 weeks old (45% of farmers) or at turnout to pasture (26%). For farmers who *treated* calves for cocci, the majority did so when calves were 3-5 months old (30% of farmers) or 3-5 weeks of age (25%). The most commonly used cocci medications were Vecoxan (33% of farmers), Bovicox (28%) and Sulpha No. 2 powders (20%).

Pathogenic cocci strains

Calf faecal samples submitted to DAFM Regional Veterinary Laboratories, which had coccidia detected via the McMaster technique, underwent molecular analyses. Coccidia-specific primers were developed and tested on these samples. Pathogenic strains of coccidia (*Eimeria bovis, E. zuernii* and *E. alabamensis*) were identified by PCR in the calf faecal samples.

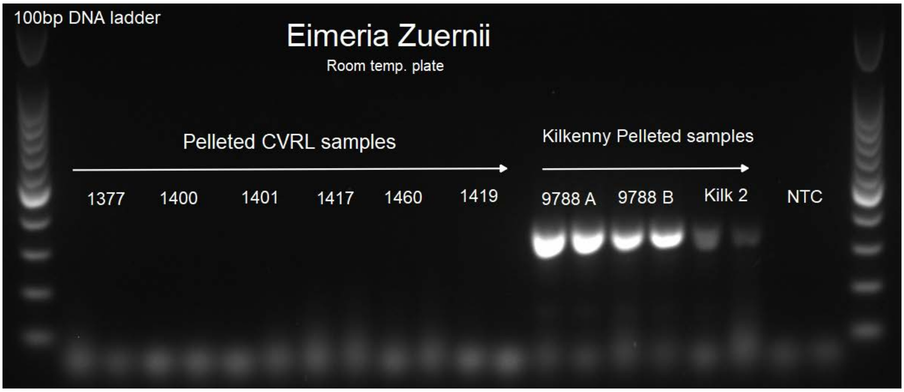

Figure 2. *Detection of harmful coccidia by PCR in calf faecal samples*

Conclusions

Results of the survey show that farmers have a good awareness and knowledge of cocci management and medication and may benefit from further education on coccidia transmission. PCR testing can successfully be used to identify pathogenic coccidia in a research study; the challenge will be to do so in a routine lab diagnostic environment.

Acknowledgements

The project team thank the farmers for responding to the survey and the many colleagues within Teagasc KT for facilitating the survey distribution.

Intranasal vaccination for pneumonia viruses in calves

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Summary

- Pneumonia is one of the main causes of death in young calves.
- Bovilis IBR Marker Live®, and Bovilis Intranasal RSP Live® vaccines can be safely administered together intranasally at three weeks of age.
- Calves vaccinated intranasally for RSV and PI3 showed an improved response to a booster vaccination at 15 weeks of age when compared to calves vaccinated later with parenteral injections for RSV and PI3.

Introduction

According to data from Regional Veterinary Laboratories, pneumonia is the single largest cause of death in cattle aged from 1-12 months in Ireland. Rather than treating already sick calves for pneumonia and contributing to antimicrobial resistance, farmers and vets are now focussing on disease prevention and the role vaccination can play. Intranasal vaccines contain live attenuated viruses to allow for localised immunity to develop in the calf's airways. The aim of this study was to investigate the safety of administering multiple vaccines for RSV, PI3 and IBR at the same time, in addition to measuring the antibody response the vaccines would elicit.

Study

In spring 2021, 40 calves from the Teagasc Dairygold farm, were assigned to a trial which aimed to investigate the effects of simultaneous administration of intranasal vaccines for the viruses most commonly associated with pneumonia; IBR, BRSV, and PI3. The calves (both dairy and dairy-beef breeds) were vaccinated at three weeks of age. The four experimental treatments were; Bovilis IBR Marker Live® only (IO), Bovilis INtranasal RSP Live® only (RSV and PI3)(RPO), vaccinated concurrently with both Bovilis INtranasal RSP Live® and Bovilis IBR Marker Live® (CV), and the controls (CONT) that were not vaccinated at three weeks old. Calves were penned separately in groups of 10 according to their treatment.

The calves were blood sampled before vaccination to detect their immune status for these diseases and then again after vaccination to detect changes in antibody levels. In addition to this, health scores, temperature checks, and weight was measured throughout the study. Eighty days after the initial (IN) vaccination all calves enrolled in the study received parenteral vaccinations for all three viruses. This consisted of an intramuscular dose of Bovilis IBR Marker Live® and additionally a subcutaneous dose of Bovilis Bovipast RSP®.

Results

Vaccination with these live virus vaccines did not affect weight gain, or lead to an increased rectal temperature post vaccination, it also did not induce any virus like symptoms. Intranasal vaccination for RSV and PI3 with Bovilis INtranasal RSP Live® at three weeks of age, whether on its own or with Bovilis IBR Marker Live®, resulted in a better antibody response to the booster vaccine injections (Figure 1).

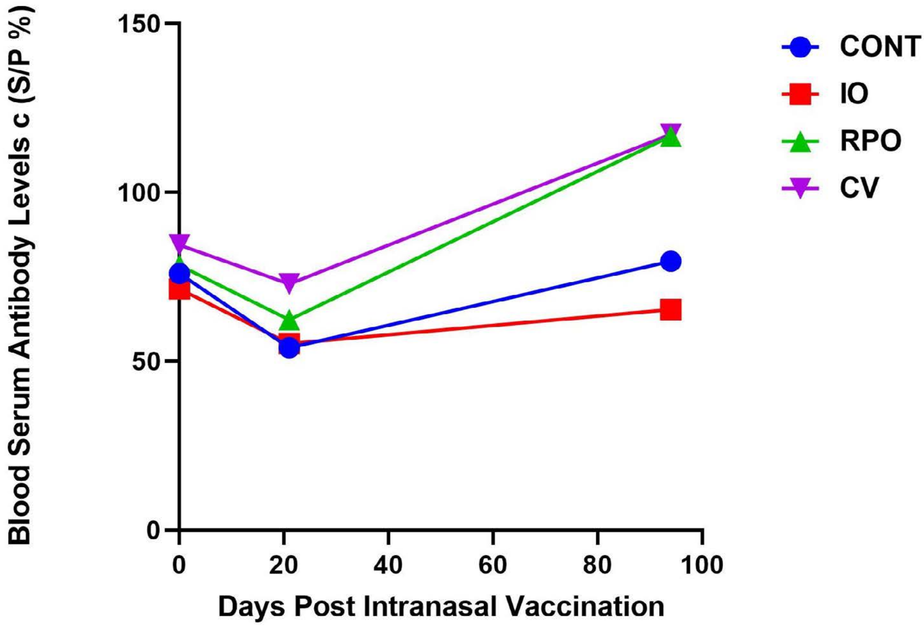

Figure 1. *PI3 antibody levels measured as OD c(S/P %) units at day 0, 21 and 94 days post vaccination at three weeks of age*

Conclusion

Risk of pneumonia can be mitigated through optimal colostrum management, good nutrition, proper hygiene, and appropriate housing. Vaccination is an additional factor in ensuring a calf's immune system is fit to tackle disease, and should be a key consideration of farmers going forward and a topic for discussion with their vet. In herds at risk from RSV and PI3, intranasal vaccination followed by an additional booster vaccine post-weaning may provide enhanced protection against these viruses in calves.

Acknowledgements

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Prevalence of calf respiratory disease on Irish dairy farms using two diagnostic techniques

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Summary

- Bovine respiratory disease (BRD) is one of the biggest health challenges during the preweaning period but its prevalence at calf-level in Ireland has not been established.
- This new national study indicates that approximately 4% of young calves on Irish dairy farms have BRD.
- This is lower than estimates in many other countries.
- A proportion of calves may have subclinical pneumonia only detectable by lung ultrasound, these calves may have reduced performance.

Introduction

Bovine respiratory disease (BRD) is one of the main health problems faced by preweaning dairy calves. It is the most commonly diagnosed condition on post mortems of calves between one and five months of age. There is limited data on the prevalence of BRD in calves in Ireland.

BRD is most commonly diagnosed using a combination of listening for changes in lung sounds with a stethoscope and observation of clinical signs. In recent years, a new technique, which uses ultrasound scanning to identify diseased lungs, has gained popularity in BRD research. There is no method of BRD diagnosis in live calves that is 100% accurate.

Some calves may have subclinical pneumonia where they have lung lesions that can be seen on ultrasound but do not show clinical signs. On the contrary, other calves may have clinical signs of BRD but have not yet developed a lung lesion that can be seen with ultrasound.

In this work, Teagasc and UCD collaborated using new techniques to produce an accurate estimate of BRD prevalence in Irish dairy calves.

BRD survey

Forty randomly recruited dairy farms across Ireland were visited during spring 2020 and spring 2021. At these visits, 20 calves aged between four and six weeks were examined on each farm. This examination involved two parts; the first part being a lung ultrasound (LUS), where the calves' lungs were categorised as either healthy or consolidated.

The calves were also examined for any clinical signs of BRD: nasal discharge, ocular discharge, drooping ears, coughing or a high rectal temperature. The Wisconsin clinical scoring system (WS) was used to categorise those clinical signs.

A statistical model was then constructed using the collected data (using both LUS and WS data) to determine the true calf level prevalence of BRD on Irish dairy farms. This model accounted for the fact that neither test used in the calf examination can correctly categorise 100% of calves.

Results

In total 787 calves were examined on 40 farms. Some farms had no BRD present at the time of visit while other farms had as much as 20% of calves showing signs of BRD on LUS or WS. In Table 1, we can see a summary of the results of both tests in the population and how they relate to each other.

Table 1. *Prevalence of respiratory disease in calves by two diagnostic methods (WS: Wisconsin clinical score, LUS: Lung ultrasound)*

Test result	No. calves	%
WS-, LUS-	678	86.2
WS +, LUS-	58	7.4
WS-, LUS+	37	4.7
WS+, LUS+	14	1.8

From Table 1 we can see that there is a proportion of calves (4.7%) that have subclinical pneumonia (WS-, LUS+), these are calves that were not showing clinical signs at the time of examination but had lung lesions that were likely to reduce performance.

A proportion of calves (7.4%) had clinical signs without lung lesions (WS+, LUS-). As the LUS was only conducted once it is impossible to know what proportion of calves went on to develop lung lesions and what would be an appropriate treatment strategy for them.

When these data were modelled to account for less than 100% accuracy of both tests, an overall estimate of four per cent prevalence of BRD at calf level was found. This estimate is lower than the prevalence seen in many other countries around the world.

Conclusions

The prevalence of BRD in Irish dairy herds appears to be low by international standards but there is a group of farms with a high prevalence of BRD. Further research is needed to address these farms and also to address management strategies to reduce levels of subclinical pneumonia.

Acknowledgements

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Impact of housing environment on calf respiratory disease

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Summary

- Bovine respiratory disease is often linked to the air quality and environment in calf housing but there is limited evidence for these links.
- A detailed search of the scientific literature identified several important parameters.
- Dust, ammonia, draughts and poor bedding management were identified as some of the factors with the strongest evidence for increasing the risk of bovine respiratory disease in calf housing.

Introduction

Bovine respiratory disease (BRD) in preweaning dairy calves presents a challenge to many dairy farmers in Ireland. Although calf housing environment is often cited as a major influence on the level of BRD on a given farm, the research in this area has not been drawn together to give a broader picture. For this reason, Teagasc and UCD undertook a detailed review of the scientific literature to identify which housing environmental factors had the strongest link to BRD.

Parameters

As part of the review eight key parameters were identified that have been measured in previous work and related to the risk of BRD in calves:

- Air ammonia
- Dust
- Microbial air contamination
- Draught
- Temperature
- Relative humidity
- Ventilation
- Bedding

Ammonia

Ammonia is a noxious gas that is produced when urine is broken down by bacteria in soiled bedding. Recent work showed that prolonged exposure to high concentrations of ammonia was associated with higher risk of lung lesions in calves. Ammonia build up can be avoided by good drainage and regular removal of soiled bedding.

Dust

Dust build up in the air of a calf house can be a result of poor ventilation or due to use of a straw blower or dusty feeds. Airborne dust can be inhaled by calves and result in irritation of the respiratory tract. High levels of dust was found to be associated with lung lesions. Dust producing practices should be avoided in calf housing.

Microbial air contamination

Microbial air contamination can occur through numerous routes, primarily it is thought that calves and bedding contribute most to the air contamination. The evidence for its relationship with BRD risk is not as strong as other environmental parameters. It is considered a proxy for risk of transmission of airborne BRD pathogens. Good ventilation is the best way to reduce microbial air contamination.

Draughts

Draughts are defined as air speed greater than 0.5 - 0.8 m/s at calf level; there is strong evidence to suggest that exposure to draughts increases the risk of BRD. Draughts are more likely to be found in calf housing that is overly open or particularly exposed.

Temperature

The relationship between ambient temperature and BRD risk is complex and appears to be modified by other factors such as bedding, nutrition and relative humidity. Both high and low temperature in a calf house may increase the risk of BRD but a range in which calves are at reduced risk could not be identified.

Relative humidity

High relative humidity is often considered a risk for BRD as it may facilitate longer survival of pathogens in air and suggests a damp environment that might increase thermal strain on calves. The evidence to support this relationship was found to be weak, but like temperature, it is likely that the relationship between relative humidity and BRD is complex and requires more investigation.

Ventilation

Ventilation rates were only measured in one study in this review, which did not find a relationship to BRD risk. However, ventilation is still likely to be very important, as it will reduce the build-up of pollutants such as ammonia, dust and microbial contamination.

Bedding

Deep wet pack bedding under calves was associated with increased risk of BRD, most likely due to increased production of ammonia and possibly increased microbial air contamination. It was found that when calves were generously bedded (legs not visible when lying down) this was protective against BRD, most likely because it acts as insulation against lower ambient temperature.

Conclusions

High levels of air pollutants such as dust and ammonia should be avoided. Calves require protection from draughts and generous amounts of dry bedding. More research is required in this area to better understand the relationship between temperature, humidity and BRD.

Acknowledgements

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New research on atresia ('waterbelly') in calves reveals a genetic link

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Summary

- Blockage of the bowel (often called 'waterbelly' due to the build-up of fluid in the guts) in newborn calves is a fatal, but under-diagnosed, congenital defect.
- A post-mortem survey of 40 dairy herds over eight years found that 0.35% of calves were affected; clusters occurred in some herds.
- The defect was twice as common in male as in female calves and was more common in progeny of older cows than in progeny of first or second lactation cows and higher on certain farms than others.
- The incidence was highest among the progeny of three related Jersey sires, suggesting a gene for intestinal atresia was segregating within this family.
- There was no evidence of a sire-effect among the progeny of Holstein-Friesian sires.

Introduction

Intestinal atresia is a congenital defect that results in complete blockage of the bowel during the early stage of pregnancy. It is sometimes called 'waterbelly' as the blockage causes intestinal fluid to build up during pregnancy so the calf may be born with a swollen stomach full of fluid. The occlusion can occur in different parts of the bowel or, less commonly, the anus. While affected calves may appear normal or swollen at birth, it may take a few days for the farmer to notice that they are not passing dung. Initially the calf may drink normally then stops sucking, lies down a lot, gets more swollen and without surgery usually dies within seven days of birth or is euthanized.

Suggested causes of the condition include early (<42 days post-insemination) pregnancy diagnosis by amniotic sac palpation, in utero foetal vascular disruptions and genetic predisposition (inherited or non-inherited).

Genetic causes

Atresia has been shown to be inherited as an autosomal recessive defect in Holstein-Friesian, Jersey and Swedish Highland calves. However, inconsistent with this genetic theory is a report of identical twin calves, resulting from transfer of a single embryo, where only one twin exhibited atresia coli. Incomplete penetrance is one possible explanation for such cases.

Research study

In order to determine what role genetics may play in the atresia seen in Irish dairy herds, a large-scale study was conducted in 40 herds involving 56,454 calves across eight years. In total, 197 cases of intestinal atresia were examined at the post-mortem laboratory in Moorepark where samples were collected for genetic analysis and associated risk factor information was collected both from the herds of origin and the affected calves. In addition, a case-control genome wide association study (GWAS) was undertaken to detect genomic variants associated with intestinal atresia.

Results

The overall incidence of intestinal atresia was 0.35%, varying by farm between 0 and 1.34%. The majority of calves were affected in the small intestine (83%) and the remainder in the large intestine (14%) and anus (3%). In addition to the blockage of the bowel, fifty of the atretic calves had other congenital defects.

Risk factors

Calves born to dams of higher parity (≥3) were at increased risk of intestinal atresia compared to calves born to dams of first or second parity. Calf sex was also a risk factor for intestinal atresia with the condition twice as common in male calves compared with female calves. Farm of birth was a risk factor for the development of intestinal atresia with some farms significantly more affected than others. Year of birth was also significantly associated with intestinal atresia with the incidence declining over time.

Genetics

Regarding breed, percentage contribution of Aberdeen Angus, Holstein-Friesian and Jersey to ancestry was significantly associated with occurrence of atresia. The incidence was 0.09%, 0.07% and 1.02%, respectively. Regarding sires, the three Jersey sires with the highest incidence of atresia among their progeny (2.5, 2.7 and 4.1%) were paternal half-sibs while one shared a grandsire. This indicated the potential presence of a gene or genes for atresia within this family. Among the Holstein-Friesian sires, the maximum number of affected progeny per sire was four with the majority of sires (78%) having only a single case among their progeny; no sire effect was detected. A number of genomic regions were associated with intestinal atresia in Holstein-Friesians using GWAS but no obvious candidate genes were found. Thus, the genetic causation of intestinal atresia is likely to be complex and may vary between families and populations, with a simple autosomal recessive mode of inheritance unlikely to explain all cases. It is possible that sporadic cases arise due to development anomalies or de novo mutations.

Conclusions

Blockage of the intestines was more common in male calves and the progeny of older cows and on certain farms. Jersey sires with high offspring incidence were inter-related.

Acknowledgements

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A new App to record congenital defects in dairy and beef calves

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Summary

- A mobile phone app. was developed for veterinary practitioners to collect data and images of 90 deformed calves in dairy and suckler herds.
- The three most common individual defects recorded were intestinal atresia / hydrops (blockage of the bowel), schistosomus reflexus, (calf turned inside-out) and palatoschisis (cleft/split in the hard palate of the mouth).
- The most common reasons for farmers to call the vet to attend these cases were to assist at a difficult calving (hydrops and schistosomus), to euthanise a calf (atresia) or to address a calf health problem (cleft palate).
- Use of a veterinary practitioner mobile app ensured more accurate recording of the types of congenital defects occurring in dairy and suckler herds.

Introduction

It is probable that the nature and extent of congenital defects (deformed calves) seen by veterinary practitioners on farms in the spring differs from that seen in the vet labs. This is because only a very small proportion of affected calves are brought to the vet labs and these are probably a biased sample of affected calves. Thus, the official presentation of such defects may not accurately reflect what is happening on farms. This has implications for the prioritisation of control of congenital defects. In order to determine whether this recording bias exists, a nation-wide study was set up with the largest corporate veterinary practice in Ireland. The objective of the project was to field-test a mobile phone app designed for use by veterinary practitioners to collect clinical case data on routine farm visits. Bovine congenital defects were used as an exemplar topic; others will follow. Ultimately, the aim was to assess the potential for practitioner-gathered clinical information, allied with analytics, to generate a repository consisting of an image gallery and associated clinical notes.

Research study

In total, 35 vets in 21 veterinary practices distributed nationally across 15 counties participated in the project. Information and images were collected during routine farm visits (mainly calvings) onto a mobile phone using Typeform. The questionnaire consisted of 15 questions; three photos could be collected/case. The results from the pilot study are reported here.

Description of the animals

Congenital defects were recorded in 90 dairy and beef calves; 59 in dairy (n=57 Holstein/ Friesian) and 28 in beef cows' (10 Limousin, 8 Charolais) calves. The dairy cows were most commonly bred by Holstein/Friesian (19) or Aberdeen Angus (16) sires and the beef cows by Charolais (9) or Limousin (8) sires. Both the dairy (17) and the beef (8) dams were most commonly bred by stock bulls, though breeding method was poorly recorded (53 missing). The majority of both dairy (46) and beef cows (18) were multiparous. The majority of calves were singletons (83), born at fullterm (86) mainly at assisted calvings (48).

Most common defects

The three most common body systems affected by the defects were the musculoskeletal (45), digestive (30) and multiple systems (5). The three most common individual defects recorded were intestinal atresia (17)/hydrops (10, blockage of the bowel), schistosomus reflexus (19, calf turned inside-out) and palatoschisis (7, cleft/split in the hard palate of the mouth). The most common reasons why the farmer called the vet to attend these cases were, in descending order, to assist at a difficult calving (hydrops and schistosomus), to euthanise a calf (atresia) or to address a calf health problem (cleft palate). On the majority of farms, no (49 farms) or only one case (10) of the recorded deformity had been seen previously.

The preponderance of externally-visible body system defects is not surprising given that necropsy examinations were not conducted. This mirrors farmer-recorded defect recording but diverges from necropsy-confirmed defects. Of the common individual defects recorded, the study confirmed the often under-diagnosed prevalence of intestinal atresia in Irish cattle herds. In contrast, the high relative incidence of schistosoma reflexus and palatoschisis differs greatly from both vet lab submissions and research study data.

Potential role for veterinary apps

By using farmer-, veterinary practitioner- and veterinary laboratory/researcher-recorded data a more accurate picture of the actual occurrence of congenital defects on cattle farms will emerge. To date the veterinary practitioner component of this conceptual model has been overlooked; this proof-of-concept study attempts to correct this deficit. The project also highlights the potential and capability of veterinary-practitioner apps to pick up changing trends in endemic, or the emergence of novel, congenital conditions. The Schmallenberg virus outbreak emphasised the importance of this veterinary practitioner and vet lab role. The repository generated here can be a valuable peer-to-peer awareness-raising, educational, investigative and surveillance, mobile phone-accessible, resource. This veterinary-practitioner-led data-recording model is also latent with possibilities for similar uses across other clinically relevant conditions for farmers.

Project upgrade

Following completion of this pilot project, a re-evaluation of the questionnaire has highlighted potential improvements to reduce missing data (no by-pass answer edict) and improve data (more precise question wording) and photo quality (specific image collection protocol).

Conclusions

This project highlighted a new picture of deformed calves occurring on dairy and suckler farms. The key value points arising from this pilot project were 1) app convenience of use by busy practitioners, 2) generation of a unique photo-archive and 3) ease of model upgrade based on practitioner feedback.

Acknowledgements

The authors thank the participating veterinary practitioners and their clients for collecting these data and images.

Measuring dairy calf welfare during long-distance road/ferry transportation

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Summary

- Large numbers of unweaned Irish dairy calves are exported annually to continental Europe for veal and beef production.
- Long-distance transport presents challenges to young animals and public concern for the welfare of these calves has been growing.
- Scientific research is required to establish the true welfare status of these calves.
- Access to calves while in transit is limited, novel sensor technology such as activity sensors and glucose monitors have not been used in transported calves previously, but may play an important role in supplementing traditional methods of measuring calf health and welfare during transport.

Introduction

The annual intra-community trade (I-CT) of more than 120,000 Irish born unweaned dairy calves contributes significantly to the Irish live export trade. Unweaned dairy calves, typically male and between two and six weeks of age, are transported overseas via road/ferry for veal and beef production, most often to The Netherlands, Spain, Italy, or France. Transport of calves from Ireland to The Netherlands was the main focus of this project. The total journey spans approximately three days. Calves are transported from the dairy farm of birth, sometimes via a livestock mart, to an assembly centre where they are prepared for export. Calves are loaded onto a livestock lorry and travel by road to Dublin or Rosslare port where they board a ferry to Cherbourg, France. From here, calves are transported by road for a short distance to a control post where they are offloaded, fed and rested for 13 hours. Subsequently, calves are transported by road to a veal farm in The Netherlands. Extended feed intervals and mixing of calves from different farms and the associated exposure to pathogens challenges the health and welfare of these animals.

Assessment of health and welfare

In spring 2022, the health and welfare of 66 calves transported from Ireland to The Netherlands was monitored from source (dairy farm or livestock mart) to destination over two separate commercial transports. Health and physiological data were collected at source farms, livestock marts and the assembly centre in Ireland, the control post in France, on arrival at the veal farm in The Netherlands, and continually for three weeks post arrival at the veal farm. Measurements included blood samples, detailed clinical health checks and weights to assess health and welfare, as well as novel methods using thoracic ultrasound, activity sensors and continuous glucose monitors.

Clinical health scoring was used to identify signs of respiratory disease (eye discharge, nose discharge and/or coughing), diarrhoea (faecal consistency and/or high rectal temperature), and other general signs of ill health (navel inflammation and/or slow to respond). Blood samples were taken to assess energy balance (glucose, non-esterified fatty acids and beta-hydroxy butyrate), as calves experience extended feeding intervals during transport, as well as to assess hydration, stress, immunity, and inflammation parameters. Body weight and body weight loss were measured to provide an indication of the health status of calves, and may be linked to dehydration during transport.

An ultrasound machine was used to take a thoracic ultrasound scan of each calf on five different occasions; at the source dairy farm or livestock mart, one day post arrival on the veal farm, and at approximately one, two and three weeks post arrival on the veal farm. For the thoracic ultrasound, an ultrasound probe is moved over the ribs of the calf to view both lungs. The observer records anomalies in the image, which may indicate mild inflammation, abscess formation, or severe damage resulting in the loss of lung function.

These data could only be collected when calves are unloaded from the lorry. Therefore, more novel methods were employed to assess the welfare of calves while they were in transit. Firstly, forty calves were fitted with IceTag activity sensors (Figure 1), which provided data on lying and standing times as well as step count. Calves are restricted in space during transport, and are exposed to the motion of the lorry or ferry, which can impact their natural behaviour. Additionally, long-distance transport may be tiring for animals who may experience fatigue during and after the journey. By utilising activity sensors, changes in these behaviours before, during and after transport can be measured.

Figure 1. *A calf equipped with an IceTag activity sensor (left front leg) and a CGM (white device on left side of chest)*

The same forty calves were equipped with 'continuous glucose monitors' (CGMs; Figure 1), which are typically used to monitor glucose levels in diabetic humans. These minimally invasive sensors use a single pin-prick to insert a flexible filament into the skin, which samples interstitial glucose. CGMs measure glucose levels every fifteen minutes thus showing changes in glucose, or the calves' energy status, over time. By using CGMs, the need for more frequent blood sampling is reduced, while still providing a detailed set of data on the energy status.

Conclusion

The objective of this study was to assess the health and welfare of calves undergoing long distance transport from Ireland to the Netherlands. Both traditional and novel methods of data collection were used to measure this. Data analysis is in progress. Future research will focus on strategies to alleviate the negative impacts that long-distance transport may have on the health and welfare of unweaned dairy calves.

Feeding strategies to improve dairy calf welfare during long-distance road/ferry transportation

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Summary

- Extended feed intervals present challenges to calves undergoing long-distance transport.
- Pre- and post-transport feeding strategies that may alleviate the negative effects of extended fasting are being investigated on commercial exports from Ireland to the Netherlands.

Introduction

Due to its seasonal calving system and growing herd size, the Irish dairy industry produces a large number of calves that are not needed for replacement in the dairy herd. Every year, over 120,000 of these unweaned calves are exported to continental Europe for veal and beef production between the ages of two and six weeks. These long-distance journeys via road and ferry typically take more than 48 hours in total, during which calves must undergo a period of extended fasting.

Livestock transport, especially of young animals, is a topic of growing public concern due to its many challenges to animal welfare. Adverse effects on the welfare of calves can include hunger, dehydration, social stress, discomfort, injury and infection, handling and mixing with other animals, and exposure to novel pathogens. Transition to a new housing and management system following transport can additionally affect calf health. Long-distance transport is particularly challenging for calf welfare due to the prolonged fasting times and resulting energy loss and hunger.

Pre- and post-transport diet may improve calf welfare

Pre- and post-transport diet are key factors in managing the adverse effects of extended fasting periods. For example, dehydration, low blood glucose levels, and stress are reduced when feeding calves milk replacer instead of electrolytes before long journeys. Feeding larger volumes of milk replacer pre-transport than is current standard practice may help calves to maintain a positive energy balance and reduce hunger. Additionally, increasing the nutritional value of calves' diets following transport may contribute to a faster recovery post-transport and improve immune function, potentially reducing the risk of disease and mortality on destination farms.

Investigating the effects of alternative feeding strategies

A study was carried out during the 2022 spring calving season to investigate the effects of different pre- and post-transport feeding protocols on calf welfare during and following long-distance transport. Two commercial transports from Ireland to the Netherlands were monitored, during which a number of physiological, immunological, and health-based welfare indicators were measured in 120 calves. At the assembly centre, calves were either fed according to standard feeding practices (no feed the evening before transport and 2L of milk replacer on the morning of transport) or with an alternative feeding protocol providing higher volumes of milk replacer and an additional pre-transport feed (3L of milk replacer the evening before and on the morning of transport). On the destination farm, calves were fed milk replacer either according to the standard veal farm protocol (1.6L twice daily increasing to 2.9L over three weeks) or received 25% more milk replacer for three weeks after arrival (2.0L twice daily increasing to 3.6L).

Welfare indicators were measured at an Irish assembly centre prior to transport and at a control post in Cherbourg, France, after ferry transport. At the control post, calves were fed and rested for 13 hours before continuing by road transport to a Dutch veal farm. Measurements were taken upon arrival at the veal farm and for the following three weeks (Figure 1). Changes in body weight over the journey reflect calf hydration and metabolic status. Blood samples were analysed for parameters indicating energy balance (e.g. glucose), hydration (e.g. urea, haematocrit), immune status (e.g. white blood cell count, immunoglobulins), and stress (e.g. cortisol). Calf health was monitored by regularly recording rectal temperatures, clinical health scores (e.g. eye and nose discharge, coughing, diarrhoea, hanging ears), lung ultrasounds to identify respiratory disease, and medicine use on the veal farm.

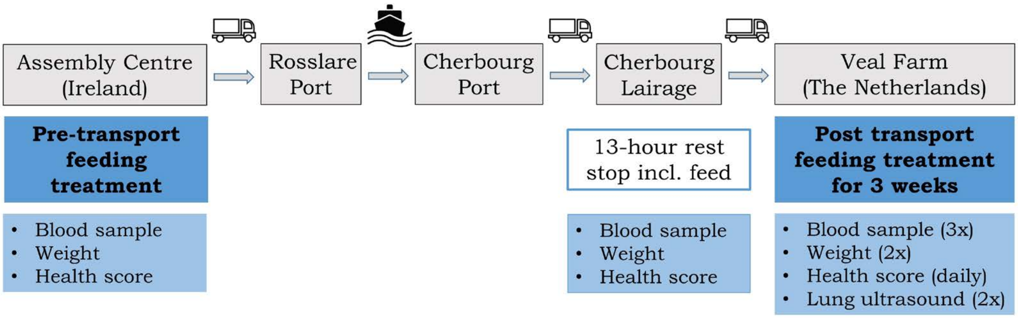

Figure 1. *Calf transport feeding study outline and sampling schedule*

Conclusions

Data analysis to investigate the effects of alternative feeding strategies on calf welfare is ongoing. The outcomes of this study may inform the introduction of optimised feeding protocols to improve the welfare of Irish calves undergoing long-distance transport to continental Europe.

Biosecurity in the dairy herd – basic principles

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Summary

- Biosecurity is a set of management and physical measures designed to reduce the introduction (Bioexclusion), and spread (Biocontainment) of animal diseases.
- Reducing cattle movement into the herd is the best bioexclusion practice.
- Restricting infection spread from sick cattle is the most important biocontainment practice.
- Prompt, veterinary diagnosis is the best protection against rapid disease spread within the herd.
- Long-term, building up herd resilience through genetics, nutrition and vaccination will reduce the impact of infectious diseases.

Introduction

Biosecurity is defined by the World Organisation of Animal health as "a set of management and physical measures designed to reduce the introduction (Bioexclusion), establishment and spread (Biocontainment) of animal diseases, infections or infestations to, from or within an animal population". Infectious diseases are caused by pathogens which can be viral, bacterial or fungal.

Bioexclusion includes all management practices implemented to prevent infectious diseases entering a farm holding/herd. This has become more important in recent years as herds expand. However, when an infection does occur on farm, biocontainment practices will reduce and slow down the spread of disease throughout the herd. While both bioexclusion and biocontainment are important, they are best implemented with a rapid diagnosis of infection. In addition to bioexclusion, biocontainment and diagnosis, herd resilience can be improved through genetics, nutrition and vaccination. All four of these are components of a Herd Health Plan.

Bioexclusion

The most common route of infection entering a herd is the purchasing of cattle. This has risen in recent years due to the expansion of dairy herds and new entrants to the dairy industry. A prime example of this is Bovine Viral Diarrhoea virus (BVDv). Purchasing a dam (a Trojan cow) carrying a persistently infected (PI) foetus will introduce BVDv infection to a herd. This is a risk for larger herds as they are more likely to have an "open" herd status. And now that BVD control is progressing successfully more naïve herds are being created, which if not vaccinated run the risk of serious BVD outbreaks. Maintaining a closed herd and aiming to produce replacement heifers through sexed semen can reduce a herd's risk of infection. There are many other routes of transmission such as visitors onto the farm who may visit multiple other farms on the same day. These include vets, AI technicians, scanners, hoof trimmers, dead stock collectors and farm labourers. Regular use of disinfection points at the entrance to the farm and buildings, especially the calf house, can reduce this transmission.

Biocontainment

Biocontainment is the control of infection within a herd. These practices are key to reduce the speed of disease spread within a herd. For example, having an isolation pen away from other cattle with a separate airspace prevents infection transmission between sick and healthy animals. Furthermore, ensuring healthy animals are always attended (fed/watered) to prior to sick animals ensures you are not bringing any infection from the isolation pen into healthy animals. Placing, maintaining and using, foot baths at the entrance and exit to housing/sheds and having separate equipment in these sheds also prevents the spread of infection.

Diagnosis

How fast can you detect the cause of an infectious disease outbreak? It is important where any symptoms of illness and/or signs of reduced production are observed, that action is taken to identify the source of infection. Because reduced milk yield is a non-specific potential sign of disease, e.g. Infectious Bovine Rhinotracheitis (IBR), Johne's disease, pain – lameness etc., diagnosis of the actual cause is important for herd biosecurity. Additionally, trends in locomotion scores and body condition scores recorded regularly can indicate changes in herd health before other clinical signs are observed, thus acting as an early warning system. It is also advisable that a post mortem is carried out on any animal that dies, in order to determine the cause of death and prevent further infection. Where a clinical disease outbreak occurs, samples should be submitted to the lab for further investigation. The Regional Vet Labs are a critical resource available to all farmers.

Herd Resilience

Resilience describes the herd's ability to withstand/overcome infection. Animals who have a balanced diet are less likely to get sick as their body has the required energy reserves to support its immune system. Vaccination programmes are also important as part of herd health and resilience. These can be drawn up with a veterinary practitioner to suit individual farm requirements as part of a Herd Health Plan. The genetics of the herd can also have an impact on herd resilience. For example, breeds such as the Norwegian Red have shown, both as a pure bred and cross bred animal, to have lower Somatic Cell Count (SCC) in comparison to that of Holstein Friesians. Additionally, the Economic Breeding Index (EBI) can be used to improve herd resilience in the long-term. There are six sub-indexes, one of which is health. This health score includes udder health (somatic cell count and mastitis) and lameness.

Conclusions

The top four tips to prevent introduction and spread of infectious disease in a herd are to 1) keep a closed herd where possible, 2) implement a good vaccination programme and good isolation pen management, 3) monitor animals for potential infectious diseases and always get veterinary opinion where unsure and 4) ensure a good Herd Health Plan is in place.

Dairy herd biosecurity – Assessment and intervention

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Summary

- A new joint Teagasc-UCD biosecurity research study started in late 2022.
- The study will assess the biosecurity status of Irish dairy herds through the National Farm Survey, Animal Health Ireland and e-Profit Monitor farmers.
- The study will also assess the impact of biosecurity interventions.

Introduction

Given the recent expansion of the dairy herd and the associated increase in cattle movements, the Department of Agriculture, Food and Marine (DAFM) launched the National Farmed Animal Biosecurity Strategy (NFABS; 2021-2024). This strategy builds on the National Farmed Animal Health Strategy with a focus on preventing infectious diseases in farmed animals. In support of the NFABS, a new project began in Moorepark and University College Dublin in September 2022. The research project has two overarching aims; 1) assess the current status of biosecurity among Irish dairy herds and 2) assess the impact of interventions on this biosecurity status and associated herd health and productivity.

Biosecurity risk assessment

A biosecurity risk assessment is an audit of farm biosecurity status. This is usually implemented using a questionnaire where the risk of disease entry and spread within a herd is monitored. In Ireland, there is currently no cattle biosecurity risk assessment tool. University of Ghent in Belgium developed a risk assessment tool known as Biocheck. This tool is used in agricultural industries such as the pig industry, however, the dairy version is based on indoor production systems.

Hence, as part of this project a risk assessment tool has been designed focusing on pasture-based cattle production in Ireland. This online risk assessment tool contains four sections; Risk of disease entry, Speed of spread of disease, Diagnosis and Baseline resilience/ Vaccinations (ESDR). The risk assessment tool will be administered to farmers, via Animal Health Ireland and Teagasc's e-Profit Monitor (ePM) farmers. Additionally, the National Farm Survey will contain a set of supplementary biosecurity questions.

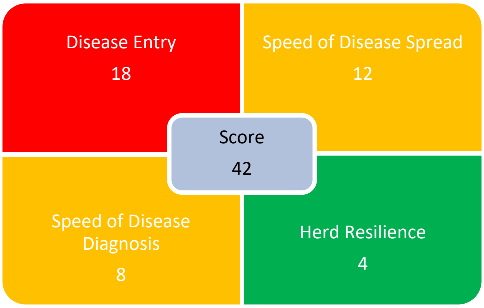

Figure 1. *Example of farm Risk Assessment Score in four sections and overall*

The responses to the questions in each of these four sections will be weighted and a farm-level score calculated. This will highlight areas of highest risk, moderate risk and lowest risk. A traffic light system of red, amber and green will be used to demonstrate such risk factors as in Figure 1.

The development of the scoring of the responses is being carried out using a platform called "Conjointly". This allows for a large network of expert opinions to be compiled into scores from best management practices to worst. For example, in Figure 2, there are four answer options for a question relating to clinical disease outbreaks. Experts selected the best and worst answers and Conjointly software calculated scores and ranked the answer options.

Clinical disease outbreaks are always investigated		0.3400717
Clinical disease outbreaks are sometimes investigated		0.14883585
Clinical disease outbreaks are rarely investigated		-0.28057971
Clinical disease outbreaks are never investigated		-0.47957127

Figure 2. *Example of Best/Worst Scaling responses from expert opinion on a single biosecurity question; always investigating was scored best and never investigating was scored worst*

Biosecurity interventions

The second objective of this project is to assess the impact of intervention on biosecurity status and the herd's production, health and economic status. This will be carried out through the recruitment of ePM spring calving dairy herds. Farmers will be recruited and randomly allocated to three subgroups. Group 1) Data analysis only 2) Data analysis and annual risk assessment and 3) Data analysis, annual risk assessment and farm visit feedback. This process has begun in 2023 and will continue through 2024 and 2025.

Conclusions

Ireland's dairy cow population growth has led to concerns surrounding biosecurity. This project will determine current national biosecurity status and assess the impact of implementing good biosecurity on herd health, production and economic status.

Acknowledgements

The project team thank the participating farmers, Teagasc KT advisors, Animal Health Ireland, National Farm Survey and ICBF and veterinary colleagues who participated in the Conjointly scoring development for the risk assessment tool.

Implementing biosecurity practices to control Johne's disease also reduces calf mortality on IJCP farms

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Summary

- Calf mortality rates (1-100d) in Irish dairy herds nationally declined significantly between 2016 and 2020 and were low (4% calf mortality rate) by international standards.
- Herds in the Irish Johne's Control Programme (IJCP) had a significantly greater reduction in calf mortality than non-IJCP herds.
- Implementation of recommended biocontainment practices to control Johne's disease was associated with a reduction in calf mortality.

Introduction

Postnatal mortality (excluding stillbirths) among replacement stock has a detrimental impact on the social, economic, and environmental sustainability of dairy production. Calf mortality rates vary between countries and show differences in temporal trends. Most calf mortality rates however, are characterised by high levels of between-farm variability. Explaining this variation can be difficult since herd-level information on management practices relevant to calf health is often not available.

Irish Johne's Control Programme (IJCP)

The Irish Johne's Control Programme (IJCP) was launched in 2013, by Animal Health Ireland (AHI) for the control of Johne's disease on Irish dairy farms. Improved calf health through enhanced farm biosecurity is a stated objective of the IJCP. A key component of this programme is a requirement for IJCP-registered herds to complete an annual herd-level Veterinary Risk Assessment and Management Plan (VRAMP), undertaken by an approved veterinary practitioner. The VRAMP provides the framework for a systematic review of factors associated with bioexclusion and biocontainment risks of Johne's disease, including consideration of 'calf protective' measures that are considered to be beneficial for improving calf health generally. Briefly, a series of questions and observations relevant to Johne's disease transmission are assigned risk assessment scores in four areas: pre-weaned calves; weaned calf; adult cow; and calving area. A lower VRAMP score reflects lower assessed biosecurity risk. Whilst this risk assessment is largely focused on factors relevant to the transmission of Johne's disease, many of its principles are good practice biocontainment policies that are also advocated for the protection of calf health.

Research study

In order to determine if this theoretical connection between IJCP/VRAMP and reduced calf mortality exists, a nation-wide study was conducted. Data on the national calf population (sex, breed, herd size, etc.) and calf mortality were extracted from the Animal Identification and Movement (AIM) system for all calves born between 2016 and 2020 in dairy herds (16,154) either registered in or not in the IJCP. The results of the VRAMP scores for the IJCP herds (1,696) were retrieved.

Results

Male calves were 1.45-times more likely to die than females. Jersey or Jersey crosses were 1.26-times more likely to die than Holstein-Friesian while Norwegian Reds were 0.94-times less likely to die. Beef-sired calves were 1.19-times more likely to die than dairy-sired calves. Calf mortality rates were higher in larger herds (>135 cattle) and on farms of birth that contract-reared out their heifers. Calf mortality was 0.83-times less likely in 2020 than in 2016. Farms in the IJCP had a 6% higher risk of calf mortality but also a greater reduction in calf mortality than non-IJCP herds. There was an interaction between IJCP and year of birth; IJCP herds registered farmers reduced their calf mortality to a greater extent than non-IJCP herds registered farmers between 2016 and 2020. In IJCP herds, higher VRAMP scores (higher biosecurity risk) were positively associated with higher calf mortality.

Discussion

While Irish calf mortality rates are relatively low, comparisons between countries is difficult due to differences in data gathering methods and definitions of 'calf mortality'. The decline in postnatal calf mortality detected here is encouraging, but with only five years' data it is not possible to determine if this is a long-term trend. The higher mortality in male calves and Jersey calves may reflect their lower economic value. This may also apply to beef cross calves though they may also be born later into a more challenging rearing environment. Greater calf mortality in large herds may reflect lower labour units:calf ratios with attendant limitations in individual calf health care.

The higher calf mortality in IJCP herds may reflect larger herd size and common biosecurity risk factors between Johne's disease and higher calf mortality as reasons for entering the programme. However, IJCP herds had a greater reduction in calf mortality over time than non-IJCP herds and IJCP herds that reduced their VRAMP scores over time had lower calf mortality, independent of herd status. This suggests that implementation of recommended biocontainment practices to control Johnes' disease in IJCP herds was associated with a reduction in calf mortality.

These findings were based on a large animal dataset comprising over 6.5 million calves in 16,154 dairy herds over five years; hence, the findings reliably represent the relationships between dairy calf demographics, herd IJCP and VRAMP status and calf mortality.

Conclusions

Membership of the Irish Johne's Control Programme and reduction in biosecurity risks over time were associated with a significant reduction in postnatal calf mortality in Irish dairy herds.

Acknowledgements

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New technique to monitor Johne's disease on infected farms

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Summary

- Transmission of *Mycobacterium avium* subspecies *paratuberculosis* (MAP) from infected adult cattle to susceptible calves occurs mainly through contamination of the calf environment with adult faeces.
- This study evaluated a novel technique for monitoring the calf environment
- Boot swabs along with faecal grab samples were used to detect MAP in 28 infected dairy farms.
- In total, 46% of farms had detectable MAP in the overall calf/calving environment, with 36% of farms having detectable MAP in the calving area.
- It was concluded that environmental sampling is a potentially useful tool to objectively measure transmission risk in the calf/calving environment on farms.

Introduction

Mycobacterium avium subspecies *paratuberculosis* (MAP) is primarily transmitted orally through ingestion of faeces, colostrum or milk from an infectious animal. Environmental contamination of housing and pasture with faeces from infected animals constitutes a risk for transmission of infection to susceptible animals. Faeces is the most important source of transmission, both through faecal contamination of the calf environment and through faecal contamination of colostrum and milk fed to calves. Environmental sampling may be a potentially useful technique to detect MAP in the pre-weaned calf area and calving area of farms.

Control programmes for Johne's disease (e.g. Irish Johne's Disease Control Programme - IJCP) usually involve a combination of herd testing to detect infection (e.g. ELISA blood/milk testing) and biosecurity measures following a risk assessment and management plan (RAMP) to reduce the spread of disease within herds and between herds.

The objectives of this study were (1) to determine what proportion of MAP-infected farms enrolled in a control programme had detectable MAP in their calf/calving environment, and (2) to compare RAMP scores and apparent within-herd prevalence (aWHP) of PCR-positive and PCR-negative farms.

Materials and methods

Dairy herds with confirmed MAP infection within the last five years based on individual faecal PCR were identified in the IJCP database. Of these, 28 farmers agreed to participate in this study. Annual RAMP score data were available for these herds. The aWHP for each herd was calculated based on the most recent annual whole-herd ELISA test recorded on the IJCP database. These were all spring calving herds, located mostly in the south and east of Ireland. Herd size ranged from 41-393 cows with a mean herd size of 166 at the time of sampling. On each farm three boot swab samples were obtained, one pair from the calving area and two pairs from the pre-weaned calf area. Manure grab samples were also obtained off the floor of the calving pen. All samples were tested for MAP using PCR.

Results

Overall RAMP scores (biosecurity assessments) ranged from 47–155 (out of a total score of 227). The lower the score, the lower the perceived risk of transmission of MAP. The mean overall RAMP score in PCR-positive and PCR-negative farms was 96.8 and 95.9, respectively, with no significant difference between mean scores.

The aWHP (blood ELISA results) for the herds ranged from 0–21%, with a median of 3.5%. The median aWHP for PCR-positive and PCR-negative farms was 5% and 3% respectively, with no significant difference identified between groups.

Table 1 shows the distribution of positive, negative and inconclusive dung results when boot swab sub-samples and calving area floor samples were pooled to give one result per location on each farm.

Table 1. *Distribution of pooled MAP PCR results for calf pens and calving pens*

Environment	Positive	Inconclusive	Negative	Total
Calf pens	6	6	16	28
Calving pens	10	5	13	28
Total	16	11	29	56

In total, 10/28 (36%) and 6/28 (21%) of farms had positive PCR results in the calving area and pre-weaned calf area, respectively. A total of 13/28 (46%) farms had at least one positive sample from either location. There were 4/28 (14%) farms that had at least one inconclusive sample from either location, and no positive samples.

Discussion

This study presents a novel and objective strategy for monitoring the efficacy of RAMPs conducted in herds engaged in the IJCP for reducing the risk of transmission of MAP within herds. The median aWHP across all herds was relatively low at 3.5% however, the proportion of truly infected animals may be much higher than this, due to the low sensitivity of blood tests for MAP. The relationship between PCR test result and aWHP or RAMP scores at farm-level, location-level or sample-level was not significant. This may be due to insufficient number of herds/samples examined, and/or the limitations of using RAMP scores or aWHP to assess transmission risk. It may be concerning that 46% of the herds had detectable MAP in either their calving pen, calf pen, or both locations. On a typical Irish spring-calving farm the compact calving season may increase the chances of contamination of calf pens with faecal material from adult cows due to the frequent movements of animals and personnel between cow housing (including the calving pen) and the calf rearing areas.

Conclusions

This research has demonstrated a potential novel application for environmental sampling as an objective test to complement the annual RAMP, to help monitor the progress of infected farms in reducing the risk of transmission of MAP to calves. However, further research on a larger scale is needed to support these results.

Acknowledgments

We wish to acknowledge the collaboration and technical support of the microbiology laboratory of the Irish Equine Centre during the planning and completion of this study.

Taking action to reduce the risk of a TB breakdown in dairy herds

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Summary

- Levels of TB have been increasing since 2016.
- Dairy herds accounted for 35% of TB breakdowns and 58% of TB reactors in 2022.
- There are several preventive measures farmers can take to reduce the risk of a TB breakdown.
- Stakeholders working together in the TB Forum can help reduce the disease levels through policy development.
- International experience has shown that such stakeholder groups working together have been successful in eradicating disease.

Introduction

Levels of bovine TB (bTB) have been increasing since 2016. Dairy herds accounted for 35% of TB breakdowns and 58% of TB reactors in 2022. By mid June 2023, 4.6% of herds had a breakdown in the preceding 12 months, with 25,448 reactors removed in that period. Until recently, the overall trend was that the number of breakdowns was falling slightly, however, recently herd incidence has begun to increase and aligned, with this, there has been a substantial increase in reactor numbers; essentially, an increasing number of herds with larger breakdowns. These figures are concerning and indicate a need for action by all stakeholders.

Actions that farmers can take to reduce the risk of TB in dairy herds

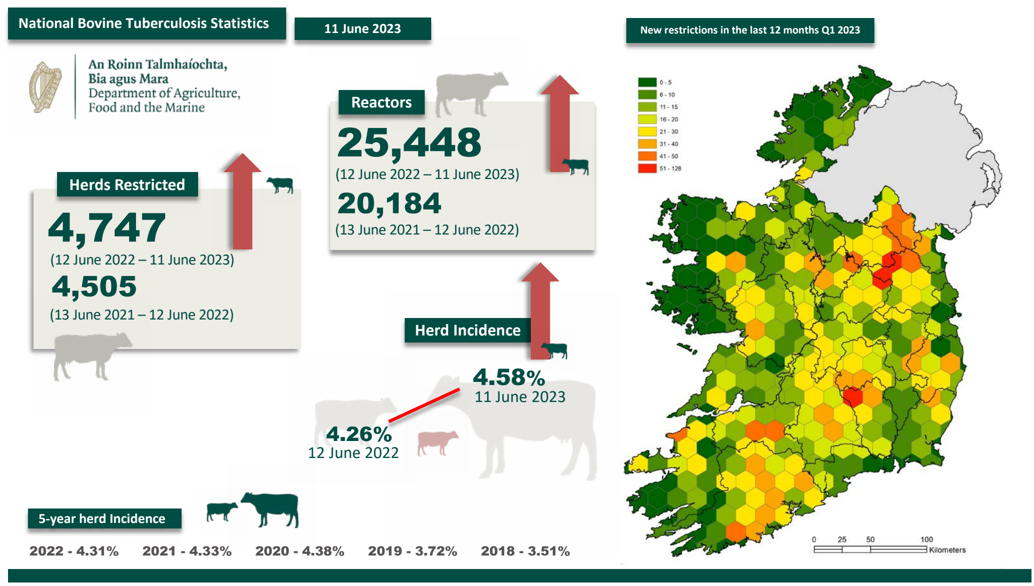
Individual farmers can protect their herd from TB by taking steps to address the risk factors for a breakdown. These include:

- Cull any cattle, which were inconclusive at a previous test no later than the end of the current production cycle. Inconclusive cattle are 12-times more likely to be become reactors at a subsequent test.
- Likewise, cull any cattle which had bovine reactions at a previous TB test, these are 4-times more likely to become reactors at a subsequent test.
- Consider culling any older cattle, which were present at a previous restriction, particularly age cohorts of any infected cattle.
- When sourcing breeding replacements, source cattle from herds which have not been restricted in recent years, and buy cattle with a recent test date. Cattle exposed to TB recently may have undetected infection and bring the disease into your herd.
- Ideally breed your own replacements to avoid the potential introduction of disease.
- If you haven't already done so, locate all badger setts on your farm. Notify the Department of Agriculture, Food and the Marine of any setts you find.
- Fence off the setts and latrines to prevent cattle consuming any grass potentially contaminated with TB bacteria (Mycobacterium bovis).
- Raise water and feed troughs to prevent badgers accessing them.

- Do not feed concentrates on the ground, as badger saliva can contaminate the area, when they eat any leftover feed.
- When selecting bulls for breeding, choose those bulls with greater genetic resistance for TB, based on the health traits subindex of the EBI. If your herd is subsequently restricted for TB, this can reduce the number of cattle exposed that become infected. Many bulls with historically high EBI figures have inferior TB resistance figures, so it is important that the genetic resistance to TB is improved in the national herd. There are still sufficient bulls with both high EBI and good TB resistance figures. Ensure you identify these bulls to increase both the genetic merit of your herd and increase the genetic resistance to TB within your herd.
- Ensure good quality testing facilities and assistance are available for TB tests to ensure the test is carried out properly. Each animal must be identified and have its skin measured on both days of the test. If the test is not carried out properly, infection may be missed and this may allow the infection to spread widely before the infection is detected at a later test, resulting in many more reactors than if the disease was detected early.
- Wash and disinfect any machinery and facilities, which may be shared with neighbours, as the TB bacteria can survive in the environment and lead to new infections.
- Ensure boundary fences are well maintained to avoid mixing with cattle from other herds.
- If you have your youngstock contract-reared, ask the rearer to take steps to reduce the risk of TB and have a contingency plan for a TB breakdown in either herd.

Conclusion

Freedom from TB is important from an international trade perspective, and individual farm profitability. However, the control of bovine TB remains a challenge for the dairy industry. Each TB restriction brings significant financial and emotional challenges for those involved. There can be several risk factors involved in any TB outbreak, which makes dealing with the disease more challenging. By addressing each of the risk factors the likelihood and extent of TB breakdowns can be reduced. This can be achieved by working together.



Attitudes of farmers towards pain in pasture-based dairy cows

Natasha Browne[1,2], Chris Hudson[2] and Muireann Conneely[1]
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Summary

- Non-steroidal anti-inflammatory drugs (NSAIDs) reduce pain and inflammation and can therefore benefit cow welfare, recovery from various conditions and procedures, and production.
- Farmers are more likely to want NSAIDs used in their cattle for conditions and procedures they consider to be most painful; however, NSAID use was low for Burdizzo castration (calves), white line separation, mastitis (clots only) and calving (no assistance) despite them being considered painful.
- Farmers would benefit from education regarding the benefits of NSAIDs and should discuss a plan with their vet.
- Cost was not seen as a major limitation in the willingness of farmers to provide NSAIDs as part of dairy cow treatment.

Introduction

Pain in dairy cows is a huge welfare concern. Preventing and effectively recognising and treating pain is key for safeguarding the welfare of our dairy cows. Non-steroidal anti-inflammatory drugs (NSAIDs) have pain-relieving and anti-inflammatory properties, and can be used during various procedures (surgical and non-surgical), and to treat various diseases and conditions. Unlike anaesthetic drugs, which only provide short-term pain relief, NSAIDs provide pain relief for 24-72 hours per dose. The use of NSAIDs also improves the rate of recovery and can increase productivity. Non-steroidal anti-inflammatory drugs can only be obtained via a veterinary prescription; however, farmers can administer NSAIDs themselves.

Teagasc pain relief survey

A survey to investigate the attitudes of farmers towards pain in pasture-based dairy cows was completed by over 1,000 dairy farmers in Ireland. Farmers were asked if they agreed or disagreed with various statements relating to pain and pain relief use in dairy cows. Participants were also required to give a pain score to various dairy cow and calf conditions and procedures (1 = no pain, 10 = worst imaginable pain). Farmers also reported if they would like a cow in their herd to receive NSAIDs for each of these conditions and procedures.

Conditions and procedures farmers considered to be most painful

The median pain scores for each condition and procedure are shown in Figure 1. Farmers scored caesarean section and digit amputation surgery as the most painful (score 9). Calving with no assistance (score 4) and mastitis (clots only; score 3) were considered the least painful. These pain scores can be used to benchmark farmers to determine their perception of pain.

Factors associated with NSAID use

Conditions and procedures seen as the most painful were associated with a greater willingness for NSAIDs to be used. This emphasises that farmers recognise pain and are generally willing for their cows to be treated with NSAIDs. Despite this, for Burdizzo castration, white line separation, mastitis (clots only) and calving (no assistance), farmers wanted less NSAIDs used relative to the pain score (Figure 1). It is considered best practice to provide NSAIDs to all calves during castration.

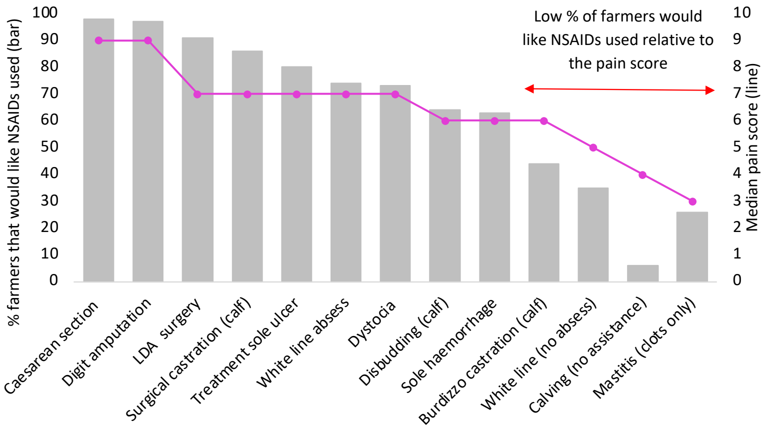

Figure 1. *The median pain score given by farmers and the percentage of farmers that would like non-steroidal anti-inflammatory drugs (NSAIDs) used for each condition and procedure*

Farmers who appeared to have less knowledge on the use of pain relief wanted less NSAIDs used as part of treatment. For example, farmers who disagreed that 'Cattle recover faster if given analgesic drugs' were less likely to want NSAIDs given to their cows. There is therefore a need to educate farmers on the benefits on NSAID use. Sixty-three percent of farmers agreed that 'Farmers do not know enough about controlling pain in cattle', and over 56% of farmers agreed that 'Vets do not discuss controlling pain in cattle with farmers enough'. Vets should be encouraged to discuss the use of NSAIDs with farmers more readily.

Cost of NSAIDs

Three quarters of participants agreed that farmers are happy to pay the cost of giving pain relief to dairy cows, with 90% agreeing that giving pain relief benefits the cow. This emphasises that vets should offer NSAIDs more readily when treating dairy cows. Farmers were also more willing to pay higher amounts for cow conditions and procedures as opposed to calf conditions and procedures.

Conclusion

This survey showed that generally Irish dairy farmers are aware of cattle pain and would like NSAIDs provided accordingly. Despite this, there are some conditions and procedures where NSAID use should be increased to improve dairy cow and calf welfare. The majority of dairy farmers agree that pain relief is beneficial as part of treatment and that cost was not an issue. Vets and farmers should discuss the benefits and use of NSAIDs within the herd.

Acknowledgements

Thank you to all the farmers that completed the survey. This project was funded by Dairy Levy Trust and the Walsh Scholarship Programme.

Hoof lesions in lame pasture-based dairy cows

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Summary

- Hoof lesions are the predominant cause of lameness in dairy cows.
- Non-infectious lesions are the most common lesion type in lame pasture-based dairy cows, with sole haemorrhage, white line separation and overgrown claws being most prevalent.
- Identifying the most prevalent hoof lesions on your farm can help you put prevention and treatment methods in place.
- Farmers should consider preventative hoof trimming to reduce overgrown claws, prevent future lesions and to treat any lesions detected on examination.

Introduction

Lameness in dairy cows is a major animal welfare concern, and is primarily caused by the presence of hoof lesions. Understanding the prevalence of different hoof lesion types will provide focus for management practices to prevent and treat these hoof lesions within the dairy herd.

Teagasc hoof lesion study

A study was carried out to investigate hoof lesions in lame Irish pasture-based dairy cows. Ninety-eight farms were visited during the grazing period and 74 farms were visited a second time during the subsequent housing period. At each visit the entire herd was lameness scored using the Agriculture and Horticulture Development Board scale from zero (good mobility) to three (severely impaired mobility). Following lameness scoring, the hind hooves of up to 20 lame cows (mild and severe lameness score 2 and 3) were lifted in a hoof trimming crate and examined to collect data on hoof lesion prevalence. A total of 941 lame cows were examined during the grazing period and 631 lame cows during the housing period (235 of these cows were examined during both the grazing and housing visit).

The most common hoof lesions

Non-infectious lesions were more prevalent than infectious lesions. Over 95% of lame cows examined had a non-infectious lesion present, whereas less than 25% of lame cows had an infectious lesion. Over 60% of the lame cows had a sole haemorrhage, white line separation or overgrown claw (Figure 1). All other lesion types were present in less than 15% of cows examined. The most prevalent infectious lesion in all lame cows was digital dermatitis. The prevalence of each lesion type is shown in Figure 2.

Figure 1. *The three most common hoof lesions identified in lame Irish dairy cows (sole haemorrhage, white line separation and overgrown claw)*

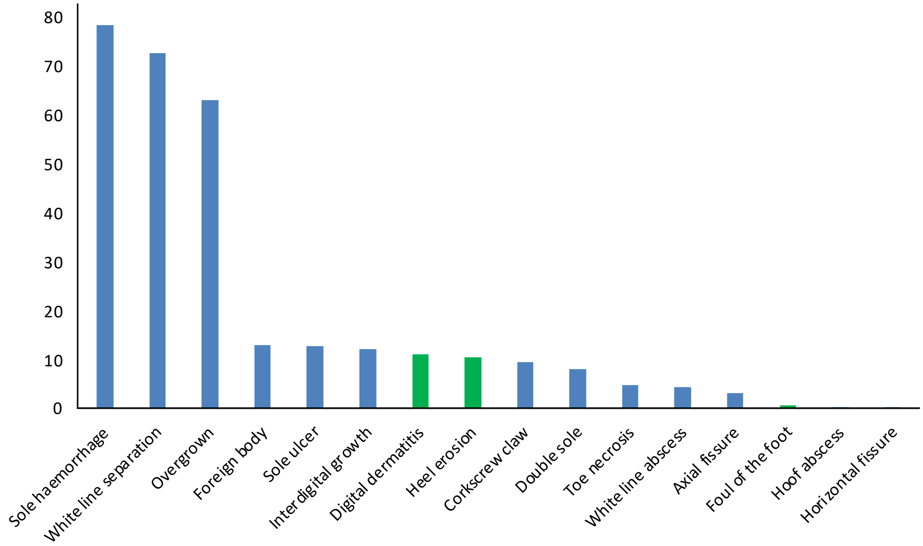

Figure 2. *Cow-level lesion prevalence (%) based on 1,572 lame cow examinations over the grazing and housing periods. Blue shows the non-infectious lesions and green the infectious lesions*

Grazing vs. housing

The presence of foreign bodies in the hoof, such as stones, were higher during the grazing period than the housing period. This highlights the importance of reducing the number of loose stones present on the cow tracks that can penetrate the hoof sole. Overgrown claws were also found to be more prevalent during the grazing period compared to the housing period. Farmers should consider preventative hoof trimming to reduce overgrown claws. Preventative trimming also allows detection of lesions that are not yet causing lameness, and helps to prevent future lesions occurring. A good time to carry out a routine inspection of the whole herd is prior to drying off. The prevalence of other hoof lesion types did not differ between the grazing and housing period.

The most painful hoof lesions

Cows with foul of the foot, sole ulcers, white line abscesses and toe necrosis were more likely to be severely lame compared to mildly lame. This indicates that these lesions are associated with more pain. Farmers should promptly detect and treat mild lesions before they turn into these more severely painful lesions. For example, treating sole haemorrhages may prevent future sole ulcers. Regular lameness scoring will ensure that mildly lame cows (score 2) are being recognised as lame, and are treated accordingly. The use of non-steroidal anti-inflammatory drugs should be considered for all lameness cases; however, this is particularly important for these most painful lesions to improve cow welfare.

Conclusions

A large range of hoof lesions were present in lame Irish pasture-based dairy cows, with non-infectious lesions being most prevalent. Some lesions were also shown to be more painful than others. Management plans should be put in place to mitigate the risk of dairy cows developing these hoof lesions, thus reducing lameness within the herd.

Acknowledgements

Thank you to all the farmers that took part in the study. This project was funded by Dairy Levy Trust and the Walsh Scholarship Programme.

Pre-calving feeding impacts on calf health – latest findings

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Summary

- Once dietary energy, protein and micronutrient requirements are met, body condition score and dry cow feeding have limited impact on colostrum formation.
- Maternal feeding that leads to foetal oversize, slow or difficult calvings or micro- or macronutrient imbalance increases the risk of stillbirth.
- Underfeeding dry cows energy, protein and micronutrients reduces young calf immunity and health; supplementation improves calf health.

Introduction

The effects of dairy cow feeding on calf health are mediated through colostrogenesis (colostrum formation) and consequently, calf immunity, and, ultimately, mortality. The nutritional adequacy of the forage and supplementary diet fed and the metabolic status and body condition score (BCS) of the dam can impact calf health. In addition, the uterine environment experienced by the foetus can influence its future long-term productivity, fertility and health (foetal programming). The new concept of the nutritional/metabolic status of one generation (the cow) impacting the health/disease status of the subsequent generation (the foetus/calf) can be described as the transgenerational metabolic-disease complex (Figure 1).

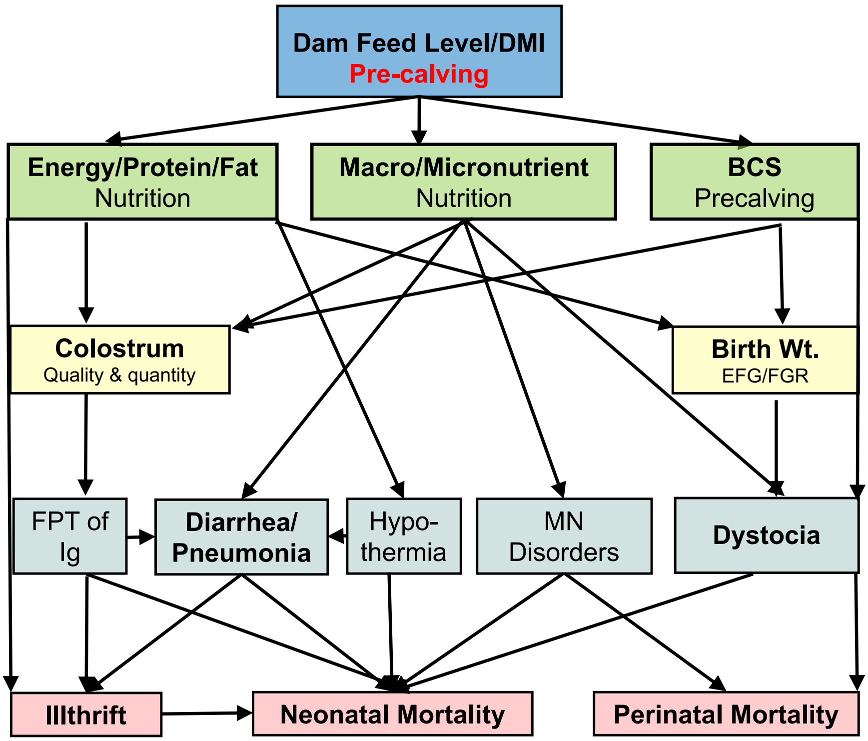

Figure 1. *The transgenerational metabolic-disease complex; DMI = dry matter intake, BCS = body condition score, EFG = excessive foetal growth, FGR = foetal growth restriction, FPT = failure of passive transfer of Ig, MN = macro/micronutrient.*

Results

The results of dry cow feeding can impact calf health pre-weaning (short-term) but also throughout life (long-term); only short-term effects are covered here. These predisposing effects on calf health occurring in the dam in the autumn, can easily be overlooked when poor calf health is a problem in late spring, e.g. outbreaks of scour or pneumonia. These maternal factors (BCS and feeding) should be considered when preparing for the new calving season as management of the dry cows, and heifers, can have direct and indirect impacts on calf health later in the season.

Maternal feeding and colostrum formation

There is only a limited number of studies on the effects of pre-calving feeding or BCS/ change of dairy cows on colostrum quantity and quality. Most previous studies are in beef cows on severe energy or protein restriction, which may not be applicable to dairy cows. In general, the ability to significantly alter colostrum quantity or quality by dietary means is limited once the metabolisable energy, protein and micronutrient requirements of the dairy cow are met (optimised), but not unmet, or exceeded (the 'Goldilocks principle'). For example, over feeding energy to dry cows can lower colostrum quality (dilution effect of increasing colostrum quantity).

Maternal feeding and stillbirth

Feeding that leads to excess BCS (>3.5; 1-5 scale), particularly in heifers, can result in foetal oversize and longer, more difficult calving ('slow calving syndrome') with increased risk of stillbirth. In addition, both dietary micronutrient imbalances, e.g. iodine, and dietary macronutrient imbalances, e.g. calcium, can result in perinatal mortality through weak calves and uterine inertia, respectively. Supplementation of grass silage is particularly important for heifers, e.g. those returning late from out-farms pre-calving in late winter/ spring.

Maternal feeding and calf health

Cows in optimum BCS pre-calving (3-3.5) have healthier, faster growing calves, probably mediated via better colostrum quality and calf immunity. Calves born from nutritionally restricted dry cows have poorer immunity and subsequent health. Supplementation of cows pre-calving with protein, energy, fat and (organic) micronutrients results in better calf immunity, less calf ill-health and better growth rates.

Conclusions

Dairy cows pre-calving need to be in target BCS range (3-3.5) and when fed a grass-silage diet, adequately supplemented with protein, energy, fat and micronutrients. Under or excess dry cow feeding will result in poorer calf health via abnormal foetal development, inadequate colostrogenesis and reduced calf immunity.

Transition cow management and health in Irish dairy herds: Results from an on-line survey

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Summary

- The transition period (three weeks pre to three weeks post-calving) involves physiological, immunological and metabolic challenges for the dairy cow.
- An on-line survey of transition cows' management and health was conducted; 525 dairy farmer responses were analysed.
- The majority (57%) of farmers reported observing the highest incidence of disease within the first three weeks after calving.
- Milk fever and subclinical hypocalcaemia were identified as a concern.
- An on-farm study is currently ongoing in commercial farms to characterise transition in Irish dairy cows' and assess its impact on health and performance.

Introduction

The transition period, defined as three weeks pre to three weeks post-calving, is a key determinant of future performance in dairy cows. Suboptimal management during this period has been repeatedly associated with higher disease incidence, poorer production and reproduction, and higher herd removal rates. Compact spring-calving, accentuates the importance of directing efforts to guarantee a smooth transition to prevent and minimise undesired long-term production and reproduction effects at herd level. However, there is a lack of current data on transition cow health and management in Irish dairy herds. The main objective of this research is to establish a national-level baseline and benchmark for transition cow health and management, as the first step to unfold possibilities for its optimisation.

Survey study

An on-line survey was designed to assess farmers' perception of the transition period, reported disease incidence and management practices. The survey, distributed among 3,899 Teagasc Dairy Advisory clients during autumn 2022, yielded 525 responses for use in analysis. The majority of respondents owned spring calving only herds (84%) and defined themselves as high-input, grazing herds (52%; >1 ton of bought-in feed/cow).

Perception of the transition period

Fresh cow diseases (e.g. milk fever, retained placenta, metritis) were ranked to be of highest importance to 49% of respondents; whilst others ranked mastitis (27%), lameness (17%) or infectious disease (7%) first. Most respondents indicated that freshly calved dairy cow health is critical (86%) and that correct dry cow management is essential for future health and performance (90%). Less than three per cent of respondents considered both freshly calved cows health and dry cow management to be moderately or not too important.

Disease

The highest incidence of disease has been reported for fresh cows (57%; within three weeks after calving), compared to cows in other stages of lactation (early (3rd week to 3rd month of lactation): 29%, late: 7%, mid: 5%, dry: 2%). Within the calving season, disease incidence was reported to be highest with late calvers (48%) and multiparous cows (second and greater calvers; 52%). Problems arising throughout the entire calving season (41%) and disease affecting all parities (43%) were both indicated by a high proportion of respondents also.

Most respondents indicated that occasional cases without major effect on herd performance were observed for; milk fever (73%), metritis (wash out, dirty cow; 72%), retained placenta (69%), displaced abomasum and/or digestive problems (62%), and ketosis (61%). However, regarding clinical and subclinical milk fever, 22% of respondents reported these conditions to be a routine problem (regularly treating cows to control issues). Nearly half of respondents (49%) reported treating 1 to 3% of their herd for milk fever and 17% reported treating 4-6% of their herd.

Management practices

In respect of management practices for dry cows, body condition monitoring was the most commonly implemented by respondents (74%) followed by managing cows in >1 group (56%), magnesium supplementation (51%) and provision of feed sources other than silage (43%) to late-pregnancy cows. Less commonly implemented management practices included calcium (35%) and vitamin D (23%) supplementation to late-pregnancy cows diet, feeding a low potassium diet to dry cows (20%) and negative dietary cation-anion difference diets for late-pregnancy cows (DCAD: 6%). Regarding management of freshly calved cows, most respondents reported keeping freshly calved cows indoors for a short period after calving (67%) and supplementing calcium to high risk cows at calving (e.g. bottle, bolus; 56%). Additionally, implementation of once a day milking for a few days after calving (35%) and dietary supplementation with magnesium (26%), calcium (18%) or vitamin D (9%) were reported by some respondents.

On-farm study (ongoing)

With most farmers acknowledging the importance of the transition period, an on-farm study is being conducted. Twenty-seven commercial farms across nine counties are enrolled in the study. Through the 2023 spring calving season, each farm was visited three times during the dry (≈2 weeks pre-calving), early fresh (1-2 weeks post-calving) and late fresh periods (2-4 weeks post-calving). Across all visits, blood samples for mineral (Ca, Mg, P) and energy metabolite (NEFA, BHB) determinations were collected, and body condition scoring was performed. Nutrition, management and production were assessed across all farms during the visits also (silage samples, questionnaire, milk sampling). The above outcomes, along with additional cow-level information obtained from herd records, will be used to establish a baseline and benchmark of transition cow's health, and to identify opportunities for its optimisation in Irish dairy herds.

Conclusion

Irish dairy farmers acknowledge the importance of transition period management on cows' health and its association with future performance. In particular, this survey has identified milk fever and subclinical hypocalcaemia as a concern in Irish dairy farms. Further analysis of the data presented above and of data collected as part of the on-farm study will identify needs that should be targeted by future Irish research.

Acknowledgements

We would like to gratefully acknowledge the co-operation of all participating farmers in this study. We also wish to acknowledge the Walsh scholarship programme and all collaborators involved in this project.

Antimicrobial use in Irish dairy herds: A comparison of three recording methods

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Summary

- This study provides the first overview of antimicrobial use in a sample of Irish dairy farms.
- Results show that antimicrobial use is low on average with a small number of high users making up a large proportion of use.
- There were variations in the antimicrobial use recorded by the three recording methods, with veterinary data giving the highest figures for use.

Introduction

Antimicrobials (AMs) are used on Irish dairy farms to maintain animal health and welfare, however there is no published information on the amounts and types of AMs used on these farms. In Ireland, the sales of veterinary AMs are published annually by the Health Products Regulatory Authority (HPRA) and from 2023 the Department of Agriculture, Food and the Marine will collect all veterinary prescriptions in a central database. Farm-level antimicrobial use (AMU) data has been collected in the pig and poultry sectors but to date has not been collected in the dairy sector. This study aimed to provide the first overview of AMU in a sample of Irish dairy farms comparing three different recording methods.

Materials and methods

Thirty-three dairy (Table 1) farms were randomly selected from the dairy client lists of six private veterinary practices across Ireland and enrolled in the study for a 12-month period between 2021 and 2022. Three recording methods were used to assess AMU on the farms;

- Veterinary prescription records (VET)
- Herd recording software records (FARM)
- Inventory of empty medicine packages (BIN)

Table 1. *Farm characteristics of the 33 participating dairy herds*

Farm characteristics	
Average herd size	100 milking cows Range (24–400 milking cows)
Average farmer age	42 years old
Calving systems	22 farms – Spring 11 farms – Split
Cow breeds	21 farms – Holstein Friesian (HF) 5 farms – Jersey crossbred 7 farms – Majority HF & some crossbred
Average somatic cell count (SCC)	152,000 cells/ml

The VET data was obtained directly from the farms veterinary practice. For the FARM data, farmers were asked to record their AMU using a herd recording software or 'app' on their phone. Ten farmers did not use the software to record their use, they kept paper records, however these were not included in the analysis. For the BIN data, farmers were asked to throw all empty medicine packages including bottles, tubes, sachets and cans of antibiotics, anti-inflammatories and vaccines into a 60L bin provided to them and this bin was collected twice during the study.

Population Correction Unit (mg/PCU)

The results of this study are reported in the mass-based metric milligrams of active ingredient per Population Correction Unit (mg/PCU). The PCU is an estimate of weight at treatment defined for each species. In this study it is calculated by multiplying the herd size (no. of milking cows) by a standardised weight (425kg).

AMU by recording methods

The results are shown in Table 2, which illustrates that the VET data gave the highest recorded use. This is to be expected as the VET data will show all medicines prescribed to the farm including medicines in stock which are not yet used. A stock of medicines on the farm was taken at the initial and final visits. Most farms had a low amount of medicine stock kept on the farm, suggesting that any medicines bought were used straight away. The farmers treatment records (FARM) showed the lowest recorded use. Six different herd recording systems were used to record AMU and ten farmers did not use any herd recording software to record their AMU. The inventory of empty medicines is considered one of the most reliable sources of AMU data however some farmers did not dispose of all medicine containers used into the bin. AMU recording varied greatly between farms as did the usage of the bins to dispose of AMs used.

Table 2. *Antimicrobial use by recording method*

	VET	BIN	FARM
Min	2.86 mg/PCU	2.05 mg/PCU	1.04 mg/PCU
Max	84.55 mg/PCU	86.27 mg/PCU	23.44 mg/PCU
Mean	18.70 mg/PCU	13.89 mg/PCU	9.13 mg/PCU

Levels of AMU recorded

The levels of AMU recorded on Irish dairy farms are comparable to similar studies carried out on dairy farms in the United Kingdom (UK). Usage was low on average, with a small number of farms accounting for a large proportion of overall use. When looking at the VET data, four farms made up one-third of the total use.

Routes of administration

When looking at the VET data the most common route of administration was the systemic route (injectables) making up 78% of use, followed by dry cow intramammary (IMM) tubes accounting for 12% of use, with other (oral and intrauterine routes) accounting for 7% and IMM tubes for lactating cows making up 3 % of use. For the BIN data, injectables accounted for 82% of use, dry cow tubes made up 12%, lactating cow tubes were 4% and other made up just 1% of use. For the FARM data injectables made up 76% of use, dry cow tubes were 17%, lactating cow tubes were 4% and other made up 3% of use.

Conclusions

This study gave the first overview of AMU in a sample of Irish dairy farms. On average AMU was low on these farms with just a small number of high users. There was variation in the levels of AMU recorded by the three recording methods, for the majority of farms the veterinary data gave the most accurate representation of actual AMU on the farm. Collecting veterinary data at the national level will allow us to gain a better insight into AMU in the Irish dairy sector as a whole.

Acknowledgements

A special thanks to all the farmers who took part in the study and the veterinarians who helped with data collection. This study was part of the AMU-FARM project and funded through the Teagasc Walsh Scholarship programme.

Cow and management factors associated with SCC in the following lactation

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Summary

- Higher milk yield at the last milk recording prior to drying off was associated with higher somatic cell count (SCC) in the following lactation.
- This was particularly true for cows dried off with internal teat sealant alone (i.e. without dry cow antibiotics).
- Twice-a-day cleaning and disinfection of cubicles during the dry period, and use of California Mastitis Test (CMT) to detect high SCC cows were management practices associated with lower SCC in the following lactation.

Introduction

Over use of antibiotics has been linked with antimicrobial resistance. To reduce this risk, EU regulations mandate that dry cow antibiotics (intramammary infusion of antibiotics at dry-off) can be used only on cows that have an intramammary infection at dry-off. Cows that are not infected should be treated with an internal teat sealant alone. Irish research shows that the impact on SCC of treating cows with internal teat sealant alone compared to antibiotic plus internal teat sealant varied depending on the herd. Cow characteristics and farm management practices are key for the control and prevention of mastitis and may play a role in the impact of dry-off treatment on infections and SCC. Therefore, the aim of this study was to assess the associations between dry-off treatment, cow and farm management factors (milking and dry-period management) on SCC in the following lactation.

Factors associated with SCC in the following lactation

Twenty-one herds with an average bulk tank SCC <200,000 cells/mL were enrolled in this study. All herd owners had previous experience of implementing selective dry cow treatment and carried out a minimum of four milk recordings across the lactation. The allocation of antibiotic plus internal teat sealant (AB+TS) or internal teat sealant alone (ITS) to cows at dry-off was at the discretion of herd-owners. Quarter-level milk samples were collected in late lactation from all cows for bacteriological culturing. Bacteriological results were used to define cows as infected or uninfected, but were not shared with herd owners. Milk yield and SCC data were obtained from milk recording reports. All herd owners completed a survey describing milking and dry period management practices. Only cows with a milk recording between five and 60 days in milk (DIM) in the following lactation were included in the study (n=1,869).

Results

The average SCC at the last milk recording (37-64 days before dry-off) was 55,000 (± 40,000) cells/mL and 197,000 (±480,000) cells/mL for cows treated with ITS and AB+TS, respectively. Cows treated with an ITS and with higher milk yield at the last milk recording had higher SCC in the following lactation compared to those with an ITS and lower milk yield (Figure 1). Cows with an infection in late lactation and older lactation cows were associated with higher SCC in following lactation (Figure 2). Cows with a lower SCC at the last milk recording had a lower SCC in the following lactation - cows with a last milk recording SCC of 50,000 cells/mL had approximately 60,000 (±30,000) cell/mL lower SCC in the following lactation compared to cows with a last milk recording SCC of 150,000 cells/

mL. Increasing the dry period length from an average of 80 days to 120 days resulted in an increase in SCC from 140,000 (±30,000) cells/mL to 182,000 (±39,000) cells/mL in the following lactation. In terms of farm management practices, using a California Mastitis Test (CMT) to detect high SCC cows, and twice daily cleaning and disinfection of cubicles was associated with 7,000 (±47,000) cells/mL and 40,000 (±26,000) cells/mL lower SCC in the following lactation compared to no CMT use and cleaning cubicles just once a day.

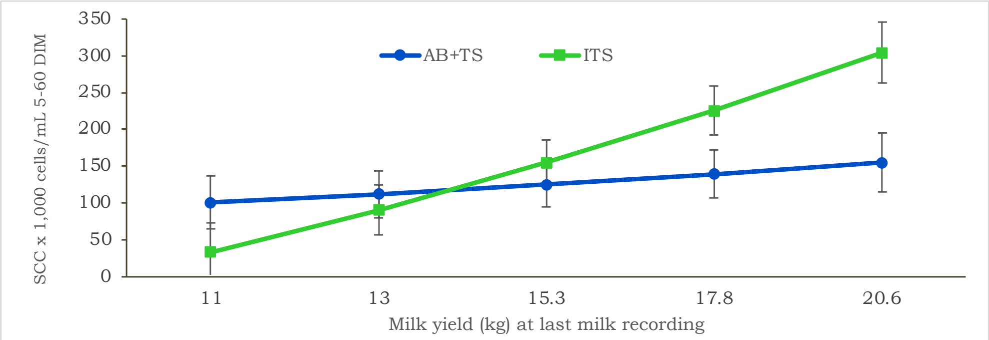

Figure 1. *Interaction between milk yield (kg) at last milk recording and dry-off treatment (antibiotic plus internal teat sealant [AB+TS], or internal teat sealant alone [ITS]) and its association with SCC in the following lactation (5-60 DIM)*

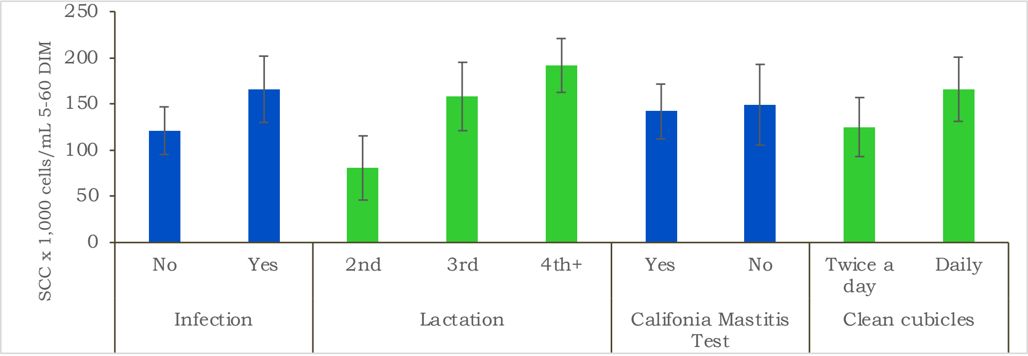

Figure 2. *Cow (infection and lactation) and farm management factors (use of CMT test to identify high SCC cows and frequency of cleaning cubicles over the dry period) associated with SCC in the following lactation*

Conclusion

Cow and farm management factors were significantly associated with SCC in herds with an average bulk tank SCC <200,000 cells/mL. Higher milk yield at last milk recording had a significant association with SCC in the following lactation, in particular when cows were treated with ITS alone. Strategies, such as reducing cows energy intake, to reduce milk yield in the lead up to dry-off may be beneficial, particularly when planning to use ITS alone. Additionally, cleaning cubicles twice per day and using CMT to identify high SCC cows contribute to lower SCC in the following lactation.

Optimising infection detection in dairy herds conducting selective dry cow therapy

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Summary

- Somatic cell count (SCC) at the last milk recording is the most useful recording to predict if a cow is infected in late lactation. It is advised to conduct at least one milk recording in late lactation (within 30 days of dry-off) to guide dry cow therapy decisions. Teagasc recommends conducting several milk recordings throughout lactation.
- The quarter SCC threshold that optimises correct classification of infected and uninfected cows in late lactation is 61,000 cells/mL and 101,000 cells/mL for first lactation and second and greater lactation cows, respectively.
- Almost 30% of first lactation cows had infections in late lactation. Measures should be implemented on farms to address this issue.

Introduction

Blanket dry cow therapy (DCT, treating all cows in a herd with an intramammary antibiotic at dry-off) to treat existing intra-mammary infections (IMI) and to prevent new IMI over the dry period has been a key pillar in mastitis control for many decades. New EU regulations state that antimicrobials should not be used as a preventive measure. An alternative strategy to blanket DCT is to treat cows that have an IMI with antibiotics, while the remaining cows are treated with an internal teat seal (ITS) alone (selective DCT). Implementing selective DCT involves correctly categorising quarters or cows as having IMI, and infusing them with antibiotics, or being uninfected and infusing them with an ITS alone.

Somatic cell counts (SCC) are a commonly used measure to detect intra-mammary infection. These reflect immune cells that are secreted in milk to try to eliminate IMIs. An IMI usually results in an increased SCC. The most common SCC threshold used to identify IMI is > 200,000 cells/mL, however, this threshold needs to be evaluated depending on the production system and bacteria most commonly causing the IMIs. Therefore, the objectives of this study were to: 1) explore cow-level factors to predict infection in late lactation; 2) describe the level of IMI in late lactation in commercial herds; and 3) determine the most effective SCC threshold to identify IMI.

Prediction of infection and SCC threshold for infection detection

A total of 21 herds (2,074 cows) located in the south of Ireland were enrolled for this study. All herds had an average bulk tank SCC of < 200,000 cells/mL in 2020. Cow data from the herds' milk recordings (parity, milk yields, SCC) were obtained from ICBF. Additionally, all cows were quarter milk sampled in late lactation (approximately 30 days prior to dry-off) and samples were cultured to detect the presence of bacteria and to determine quarter-level SCC. If samples had bacterial growth, the cow was classified as "infected", and the bacterium was identified.

Results

The average cow-level infection rate in late lactation was 19% for the 21 herds. Staphylococcus aureus was the predominant pathogen causing IMI in all herds. Of the cows with IMI (n = 393/2,074), 84% (n = 330/393) were infected with S. aureus, followed by

4.1% (n = 16/393) with Streptococcus uberis. Twenty-nine percent of first lactation cows had an infection in late lactation, compared to 14% of second to fourth lactation cows and 19.7% of five and greater lactation cows.

The last milk recording SCC provided the most important information to predict infection in late lactation. Using the average or the maximum SCC of the lactation did not improve prediction of IMI in late lactation. Also, including milk yield or the number of times that the cows had a high SCC (>200,000 cells/mL) in the lactation did not improve the prediction compared to using the last milk recording SCC alone. This highlights the importance of milk recording in late lactation to guide dry cow therapy decisions.

We found that the quarter SCC threshold that maximised the combination of correctly identifying the infected cows and correctly identifying the uninfected cows was 61,000 cells/mL for first lactation cows and 101,000 cells/mL for second and greater lactation cows. However, for older cows the accuracy of the SCC threshold was lower than that of first lactation cows. This means that using 101,000 cells/mL to classify cows as "infected" or "uninfected" will result in more cows wrongly classified in both categories, compared to using 61,000 cells/mL in first lactation cows. Table 1 shows the average SCC for infected and uninfected cows and the level of infection in different lactation categories.

Table 1. *Average SCC (cells/mL) in the last milk recording of uninfected and infected cows and percentage of infected cows by lactation category*

Lactation	Uninfected cows	Infected cows	% of infected cows (no. of infected)
1	59,700	157,400	29.3 (136)
2	55,000	98,200	14.2 (57)
3	57,800	115,700	13.3 (53)
4	59,400	158,900	15.1 (41)
≥5	90,500	198,200	19.7 (106)

Conclusion

We found that S. aureus caused the majority of IMI in the 21 studied herds. First lactation cows had a higher level of IMI compared to second and greater lactation cows. The SCC at the last milk recording of the lactation was the best predictor of IMI in late lactation. Therefore, it is very important to do a milk recording in late lactation to inform dry cow therapy decisions. Using SCC to detect infection is more accurate in first lactation cows than in second and greater lactation cows. We found that SCC thresholds of 61,000 cells/mL and 101,000 cells/mL are best to detect infection in heifers and older cows, respectively. These findings suggest that the SCC threshold for guiding antibiotic therapy at dry-off should be different for first lactation and older cows.

Acknowledgements

We acknowledge Kerry Agribusiness for their support in this study, the 21 farm owners who participated in this study and Jim Flynn for his contribution in processing the quarter milk samples. We greatly acknowledge the financial support from the Dairy Levy Trust.

Intramammary infections – prevalence and causes at dry-off and calving

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Summary

- This study investigated intramammary infection dynamics over the dry period in two research herds.
- The levels of infection varied between herds at dry-off (17% to 32%) and at calving (13% to 19%).
- Staphylococcus aureus caused most infections (over 95%).
- Intramammary infection was present in 30% and 20% of first lactation cows in the two herds at calving. Around 55% of those infections were caused by S. aureus, while most others were caused by coagulase negative staphylococci. It is recommended to house and calve first lactation cows separate from older cows.

Introduction

The dry period is one of the most important periods when it comes to mastitis management. Most new intramammary infections (IMI) occur during the first two weeks after the cows have been dried-off and within the two-week periods before and after calving. Therefore, management practices around these times need to be optimised to reduce the risk of cows being exposed to mastitis-causing bacteria.

In Ireland, the majority of infections are attributed to Staphylococcus aureus. This bacterium is a contagious pathogen. Its main reservoir is the mammary gland of infected cows and is typically spread during milking when uninfected quarters are exposed to contaminated milk. This can happen through the milking cluster, the milkers' hands or cloths and paper towels. In the scientific literature, there are usually very few reports of new infections with this bacterium during the dry period (when cows are not milked) and in first lactation cows shortly after calving. However, Teagasc research in commercial herds has found a high rate of new infections shortly after calving (which could be attributed to dry period infections) and in first lactation cows with S. aureus. Therefore, the objectives of this study were to establish prevalence and type of infections at dry-off and calving for first lactation and older cows.

Experimental design

In total, 134 first lactation, 378 second and older lactation Holstein Friesian cows from two Teagasc spring-calving research herds were sampled for convenience for this study. Herd 1 had an average bulk tank Somatic Cell Count (SCC) of less than 150,000 cells/mL in 2022, while Herd 2 had a bulk tank SCC between 200,000-250,000 cells/mL. All cows were quarter milk sampled at dry-off and at calving (before the cow's first milking after calving to ensure infections were not picked up in the parlour). Quarter samples were cultured in the laboratory to detect the presence of bacteria. If a quarter sample from a cow had growth of a mastitis-causing bacteria, the cow was classified as "infected". The level of infection at dry-off and at calving, and the bacteria most commonly causing it were assessed in each herd. With that information, we determined: 1) dry period cure rates (cows infected at dry-off and uninfected at calving), 2) new infections in the dry period (cows uninfected at dry-off and infected at calving) 3) persistent dry period infections (cow infected at both dry-off and calving), and 4) infections at calving in first lactation cows.

Results

The infection level at dry-off were 17% for Herd 1 and 32% for Herd 2. S. aureus caused over 95% percent of infections in both herds. At calving, 12% of cows were infected in Herd 1 and 20% in Herd 2. S. aureus caused 73% of the infections in Herd 1 and 75% of infections in Herd 2. Coagulase-negative staphylococci, *E. coli* and Streptococcus uberis caused the rest of infections.

Of the cows that were infected at dry-off, 91% had no infection at calving in Herd 1 and 84% in Herd 2. Herd 1 treated some cows with teat sealant alone at dry-off, whereas Herd 2 dried off all the cows using antibiotic. Target cure rates over the dry period should always be above 85%. Persistent infections were 9% and 16% for Herds 1 and 2, respectively. Ninety-one percent of persistent infections were caused by S. aureus.

New infection rate over the dry period was 8% in Herd 1 and 15% in Herd 2. Eighty percent of new infections were caused by S. aureus in Herd 1 and 78% in Herd 2.

For first lactation cows, 29.7% were infected at calving in Herd 1 and 20% in Herd 2. First lactation cows were housed and calved together with older cows. The infections were caused by S. aureus in 54.5% and 59.1% of the cases in Herd 1 and Herd 2, respectively. The second most common cause of infection in first lactation cows was coagulase-negative staphylococci, with 36% and 20% of infections in Herd 1 and Herd 2, respectively. This information is shown in Figure 1.

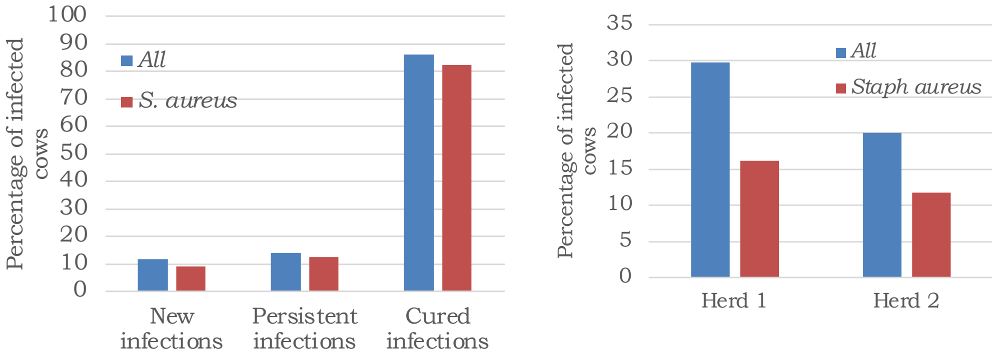

Figure 1. Left: *New infection (not infected at dry-off but infected at calving), persistent infection rate (infected at dry-off and calving) and cured cow (infected at dry-off but uninfected at calving) with any bacteria or with S. aureus for the two studied herds.* **Right:** *Percentage of infected first lactation cows at calving with any bacteria or with S. aureus*

Conclusion

We found that S. aureus caused the majority of intramammary infections in the studied herds. Heifers had a high level of infection at calving. This group had higher percentage of infections caused by bacteria other than S. aureus (S. aureus is still the most common bacterium). First lactation cows should be managed separately from older cows. Infection levels at calving and at dry-off were high mainly due to the high percentage of persistently infected cows. Therefore, farmers need to make decisions around their persistently infected cows as they are reservoirs for bacteria and are spreading the infection to uninfected cows.

Acknowledgements

We acknowledge Teagasc farm staff who participated in this study, Travis Coomey, Alice Walsh and Sharon Curtin for their contribution to data collection and processing.

Trichloromethane, chlorate and microbial status of farm bulk milk

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Summary

- Trichoromethane (TCM) and chlorate residues have been largely caused by milking equipment cleaning protocols that contain chlorine.
- TCM and chlorate levels are now generally within milk product specifications as a consequence of the introduction of chlorine-free cleaning.
- The microbial quality of milk must also be monitored and maintained.

Introduction

One specific challenge experienced within the dairy industry over recent years has been the management of chlorine-associated residues in milk. This significant issue has required consistent application of focus and strategy by both the dairy farming and processing sectors; the milk supply must attain national/ international standards as well as quality standards set by purchasers of dairy products/ingredients. This has represented a significant challenge in recent years as the residues involved are derived from one of the most previously widely used products in the dairy industry, chlorine. These chlorine associated residues, TCM and chlorate, can have health implications related to the consumption of two specific products, i.e. butter and infant milk formula (IMF) consumed by adults and infants, respectively.

TCM and chlorate

Contact between chlorine and milk results in the formation of organic chlorine disinfection by-products, the most important of which is TCM. This residue has an affinity for the fat fraction in milk and hence, is preferentially concentrated in high-fat derivatives such as cream and butter. The current target for TCM is < 0.00124 mg/kg in milk, with a target of 0.024mg/kg in butter. Chlorate is associated with the decomposition of stored hypochlorite solutions. The presence of chlorate in milk at detectable levels (≥0.0020 mg/kg) reduces the universality of raw milk as its processing potential is reduced for some ingredient applications. For example, such milk can be deemed unsuitable for value added ingredients such as specialist nutrition powders which demand chlorate levels of <0.01 mg/kg (10 ppb) in the final product. A maximum level of 0.01 mg/kg of chlorate has been set for infant formulae and follow-on formulae, when ready for consumption. The development and transfer of TCM and chlorate, respectively, to milk was primarily through the use of chlorinated detergents for cleaning and sanitation of equipment at both farm and at dairy processor sites. Consequently, these chlorine based detergent sterilizer products are no longer permitted for use on milk contact surfaces since January, 2021. This ban has had a very positive impact on both TCM and chlorate levels in milk, with almost all milk reaching these stringent TCM and chlorate standards.

Microbial quality of milk with chlorine-free cleaning protocols

Simultaneous with the correction of one quality parameter (chlorine associated residues) there may be potential to damage a further quality parameter, i.e. the microbial quality of milk. Although precautions have been taken with the development of new chlorine-free cleaning /detergent products and protocols, e.g. use of adequate volume and high temperature hot water together with adequate acid washes and caustic solutions of appropriate concentration, potential exists for microbial challenges. Thus, research was conducted to examine the microbial status of the national milk supply before and after the change from chlorine to chlorine-free cleaning protocols. To address this, five milk processors throughout Ireland submitted their pooled monthly total bacterial count (TBC) and thermoduric bacteria count levels for farm milks in the years 2019-2022, inclusive.

Results

Total bacterial count (TBC) data did not generally indicate any increase in association with the changeover from chlorine-based detergents to chlorine free detergents, except for one milk processor, where the average annual TBC increased from 23 $x10^3$/ml (average 2019-2021) to 31 $x10^3$/ml (2022). Some increase in thermoduric bacteria levels was observed, particularly in the months July to December in 2021 and 2022; this was evident for the majority of milk processors (Figure 1).

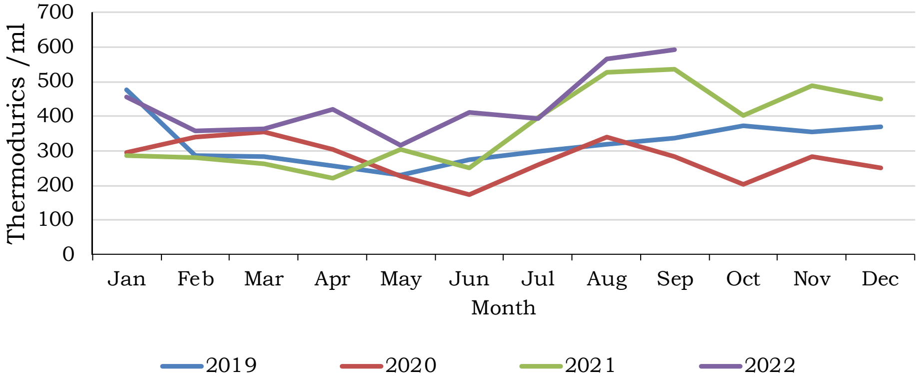

Figure 1. *Typical monthly thermoduric bacteria counts of farm bulk milks for 2019 to 2022, inclusive (source: milk processors)*

Upward trends in thermoduric bacteria levels have been observed in milks from a number of milk processors in recent years (Figure 1). This needs to be addressed and one strategy is by increasing attention to detail in a chlorine-free cleaning process through using the appropriate cleaning protocol for the milking plant, adequate acid washes and adequate volumes of sufficiently hot water. A further strategy is by presenting clean cows for milking through ensuring a clean environment, clipped tails and udders and cow teat cleanliness prior to cluster attachment.

Conclusions

Average values of the TCM, chlorate and microbial milk quality parameters are largely within target levels and standards have been passed in many cases. However, some challenges remain around the maintenance of standards and the indications of increasing thermoduric levels needs attention. Issues with high thermoduric levels occurred in the past when chlorine based cleaning was used. Many farms currently using chlorine-free cleaning procedures have excellent milk quality including low thermoduric bacteria in their milk. This supports the argument that excellent TBC and thermoduric levels can be achieved when a chlorine-free cleaning protocol is applied correctly within a clean dairy farm environment.

Chlorate levels in bulk tank milk produced in the Republic of Ireland during 2020 and 2021

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Summary

- A study was conducted to establish chlorate levels in bulk tank milk supplies before (2020) and after (2021) the regulation to remove chlorine from milking equipment cleaning routines on-farm was officially imposed.
- Fifteen percent of milk samples analysed in 2020 had detectable levels of chlorate as compared to just eight percent of samples analysed in 2021, indicating a positive impact of chlorine-free cleaning at farm level.
- The incidence of chlorate in milk needs to be reduced further; even low detection rates can cause issues for processing and value added ingredient applications.

Introduction

Changing from chlorine based to chlorine-free (CF) cleaning strategies at both farm and processing (factory) level came about in response to heightened awareness amongst European Union legislators and international customers on the necessity to produce milk and dairy products with minimal/non-detectable levels of chlorate, which is an unwanted residue in consumed products, particularly those which infants consume. Chlorine-free cleaning of milking equipment was gradually introduced by milk processors in the Republic of Ireland in late 2019/ early 2020 and became a regulation to be adopted on-farm from January 1st 2021. However, little was known about the actual levels of chlorate present in milk produced on Irish dairy farms and whether or not levels were compliant with the European limit for chlorate in milk of 0.10 mg/kg. To address this, Teagasc conducted a study to establish the rate of occurrence and actual levels of chlorate in bulk milk samples in 2020 (partially chlorine-free) and 2021 (chlorine-free).

Materials and methods

Bulk milk samples (n=3,625) were obtained from six milk processing companies (covering a wide geographical area) for chlorate analysis across the main milk production seasons (March to November) of 2020 (n=1,741) and 2021 (n=1,884). These milk samples represented a sub-set of samples selected at random from samples regularly submitted as part of the industry led Trichloromethane (TCM) analysis programme (based at Teagasc Moorepark). A sample number equivalent to 2.5% of the total number of milk suppliers that each milk processor had was targeted for chlorate analysis during each month. Samples were analysed for chlorate using UPLC-MS/MS at Teagasc Ashtown on a monthly basis; the minimum level of chlorate that could be detected was 0.0020 mg/kg.

Results

Overall rates of detection and rates of exceedance of the EU limit are presented in Figure 1. In 2020 the majority (55%) of the 261 samples in which chlorate was detected contained between 0.0020 and 0.0050 mg/kg of chlorate. Similarly, in 2021, 55% of the 150 samples with chlorate detected contained between 0.0020 and 0.0050 mg/kg of chlorate.

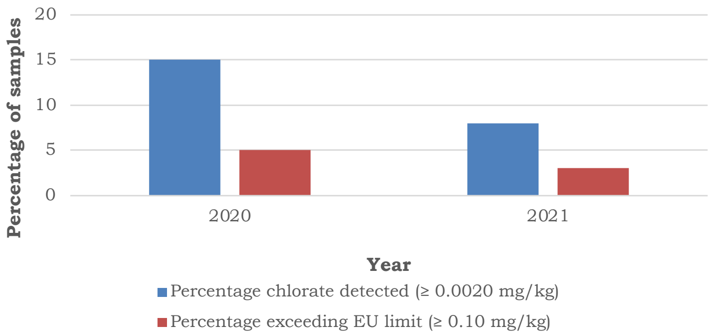

Figure 1. *Percentage of bulk milk samples with chlorate detected and percentage of these samples which exceeded the EU limit for chlorate*

Discussion

Chlorine based cleaning strategies remained on some farms in 2020, yet 85% of the milk samples analysed had no chlorate detected. Moreover, chlorate was present at low levels (0.0020 – 0.0050 mg/kg) where it was detected; with the exception of the 5% of samples which exceeded the statutory EU limit. This indicates good compliance with European regulations, even though chlorine based cleaning still remained in use on some farms at that time. The move towards CF cleaning of milking equipment in 2021 led to a seven percentage point reduction in chlorate detection relative to 2020 (85% of samples with no presence of chlorate in 2020 versus 92% in 2021) and fewer milk samples exceeding the European limit (two percentage point reduction). However, the widespread adoption of CF cleaning strategies has not eliminated chlorate occurrence in milk and even low rates of detection and/or low levels of detection (e.g. 0.0020 – 0.0050 mg/kg) can cause issues at processing level; particularly in milk powder manufacture where chlorate levels can be concentrated by 7-10-fold during the drying process from milk to powder. It is possible that chlorate from sources other than chlorine based cleaning products may also contribute to chlorate levels in milk, e.g. chlorinated water.

Conclusions

The reduction in the use of chlorine based detergents as part of milking equipment cleaning protocols has resulted in a reduction in the incidence of chlorate detected in bulk tank milk. Average levels of chlorate detected were in compliance with European limits. Regardless of this, low rates of detection and low levels (mg/kg) of chlorate detection are still significant issues for milk processors; particularly those producing powders for value added ingredient applications such as infant milk or follow-on formulae. While CF cleaning has proved to be a positive strategy in reducing chlorate incidence in bulk tank milks, a further potential contributing source may be chlorinated water and further studies are required to address this.

Acknowledgements

The authors would like to acknowledge the six participating milk processors and the DAFM and Dairy Levy Trust for funding this research.

Is chlorinated water a source of chlorate contamination of milk?

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Summary

- Chlorinated water is sometimes considered as a source of chlorate contamination of milk.
- A study was conducted to measure the impact of using chlorinated water to rinse milking equipment on chlorate residues in milk.
- Results showed that chlorinated water can result in chlorate contamination of milk when improper drainage of milking equipment occurs.

Introduction

Aside from chlorinated chemicals, chlorinated water is viewed as a potential source of chlorate contamination of milk produced on dairy farms. To date, little evidence is available to support this view. Therefore, Teagasc undertook a research study to address this gap of knowledge, which focused on investigating the impact that chlorinated water has on chlorate levels in milk where it is used to rinse milking equipment.

Materials and methods

Three chlorinated water rinsing treatments, each containing different levels of total chlorine (0.10, 0.50 and 2.00 mg/L) were applied to the 30 unit swing over milking parlour at the Moorepark dairy unit in November and December 2021. These total chlorine levels are typical of those found in group and mains water supplies in Ireland. Each treatment was applied on three occasions and in a random order. The milking machine was rinsed two hours before afternoon milking commenced (3pm). Each rinse water was sampled in triplicate for both total chlorine (tested in-situ using a handheld chlorine meter) and chlorate (UPLC-MS/MS at Teagasc Ashtown). At each rinsing event water was also sampled as it exited the plant (n=3; 40 ml) at regular intervals during the rinsing cycle, via an in-line sampling tap, again to measure total chlorine and chlorate. Milk was sampled from each of the first three rows of cows milked (300 ml from each row). This milk sample was taken after clusters were attached to all 30 cows in the row. The 300 ml of milk was then subsampled into six, 25 ml samples (plus 150ml disgard); three for chlorate analysis and three for added water i.e. freezing point depression (FPD) analysis (Milkoscan 7 at Moorepark). The minimum levels of chlorate that could be detected in water and milk were 0.00020 mg/L and 0.0020 mg/kg, respectively. Milk with a FPD value of <0.500°C was viewed as containing 'added' water.

Results

Mean chlorate levels in milk sampled from Rows 1, 2 and 3 are presented in Figure 1. Chlorate levels in the treatment waters before and after rinsing are presented in Figure 2. Added water was detected in milks sampled from the first row of cows milked, but not from Row 2 (Figure 3) and by extension of this, Row 3.

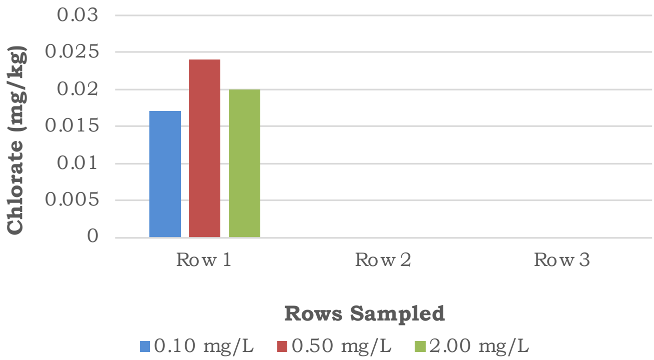

Figure 1. *Mean chlorate levels detected in milks sampled from Rows 1, 2 and 3*

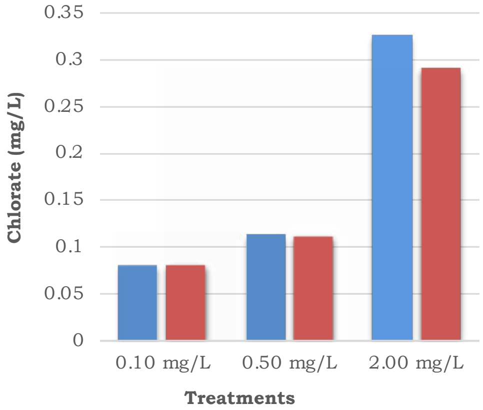

Figure 2. *Chlorate levels in waters before (blue) and after (red) rinsing*

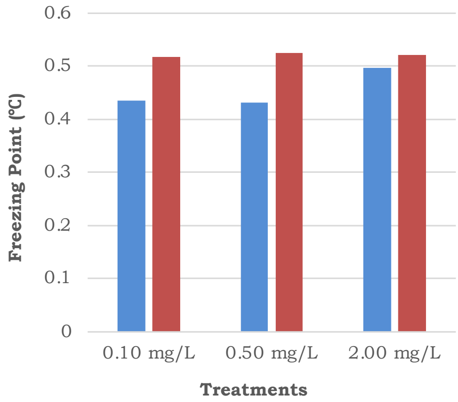

Figure 3. *Freezing points of milks sampled from Rows 1 (blue) and 2 (red)*

Discussion

This study demonstrated that increasing levels of chlorine in water results in increasing levels of chlorate in the water. When that water was used for the different rinsing treatments, the amount of chlorate present in the water before and after rinsing was almost identical. This indicated that chlorate ions did not leach from the water. Thus, the chlorate in the milk could only have derived from the rinse water coming in contact with the milk, and the only way in which this could occur was through some rinse water remaining in the milking system as a consequence of poor drainage, e.g., water remaining in key areas such as clusters, receiver vessels and milk transfer lines when milking begins. Taking steps such as installing drainage valves (automatic) along the system are vital to reduce the opportunity for water to enter milk.

Conclusions

Ample drainage of milking equipment prior to the commencement of milking is critical to avoid the possibility of chlorinated water gaining access to milk.

Evaluation of how chlorine-free cleaning protocols for milking equipment are applied on farms

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Summary

- A survey was undertaken to evaluate the degree to which chlorine-free cleaning protocols are applied correctly to milking equipment on farms.
- Numerous faults in the application of cleaning protocols were observed, particularly with regard to the use of detergents.
- The specific steps and elements/features of the cleaning protocols on-farm must be corrected if bacterial quality is to be maintained in the long term.

Introduction

A requirement for chlorine-free cleaning of milking equipment on-farm has been adopted by milk processors since January 2021. To address this scenario (and to compensate for the removal of chlorine), five new milking machine cleaning protocols have been developed and evaluated at Moorepark. The new cleaning protocols (compared to traditional protocols) require more frequent hot washes to be conducted at higher temperatures. In addition, the new chlorine-free (CF) sodium hydroxide based detergents have a higher viscosity than previous products and therefore recalibration of automated cleaning equipment is vital; otherwise, the new CF detergent take-up rate may be less than that of the previous product. As Irish dairy farmers approach the end of their second season producing milk using these new CF cleaning detergents, some farmers/advisors continue to report issues with milking equipment hygiene and an increase in bacterial counts. To establish potential reasons for this observation, Teagasc undertook a survey focusing on milk quality management on commercial dairy farms.

Farms visited

One hundred and five farms were visited in co-operation with 11 milk processors between July and October 2022. The number of farms chosen from each processor was based on the total supplier numbers of each processor; between five and 20 farms were selected per processor; with half of the farmers surveyed having a consistently high (>25k) or low (<15K) total bacteria count (TBC). Participating farmers did not receive specific advice on TBC management in the two months previous to the Teagasc visit. Each farmer was interviewed using a set number of questions and detergent usage rates, water temperatures and water volumes were measured.

Results

Many deficiencies in the application of the cleaning protocols were highlighted, in particular the frequency of hot washes, detergent circulation time, temperatures and chemical usage rates; particularly where liquid products were used with automatic cleaning. A summary of the main faults associated with the use of liquid detergents is presented in Table 1. Higher usage rates (1% solution) of CF liquid detergent are required when detergents are used with cold water, to compensate for the lack of heat, whilst a usage rate of 0.5% is sufficient where hot water is employed. Ninety seven percent of farmers surveyed were not observing this requirement. In addition, 38% of farmers were not using sufficient amounts of detergent when using hot water. Many farmers indicated that they had not recalibrated the auto-washer to facilitate the use of the new CF products. To properly recalibrate an auto-washer, it is necessary to read the recommendations on the drum, for both hot and cold-washing, ascertain the volume of water being used (measure the trough), calculate how much detergent should be used and recalibrate as necessary.

The frequency of hot washing for the milking plant depends on the wash routine employed; a minimum requirement of seven hot washes per week are necessary when liquid detergents are used. A target starting wash temperature of 75-80°C is necessary for effective hot washing. A minimum of nine litres of hot water per unit is required for effective cleaning and this increases to 12 litres per unit with larger plants that have axillary equipment, e.g. milk meters/dump lines. Fourteen percent of farmers used less than seven litres per unit. It is recommended to conduct an acid wash on a least two occasions per week and more frequently if the water used is considered 'hard' (> 300ppm CaCO3). Acid containers are generally identified as being red in colour and should match with the red take-up tubes to avoid incorrect product being used. Eight percent of farms had these tubes placed incorrectly. Twenty two percent of farms had an organic matter residue build-up on the inside of claw-pieces-indicating that a poor milking equipment-cleaning protocol is employed on those farms (Figure 1).

Table 1. *Summary of main faults associated with the use of liquid detergents*

Main faults	% farms
Shortage of detergent for cold wash	97%
Shortage of detergent for hot wash	38%
Inadequate hot washing	70%
Insufficient water temperature	62%
Inadequate acid washing	18%
Inadequate water volume	14%

Figure 1. *Residue build-up on a claw bowl*

Conclusions

The results of this survey indicate that there are many faults in the application of cleaning protocols on farms. If these management faults are not addressed, the success of CF cleaning at farm level will be limited and bacterial counts in milk may increase over time.

Acknowledgements

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Working Effectively Village

The People in Dairy Programme – developing a pathway towards socially sustainable farms

Conor Hogan

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Summary

- The People in Dairy Programme aims to address and support the human capital needs of dairy farms.
- Teagasc aims to work together with farmers and other stakeholders to enhance on-farm working situations and create attractive farm workplaces for current and future generations.
- A number of initiatives will be implemented in collaboration with industry stakeholders to achieve these goals.

Introduction

The concept of farm sustainability is generally described using three pillars; economic, environmental and social. Social sustainability, incorporating aspects such as work/life balance and quality of life, is an underdeveloped area relative to the other aspects of sustainability. This is despite dairy farm careers being traditionally associated with long and physically intensive working hours; issues that have been compounded by herd size expansion, a reduction in the number of people available to work on farms, and the seasonality of workload within the Irish dairy system. This intense workload has caused increased levels of stress, mental health issues and difficulties for farmers in maintaining an adequate quality of life. Meanwhile, the same farmers are placing greater emphasis on rewards such as a good work/life balance and increased family time, and creating a more sustainable workload will be essential to attract young people to work on farms. Accordingly, the human capital needs of dairy farms must be addressed to ensure the long-term sustainability of the industry.

The People in Dairy Action Plan

Teagasc, in collaboration with dairy industry stakeholders, developed the People in Dairy Action Plan with the aim of addressing these challenges. The overarching aim of the programme is to:

"Develop labour efficient, safe and sustainable farm businesses that offer high standards of operator quality of life for current and future generations"

Seven key action areas were outlined as part of this plan:

- Ensure adequate availability of skilled people to meet seasonal and year-round demand.
- Improve labour efficiency on dairy farms – creating desirable farm workplaces with a good work/life balance.
- Enhance farmers reputation as employers to support the attraction and retention of people.
- Develop and deliver excellent formal and informal training.
- Highlight multiple different progression pathways to becoming a dairy farmer.
- Promote dairy farming as an attractive career.
- Effectively implement the Action Plan.

Teagasc has ongoing projects in a number of areas aimed at delivering the plan. Two large-scale research projects have recently been completed, focusing on farm labour time-use and efficiency, and farm human resource management. Key results from these studies can be found in this booklet.

Currently, future priorities are being considered to further develop and deliver the points set out in the action areas. Central to these plans will be a focus on improving current on-farm working situations, and disseminating existing research in this area. Improving these situations is essential for farmers to improve quality of life and reduce stress associated with workload. This will also be necessary to create attractive careers and enjoyable workplaces for farm workers – both current and prospective. In this respect, the implementation of techniques that can improve farm work life and create more attractive workplaces will be essential; with current studies indicating that the uptake of many of the available labour saving techniques and human resource management practices could be improved. Several of these actions (many of which are discussed in detail later in this booklet) are relatively straightforward to implement requiring little cost, with no negative impact on farm profitability or animal performance.

Conclusion

The People in Dairy Programme is a long-term vision for the future of Irish dairy farming to support those working on dairy farms. Recognising that people are at the heart of the Irish farming story, the programme aims to foster collaboration between farmers, industry stakeholders and Teagasc to enhance on-farm working conditions, and create attractive and rewarding farm workplaces for current and future generations. By placing equal prominence on social sustainability alongside other sustainability pillars, we aim to support a vibrant dairy farming sector that will benefit farmers, their communities, and the environment.

Measuring and managing spring labour time-use

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Summary

- Milking and calf care accounted for 48% of all spring labour input.
- Farmers worked an average of 64.5 h/week in spring 2021.
- Labour input increased but labour efficiency improved between spring 2019 and 2021.
- On-farm case studies indicated considerable time saving benefits when new facilities and technologies were put in place.

Introduction

Increased herd sizes combined with problems in attracting and retaining people to work on farms have led to workload challenges. As 33% of all labour input occurs during springtime, it is important that farms focus on labour management improvements during this key period. This requires appropriate measurement of the seasonal workload peak on farms and an understanding of how to address it. Consequently, a study was conducted to measure spring labour time-use over multiple years and examine the impact that new facilities and technologies could have on labour demand in real farm situations.

Time-use study

A time-use study was completed on 76 farms in 2019. Farmers and farm workers recorded their time input on a smartphone app on one alternating day each week. Farm workers not using the app, together with contractor hours were recorded through an online survey. Results from the spring period (February, March and April) highlighted the time allocated to each task at that time of year (Figure 1), with milking and calf care accounting for 48% of all spring labour input.

This study was repeated in spring 2021 on 57 farms. Results showed that farm labour input increased by 3% (1,364 h to 1,403 h) and herd size increased by 10% (145 cows to 160 cows) between spring 2019 and 2021. At the same time, farm labour efficiency improved by 7% (9.4 h/cow to 8.8 h/cow). The farmer worked 64.1 h/week in spring 2019 compared with 64.5 h/week in 2021.

Farms that made substantial changes to milking and calf care facilities and practices

Case study farms that made substantial changes to their milking and calf care facilities and practices between 2019 and 2021 were selected to examine the impact that these changes had on labour demand and efficiency. Four case study farms that implemented new milking parlours or added additional milking units improved their milking efficiency by 15% (2.89 to 2.45 h/cow per farm) and reduced milking labour input by 15% (402 to 342 h per farm). Seventeen farms made substantial calf care changes including constructing a new calf shed, installing an automatic calf feeder, selling male calves and contract rearing heifer calves pre-weaning. These farms had on average 26 more cows per farm in 2021 than in 2019 (increasing from 137 to 163 cows), but calf care labour input declined by 5% (240 to 228 h per farm) and calf care labour efficiency improved by 16% (1.83 to 1.53 h/cow per farm). Of these farms the largest improvement was observed on the eight farms that installed automatic calf feeders, where calf care labour efficiency improved by 23% (1.76 h/cow to 1.36 h/cow).

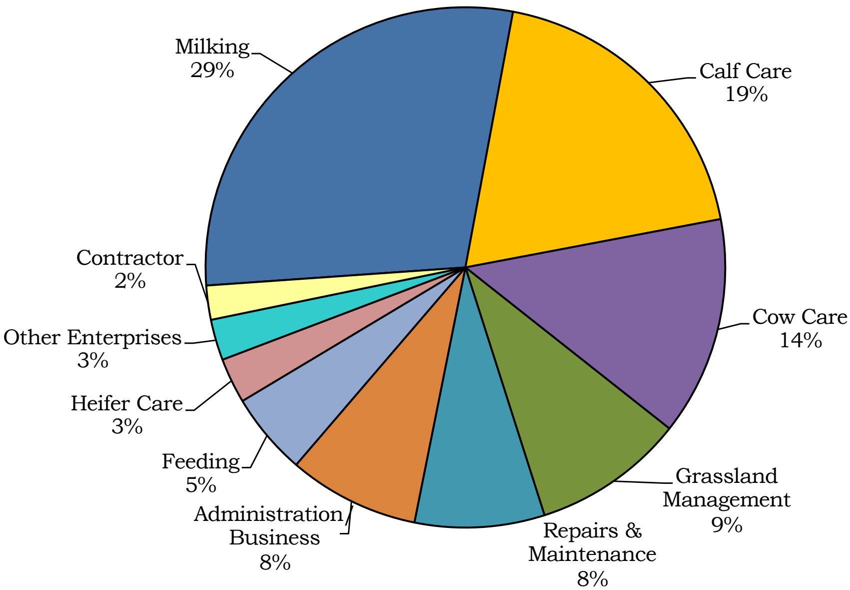

Figure 1. *Breakdown of time spent at each task and contractor input as a proportion of all farm labor input for the spring period*

Conclusion

It is important that farmers consider the extra labour input that is required to manage larger herd sizes; this involves taking a holistic approach to labour management that is not solely focused on labour efficiency. For example, the average farm in this study increased herd size by 15 cows between 2019 and 2021, and this led to 0.7 h more labour input per day. In such a scenario, farms need to consider either additional labour input (family, hired or contractor) or the implementation of further labour saving techniques to meet the increased labour demand. The results of this study reinforce the positive impact that facilities and technologies can have on labour demand; particularly for milking and calf care tasks.

Benchmarking effective farm work organisation

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Summary

- Farms with effective work organisation were labour efficient with low farmer work hours.
- This study identified work organisation strategies effective in improving work life balance on the farm, including having set and earlier finish times and reducing the number of tasks being completed during the day.

Introduction

Work organisation is well recognised as a key element underpinning any business, with important consequences for productivity, innovation, working conditions and worker well-being. Thus, it was considered that a focus on work organisation on-farm could assist in mitigating against the negative consequences of the relatively large workload during the spring/summer period.

Effective work organisation

A sample of 55 spring-calving dairy farms with labour input data available for the spring and summer period were examined. Studying work organisation in other industries and within agriculture allowed us to identify three key characteristics or measures of work organisation: efficiency and productivity, flexibility and standardisation. Work efficiency and productivity are key characteristics of any work system, focusing on maximising the output from inputted labour without negatively affecting work quality. Flexibility is important in terms of achieving a balance between work and personal life. This can be challenging on farms due to the repetitive nature of tasks such as milking and calf care; the consequent effects of which mean farmers often work seven days per week. Standardisation refers to the sequence and structure of tasks to ensure high standards of work and productivity. Each of these measures was interpreted within the context of the on-farm labour time-use study:

- Efficiency and productivity was associated with farm hours worked per cow and farmer hours worked per day;
- Flexibility was described by the length of the farmers' working day and the number of days off for the farmer between the start of calving and end of breeding;
- Standardisation was expressed as the number of different tasks completed by the farmer per day and the finish time of the farmer.

Work benchmarks

All 55 farms were ranked for work organisation effectiveness and Table 1 presents results for the top and bottom 25% of farms. The top 25% of farms for work organisation effectiveness had better labour efficiency, lower labour input, shorter work days and earlier finishing times than the bottom 25% of farms. Some of the savings in hours worked were likely due to those farms having labour-saving facilities, technologies and work practices as well as effective work organisation.

Table 1. *Characteristics of farms (n=55) ranked in the top and bottom 25% for work organisation effectiveness*

Item	Work organisation effectiveness	
	Top 25%	Bottom 25%
Average herd size	112	113
Labour efficiency (h/cow)	17.4	20.9
Labour input per week (h/week)	51.2	70
Farmer length of working day (h)	11.4	13.2
Farmer days off between start of calving and end of breeding	2	1
Number of tasks completed by the farmer per day	9.6	12.5
Farmer finish time	18:25	19:58

The data generated allowed us to identify patterns of effective organisation which we can describe as 'the ideal working day'. 'The ideal working day' was characterised by:

- Later start and earlier finish times (than the average farm)
- More free time in the evening through earlier and fixed finish times
- Fewer different tasks completed during the day
- Longer non-farm activity time during the working day

Examples of this work day pattern during March are presented in Figure 1; illustrating an example of an 'ideal working day' (Farmer 4) and a farmer with ineffective work organisation (Farmer 55).

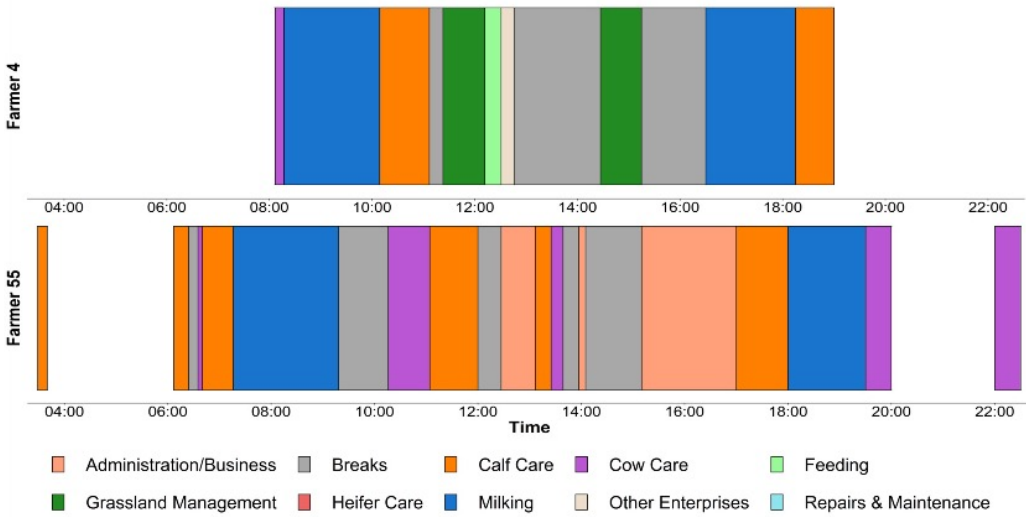

Figure 1. *Daily task timelines of example working day patterns of farmers in the most (Farmer 4) and least (Farmer 55) effective work organisation quartiles during March*

Conclusion

Improvements in work organisation can have positive outcomes for job satisfaction and optimise business performance, particularly through improved labour productivity and efficiency. The positive situations observed in this study highlight what can be achieved on farms in terms of workload and flexibility.

The impact of work practices and technologies on labour demand

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Summary

- Fifty-nine work practices and technologies were associated with labour efficiency from February to June.
- The most labour efficient 25% of farms implemented 37 of those labour efficient work practices/technologies while 25 were implemented on the least labour efficient 25% of farms.
- Each additional work practice or technology implemented was estimated to improve farm labour efficiency by 0.6 h/cow.
- The study offers an insight into the potential time savings of key labour saving work practices and technologies.

Introduction

Fifty-seven percent of all workload occurs during the spring and summer periods on spring-calving dairy farms. This, along with difficulties attracting people to work on farms have led to workload management challenges. Accordingly, improved time-use and productivity regarding the management of dairy herds have become increasingly important. The objective of this study was to identify work practices and technologies associated with farm labour efficiency and to estimate the impact of key practices and technologies on labour demand.

Time-use study and work practice/ technology implementation survey

A labour time-use study was completed from 1st February to 30th June, 2019 on 76 farms. Farmers and farm workers recorded their time input on a smartphone app on one alternating day each week. Farm workers not using the app as well as contractor hours, were recorded through an online survey.

An additional survey, involving 110 questions related to work practice/technology implementation, was completed with each farmer. Each work practice/technology was classified according to its associated farm task and statistically tested; 59 were found to be associated with labour efficiency. A score was given to each farm depending on how many of the 59 work practices/technologies they implemented; a farm received one point for each work practice/technology that was implemented.

Results

On average, farms implemented 31 labour efficient work practices/technologies (range 10-45). The most labour efficient 25% of farms implemented 37 work practices and technologies compared to 25 on the least labour efficient 25% of farms. The implementation of labour efficient work practices and technologies, along with herd size, explained 54% of the variation in farm labour efficiency. It was estimated that each additional work practice or technology implemented would improve farm labour efficiency by 0.6 h/cow. These findings demonstrate the positive impact that these work practices and technologies can have on labour demand.

Certain labour efficient work practices and technologies (e.g., reduced rows of cows, ACRs, automatic calf feeders, drafting facilities, automatic heat detection) require large capital expenditure and a cost-benefit analysis may be required. However, many other techniques are low cost requiring improved work organisation (e.g., not leaving the milking pit to herd cows into the parlour or to feed calves during milking, not transferring milk to the calf house in buckets, pushing in silage mechanically, once-a-day AI), which could have large effects on labour efficiency through the elimination of unnecessary work. Therefore, work organisation methods should be the first focus for farmers as such techniques should be more straightforward to implement than the other high cost technologies.

Milking and calf care were the most labour demanding tasks from February to June consuming 31% and 14% of all labour input, respectively. The work practices/technologies estimated to have the greatest impact on milking and calf care labour efficiency are presented in Table 1 accompanied by their estimated time saving from February to June.

Table 1. *Work practices/technologies that had the greatest impact on milking and calf care labour efficiency from February to June (estimated time saving in brackets)*

Milking	Calf care
One person in the milking pit during mid lactation (-3.0 h/cow)	Contract heifer rearing pre-weaning (-0.8 h/cow)
Automatic cluster removers (-2.6 h/cow)	Automatic calf feeders used once calves were trained and grouped (-0.7 h/cow)
Milker not leaving the milking pit to feed calves during milking (-1.3 h/cow)	Bull calves not reared on farm (-0.7 h/cow)
Ability to operate cow exit gates from any point in the pit (-0.9 h/cow)	Group feeders used to train calves (days 1-4; -0.5 h/cow)
Using a quad/ jeep when herding cows to and from the parlour (-0.9 h/cow)	

Additionally, contracted slurry spreading was estimated to improve labour efficiency by 1.8 h/cow.

Conclusion

This study demonstrates that there are a wide variety of work practices/ technologies available to farmers that can increase labour efficiency. When accumulated these practices/ technologies have the potential to have a large impact on labour demand. Additionally, many of the work practices included required minimal capital expenditure and focused on improved work organisation, and so should be relatively easy to implement. There remains scope to increase the adoption of these work practices/ technologies on-farm with even the most labour efficient farms implementing only 63% (37) of the 59 associated with labour efficiency. The full list of labour saving work practices/technologies is available online.

Milking interval effects on milk yield

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Summary

- Milking interval had no effect on milk kg per cow or SCC.
- There were a large range in evening milking finish time. Average milking finish time in study herds was 18:43 across the year. This a key issue for attracting and retaining people in the industry.
- A 16:8 hr milking interval will help shorten the standard working day on farms.

Introduction

Farm structure in Ireland has seen a dramatic change in recent years. The traditional owner-operator plus additional family help model that previously could manage an average herd size is finding it increasingly challenging to cope with increased herd size. The sustainability of dairy farming increasingly relies on recruiting people to work on farms. However, farmers need to be able to provide employment opportunities where pay and conditions of work are at least as attractive as alternative careers. Previous studies with dairy farm employees have found that hours worked on dairy farms can make these employment opportunities unattractive. Evening finish time was cited as the critical issue for employees. As Irish farms are competing with industries that typically offer a 5-6pm finish time this is an area that needs to be examined.

Data

Milk recording data from 2,366 herds across 23 counties over a one-year period (2020) were analysed. Across all herds, the mean PM milking finish time was 18:43 and the length of the working day was nearly 12 hours, however, there was large variation between herds with PM milking finish time ranging from 16:39 to 23:22 and the length of the working day ranging from 8.5 hours to 16.4 hours.

Table 1. *Mean milking time from 2,366 herds recorded during 2020*

	Mean time
Start AM	07:23
Finish AM	08:55
Start PM	17:14
Finish PM	18:43
Total hours spent milking (hrs)	02:58
Milking interval (hrs)	09:48
Average herd size	118

Relationship between milking interval and milk kg/cow/day

Milking interval is defined as the time from when the first cluster goes on in the morning to the time the first cluster goes on again in the evening. To reduce the length of the working day in a twice daily milking scenario, previous research has shown a 16:8 hour interval split is feasible, for example morning milking start time of 07:00 and 15:00. However, in this study the mean milking interval was closer to 10 hours (Table 1). One of the reasons for having a longer milking interval in the evening is the legitimate concern of reducing milk kg per cow. However, data collected on commercial herds for the current study showed no relationship between milking interval and daily milk yield (Figure 1). Milking interval had no effect on SCC.

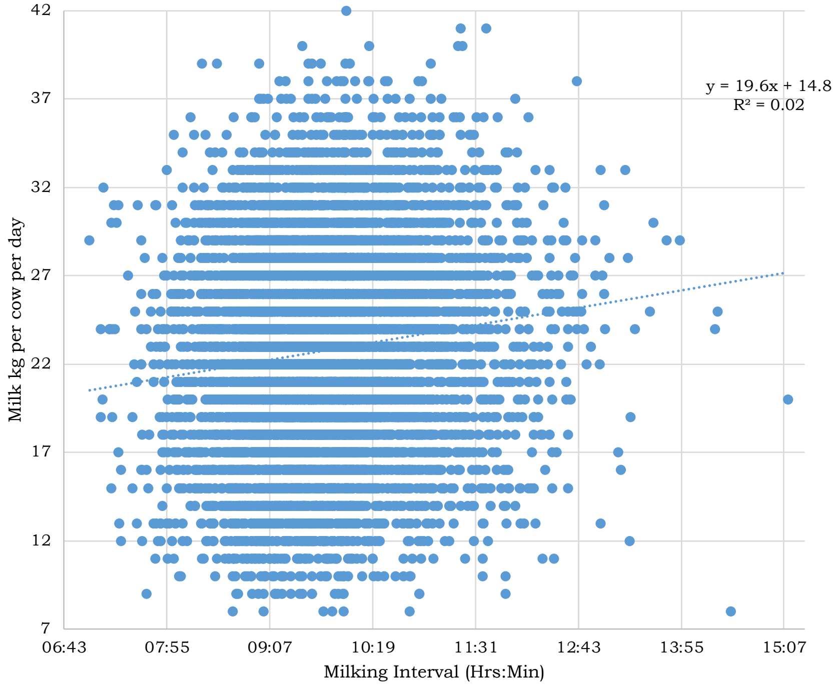

Figure 1. *Relationship between milking interval and milk kg per day*

Seasonal variation in milking time

A demanding daily workload is understandably cited as a reason why milking times cannot be changed on many dairy farms. Previous labour studies have shown that spring is the busiest time of the year for spring-calving herds. With this in mind one might conclude that milking intervals could potentially be shortened later in the season. However, our analysis found that there is very little change in mean milking interval by season; averaging 09:48 in spring, 09:51 in summer, 09:46 in autumn and 09:45 in winter. This suggests that longer milking intervals are fixed and habitual on many farms, rather than being dictated by workload.

Practical implications

Regardless of herd size, some adaptations to work routine may need to be made to ensure a good quality of life for both farmers and employees. A long milking interval is a driver of late PM milking finish time and long working days. Reducing milking interval in line with the 16:8 target interval has no effect on milk kg per cow per day. This provides an opportunity to shorten the standard working day on farms with no milk yield loss. This has benefits for the farmer and potential employee alike. Reviewing how work is organised and executed on the farm is crucial to changing milking interval.

Reducing milking frequency – effects on milk production and cow welfare

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Summary

- Milking frequency can be adjusted to provide more flexibility for farmers.
- Full-time once-a-day (OAD) milking ßreduced milk yield by 26% and milk solids yield by 21%.
- New research has started in the area of 10 times per week (10in7) milking compared to twice a day milking.

Introduction

The current perception of work on dairy farms in Ireland is one of long hours and physically demanding work. Creating desirable places to work will be among the main factors in attracting and retaining people to work on Irish dairy farms in the future. Milking is the most labour demanding task on Irish dairy farms and one which necessitates farmers being present on the farm twice daily if milking twice-a-day (TAD). Altering milking frequency could provide more flexibility for farmers and allow for a better work life balance, potentially making dairy farms more attractive workplaces. However, changes in milking frequency must consider a number of aspects before they can be recommended (e.g. milk production, cow health and welfare).

What is flexible milking?

Flexible milking is a term given to milking intervals that differ from TAD milking. It refers to flexibility in both the timing of the milking during the day as well as the number of milkings in a week. Milking once-a-day (OAD) is one flexible milking option to reduce farm labour requirements and increase flexibility as milking can occur at any time during the day, as long as it is the same time each day. Other options are milking three times in two days (3in2) which can provide increased flexibility for farmers without the milk production losses experienced with OAD. In this scenario milking interval can be, for example, 10-19-19 hours or 12-18-18 hour intervals. A third option is to milk ten times in one week (10in7), which could provide improved flexibility and minimise milk production losses compared to OAD, while employing a more structured and socially appealing milking routine (Table 1).

Table 1. *Example of a 10in7 milking schedule compared to twice-a-day milking*

	Milking	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
10in7	AM	7	9	7	9	7	9	7
	PM	3		3		3		
TAD	AM	7	7	7	7	7	7	7
	PM	3	3	3	3	3	3	3

Once-a-day milking

A three-year study to examine the effects of OAD milking on cow production was undertaken recently at Teagasc, Moorepark. On average across the three years milk yield was 26% less and milk solids (kg fat + kg protein) was 21% less than cows milked TAD (Table 2). While the OAD cows had a shorter lactation length (-10 days) and higher somatic cell count (+16%), there were positive aspects associated with OAD milking such as improved bodyweight, body condition score and fertility performance (Table 2). There was also no difference in locomotion score between cows milked OAD and TAD. Compared to the TAD cows, total dry matter intake for OAD cows was 22% less at the start of lactation, but as the lactation progressed (>167 days) there was no difference in DMI between cows milked OAD and TAD. Milking OAD also reduced overall milking time leading to reduced farm labour input, which can have positive implications for farmer work life balance. This potential time saving should be considered in conjunction with the milk production reduction when considering OAD milking for the entire lactation.

Table 2. *Milk production, body weight and body condition score and fertility performance of cows milked once-a-day (OAD) and twice-a-day (TAD) over a three year period*

	OAD	TAD
Milk yield (kg)	4,162	5,647
Milk solids yield (kg/d)	387	493
Milk fat (%)	5.35	5.05
Milk protein (%)	3.97	3.78
Milk lactose (%)	4.50	4.68
Lactation length (days)	285	294
Average bodyweight (kg)	529	496
Average body condition score	3.28	3.05
Pregnant to first service (%)	61.9	44.7

Milking 10 times per week

Last year a new study was undertaken at Teagasc, Moorepark – it investigated i) milking 10in7 for the full lactation, ii) milking TAD for the first half of lactation, switching to 10in7 for the second half of lactation (i.e. from 4th July; 20 weeks into lactation) and compared their performance to iii) cows milked twice-a-day for the full lactation. Initial results show that milking 10in7 for the full lactation reduced milk yield by 10% and milk solids yield by 11%. Interestingly, when cows switched from TAD to 10in7 half way through the lactation their production was the same as cows milked TAD for their full lactation. Milking cows 10in7 for the second half of lactation would have positive effects in terms of labour, water and electricity savings.

Conclusions

Milking frequency can be changed on farms to reduce labour input and improve work life balance. However, the longer the period of reduced milking frequency the greater the milk production losses. Therefore, the degree to which costs can be reduced to offset losses in production needs to be considered before altering milking strategies.

Part-time dairy farm employees – developing mutually beneficial working relationships

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Summary

- To remain competitive with other sectors, it is necessary for dairy farms to become more attractive workplaces, and to meet the changing career-lifestyle expectations of the available workforce.
- Current and prospective employees perceived salary, working conditions, facilities and seasonality of workload as barriers to employment on dairy farms.
- Successful part-time working arrangements at farm level featured regular work hours, close proximity to the workplace, clearly defined roles, and employee growth within the role.

Introduction

The increase in dairy farm scale since milk quota abolition has created new employment opportunities within the Irish dairy industry. Many people in local communities hold skills and aptitudes that are compatible with part-time work roles on dairy farms, however, embedded perceptions may be limiting employment opportunities from both the employer and employees point of view. A study was undertaken to identify employees' perceptions of employment on dairy farms; this was conducted through semi-structured interviews with current and previous farm employees, including students and part-time farmers. A second objective was to determine how dairy farms can become more attractive workplaces for employees. This involved examining case studies of part-time employment scenarios on farms, to determine how they could be structured to mutually benefit the employer and employee.

Perceptions of dairy farm employment

Prospective employees identified a number of negative perceptions that would deter them from pursuing a career on a dairy farm. Some negatives related to industry-wide issues (e.g., the lack of social relationships when working on farms) but others could be addressed by the individual farmer (e.g., facilities). Four key challenges identified were:

Salary – Prospective employees identified the perceived poor salary as a deterrent to dairy farm employment. It was clear that getting paid for a defined time or specific task was important. Additionally, there was often an expectation of being asked to do additional tasks on a given day without being remunerated accordingly. "*The problem about being employed by a dairy farmer is that you go to do the milking and that's what you're getting paid for and then all of a sudden they want you to do more, but you're not getting paid to do it*".

Working conditions - The relatively small scale of farm workplaces compared with competing sectors where multiple employees could be present was another negative for prospective employees. The importance of social relationships in the workplace should not be underestimated and consideration should be given to the relationship between employer and employee when recruiting farm staff. "*If you're on a building site, there are more employees, so there is a more even spread of the workload and a bit of craic. On a dairy farm, it may just be the farmer and the employee, which can be a bit intimidating for the employee.*"

Seasonality of work – Many of the interviewees perceived jobs on dairy farms to be short-term due to the seasonal nature of workload on many farms and this was highlighted as a negative to dairy farm employment. *"I see jobs advertised where dairy farmers want lads for calving during February or March. Who is going to turn up for a month's work and have nothing then after?"* Prospective employees stressed the permanency of similar work in factories as an advantage over dairy farm employment *"My job in the factory is permanent. I know my hours every week and it's as simple as that."*

Facilities - Inadequate facilities were highlighted as a limiting factor when considering employment on dairy farms. There was a perception from some prospective employees interviewed that they would be spending too long milking due to insufficient milking facilities. *"You don't want to be there milking 12-15 rows of cows, morning and evening every day. Over 10 rows or over two hours in a pit is too long".*

Factors for a successful employment relationship

A number of factors were identified which could contribute to a successful employment relationship.

Regular working hours - There was a clear desire for fixed start and finish times for employees so that they could plan their day around these times. *"From the employee's point of view, having a set end time to the day is important. Rather than finishing at six one evening and half seven the next."* Regardless of the number of hours worked per week, part-time workers required work over the full duration of the year. Sufficient time and planning should be given to rostering the employee's desired hours as tasks change over the course of the year.

Proximity - A contributing factor to the success of dairy farm employment arrangements was the close proximity of the employee to the dairy farm. Working in a local area reduced commutes to work for the employee and allowed them to go home during the day if necessary. From one case study the employer highlights the benefits of this for a part-time employee. "*I think it works well for him also, he only lives 15 minutes down the road. He has a set rota and knows his own hours and can do his own work during the day".*

Clearly defined roles - It is particularly important in part-time working arrangements that roles are clearly defined or task-specific. Vague job descriptions are a contributing factor to staff turnover. Where a working arrangement is task specific it is important that the employee is not asked to perform additional tasks unless otherwise agreed in advance.

Growing over time - With part-time scenarios, long-lasting working relationships were found to have started small and developed over time as the relationship and trust developed between the employer and the employee. *"I started off there doing four milkings a week and now it's double that. I suppose I got more familiar with the place and he got more familiar with me and approached me to do a few more and it's working well".*

Conclusions

The study identified a number of factors that would make workplaces more attractive for prospective employees. Successful part-time working arrangements at farm level featured factors such as regular work hours, close proximity to the workplace, clearly defined roles, and employee growth within the role. These are important success factors in the observed arrangements, as they are mutually beneficial to both the employee and the employer.

Employment practices for good people management

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Summary

- Good employment practices are necessary to attract and retain people working on farms.
- Word of mouth was the most commonly used method to recruit farm employees.
- Low compliance for legally required employer obligations expose farmers to difficulties in managing employee performance, disputes, and legal action, resulting in financial penalties and/or reputational damage.

Introduction

Traditionally, dairy farmers have relied on family members to assist with the labour needs of the farm on an informal basis. However, family labour is not as readily available as it once was for a number of reasons including farm succession issues and more family members pursuing alternative careers. This has led to an increased demand for farm employees, and many farmers are becoming employers for the first time. Employing staff requires the implementation of certain practices to comply with employment law while good people management creates a happy work environment, increases employee motivation and commitment to their employer. This study aimed to examine the prevalence of people management practices on Irish dairy farms.

Method

Three hundred and fifteen dairy farmers (representative of location and herd size) were surveyed regarding employment practices. Herd size ranged from 25 to 700 cows. Participation in the survey was voluntary, and the responses were collected by post or by phone.

Results

Of the 315 farmers surveyed, 64% were employing people on their farms: 37% employed one person; 17% employed two people; and 10% employed three to five people. The remaining 36% had no employees. A total of 286 people worked on 64% (n=203) of the farms surveyed, farm assistants were the most common type of worker employed. Respondents reported that 57% of the people working on their farms were employed full-time while 43% of staff were employed on a part-time/casual basis. Eighty four percent of the employees were male. Average age of employees was 42 years.

Figure 1 presents the variety of methods used by the farmers surveyed to recruit employees. Some farmers used more than one method, and word of mouth was the most commonly used method. By using a variety of recruitment methods, farmers are ensuring their jobs are advertised to a wide network of people. In the future, dairy farmers will need to attract a larger and more diverse talent pool such as urban dwellers looking for a career change. To search for these less traditional farm employees, a variety of innovative recruitment methods will be required.

Farm employers with employees external to the family have legal obligations as employers and are required to comply with employment law by formalising certain practices. Examples of practices required by law include issuing contracts of employment, issuing and retaining copies of payslips and recording employees' time, among others.

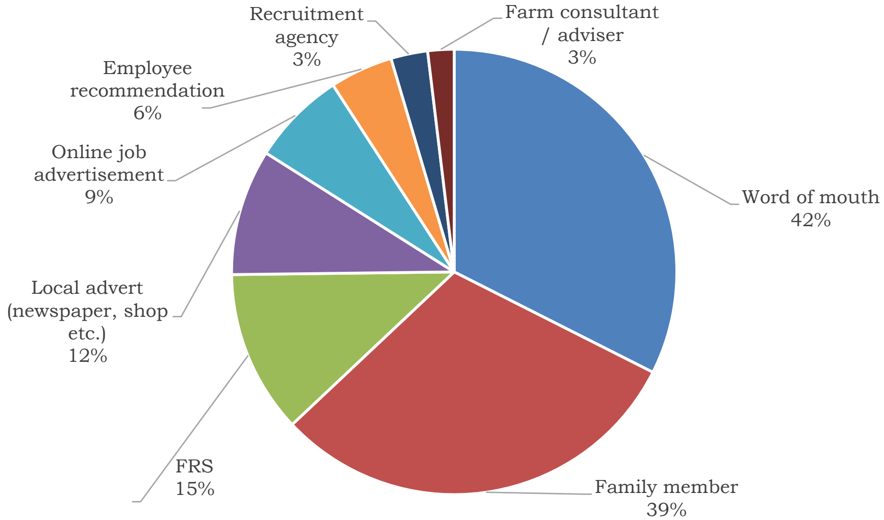

Figure 1. *Variety of methods used by farmers surveyed to recruit employees*

Presented in Table 1 are the legally required people management practices implemented by survey respondents. The lowest compliance rate were observed in relation to the completion of employee detail forms with 9.4% of respondents indicating that they have this in place. Non-compliance can lead to negative consequences for farmers such as difficulty managing employee performance, disputes, and legal action, resulting in financial penalties and/or reputational damage. Overall, the low compliance with the employment law in this study suggests that room for improvement exists. Failure to comply with employment law can leave employers exposed to inspections and fines from the Workplace Relations Commission.

Table 1. *Legally required people management practices implemented by the survey respondents who were employers*

Item	Number of respondents (n)	Percentage of respondents (%)
Contracts of employment	24	11.8%
Employee detail forms	19	9.4%
Payslip retained after each payment	38	18.7%
Payslip issued after each payment	38	18.7%
Employees time recorded	54	26.6%

Further analysis indicated that herd size, herd size change over five years, and number of employees on the farm is positively related to legal compliance. This suggests that larger farms with more employees tend to be more compliant with legal requirements.

Conclusions

Having the legal employment practices in place will ensure a good start to the employment relationship as well as help protect the business should the relationship become strained. Prioritising the legal employer obligations is essential to ensuring dairy farmers become attractive employers.

Opportunities in collaborative farming arrangements

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Summary

- Farm partnerships provide a business model for farmers within a family situation or can be used to amalgamate farm businesses in a non- family scenario.
- Share farming creates entry opportunities to farming for young farmers who have no land and is an option for farmers with no successor who wish to step back or retire.
- Long term land leasing provides security of tenure for the lessee, whilst allowing beneficial tax free income incentive up to the relevant thresholds.

Introduction

Collaborative farming arrangements such as registered farm partnerships, share farming, long term land leasing and contract dairy heifer rearing are attractive options for young farmers to enter the dairy industry. Alternatively, there are also farmers who have no identified successor and are ready to step back or retire. This paper will explore the options to pursuing a farming career through collaborative arrangements.

Registered Farm Partnerships (RFP)

In some family farm scenario's, parents may not currently be in a position to transfer the farm to a child. There are often concerns such as total family income, security for parents and family members who still have to be provided for. These concerns can be alleviated by forming a registered partnership as an interim step before succession. The benefits for the parents is that they are not giving up full control; they are sharing it with their child. Ownership of land, buildings, etc. are retained and are licensed for use by the RFP. Stock and machinery become partnership assets. The partnership allows the son/daughter to have input into the decision making and management, giving them the experience of running the farm through an agreed profit sharing ratio. Often RFP's are an interim step before considering full transfer of the farm at a later date. In this way, family partnerships are an excellent way to formalise the succession process.

In the context of non-family situations, two or more farmers can combine their respective dairy farming operations into one single operation as a partnership. A consolidated business may offer the opportunity for increased scale and efficiency, make better use of existing facilities, and avail of a wider mix of skills. When two or more people come together, they can bring different knowledge/skills to the business and contribute to improved work life balance through better workload distribution.

Tax incentives for the formation of registered farm partnerships - Depending on profit share, income tax at the low rate may be maximised. Succession farm partnerships can provide an annual income tax credit of €5,000 for up to five years. Young trained farmers are eligible for 100% stock relief in the first four years and enhanced stock relief is available to other partners in the RFP at a rate of 50%.

On-farm investment and direct payment schemes - RFP's may qualify for a double TAMS grant investment ceiling. A qualifying young trained farmer may qualify for 60% grant aid, and may receive a Complimentary Income Support for Young Farmers support payment for a maximum of 5 years. This payment is circa €170 per hectare on up to a maximum of 50 hectares.

Share farming

The key feature distinguishing share farming from a partnership is that two completely separate farming businesses operate on one land block; the business of the landowner, and the business of the share farmer. In a share farming agreement, the risks/rewards, and farm inputs/outputs are shared on an agreed basis. Each person must complete their own financial plan for their own respective business to ensure the business is financially sustainable. The benefit of a share farming agreement is for older farmers that are not ready to retire and want to continue farming. They can enter an arrangement with a younger person to share the workload, income and costs. The young motivated person will bring attributes such as new skills, a strong work ethic, modern technology and a desire to develop a profitable enterprise. Both parties have a vested interest in the overall farm business. Share farming allows a young person an entry point to farming and opportunity to build their own independent business rewarding their ability and efficiency.

Long-term land leasing

Long-term land leasing is a growing feature of Irish farming mainly due to the income tax incentives available to the owner of the land. Changes in relation to Capital Acquisitions Tax have also helped to make land available to active farmers under lease rather than the inheritor farming it themselves. The key benefit to the lessor is that the income received from a long-term land lease and the value of any Basic Income Support for Sustainability (BISS) Entitlement is tax free subject to the limits in Table 1. These limits can be doubled where land is jointly owned.

Table 1. *Income tax free thresholds for different lease lengths*

Term of lease (years)	Maximum tax free income/year (€)
5-6	18,000
7-9	22,500
10-14	30,000
>15	40,000

The lessee can also benefit from the arrangement as the long-term nature of the lease provides security of tenure to expand their business, make future plans and undertake capital expenditure on the land if term and rental price allow.

Contract dairy heifer rearing

For contract rearing to be successful, it has to be a WIN:WIN scenario for all parties involved. The main advantages to the dairy farmer include, the opportunity to milk more cows on the home farm, reducing groups of stock, easing nitrates regulations and providing more land, labour and facilities to the dairy business. The rearer needs to get paid adequately to cover variable and fixed costs whilst also leaving a margin to cover their land, labour, facilities and management. Advantages to the rearer are, cash flow is regular, no money is tied up in stock, and the risk of volatile beef price and markets are removed. The dairy farmer requires a heifer returned in calf, well reared and in good condition. Good communication, honesty, trust and regular contact to make key decisions on the heifer's progress are essential to the success of contract rearing.

Conclusions

Collaborative arrangements are options to encourage young farmers into dairying. Each arrangement requires excellent planning, and sound financial and legal advice. Specimen template agreements for all the collaborative arrangements featured in this paper are available on the Collaborative Farming section of the Teagasc website at www.teagasc.ie/rural-economy/farm-management/collaborative-farming.

Farm succession planning – taking a team approach

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Summary

- The decision to step back and transfer the farm is a significant lifecycle decision for both the farm family and the farm business.
- Clarity around expectations of family members is an important first step.
- Specialist advice is required at every stage in the process.
- A co-ordinated team focused approach can be used to streamline the process.

Introduction

Dealing with the issue of the transfer of the farm is one that every farm family will eventually have to address. This will often involve decisions around the changeover of management responsibilities as well as the transfer of both farm assets and other assets. It is vital that good advice is sought and acted on in relation to these various issues to ensure that the changeover happens as smoothly as possible. The main sources of guidance are professional advisors that farmers and their families can call on such as their accountant, solicitor and agricultural advisor.

First steps

The first key step to start the process of a farm transfer, and a vital step to ensure you get the result you want, is to sit down as a family and decide what a successful farm transfer will look like when it is completed. Issues such as who will assume overall management responsibility for the farm after the transfer, and how will the farm and non-farm assets be apportioned as part of the transfer process should be discussed by all family members affected. An important issue for the retiring generation is how they intend to meet their income needs following their step back from the farming business. If general agreement can be reached in relation to some of these bigger elements of the transfer process then this will greatly assist in getting focused and relevant advice from the various professions later.

Engaging with professional advisors

Early engagement with your agricultural advisor for guidance can be helpful to scope out key issues. Most advisors will be aware of many previous farm transfers and can provide useful advice as to what has worked well and what could cause problems. The advisor also has valuable experience regarding the income-earning potential of a farm business, which can be useful if there is another person coming in to the business with a requirement to earn a living from the farm or with expansion plans. Advisors have excellent knowledge of farm schemes, issues around the transfer of EU entitlements as well as potential tax and scheme benefits available from having a young trained farmer involved in the business. A meeting with the advisor prior to meeting the other professionals can be useful in setting out the main items on which advice needs to be sought from tax, legal and other experts.

Specialist advice in key areas

Tax is an area that is often of most concern as people are wary of triggering an unexpected tax bill for either themselves or their next of kin as a result of any transfer. Taxes such as Capital Gains Tax, Capital Acquisitions Tax, Stamp Duty and even Income Tax and VAT could potentially be triggered by a farm business transfer. Matters associated with the years of ownership and years of use of assets for farming purposes, the value of agricultural assets held by the parties to transfer as well as the ages of the parties involved could affect the final tax position. Many of the transfer tax issues can be managed satisfactorily once proper tax planning is completed in advance of any transfer. With many farms now operating using a company trading structure, specialist advice is vital to facilitate a smooth farm company succession transfer. Advance planning and reconstruction of the company structure may be required to ensure that the company can continue trading in the hands of the successors without significant tax leakage. The accountant/ tax advisor is the obvious port of call for guidance in relation to these complex tax questions.

From a legal perspective, solicitors have a vital role in checking ownership title as well as advising on changes to any proposed farm business ownership structure whether that is as individuals, partners or, as is becoming increasingly common, as company directors. There may also be input required in the process from an auctioneer and also the farms bank manager if there is significant debt at the time of the transfer.

Farm succession team

An approach, which can work well, is to bring all the individual professionals together to meet the family at a dedicated meeting to discuss the likely implications of the transfer and explore all possible options for achieving the family's desired outcome. The ultimate aim is to get the preferred transfer completed with the minimum of fuss, while ensuring that the potential tax, legal and farm scheme issues are dealt with satisfactorily. The agricultural advisor can assist the family in drawing up an outline of what the transition of the management of the farm and the transfer of assets would look like when completed. The family are then in a better position to arrange a Farm Succession Team meeting with all of their professional advisors in one focused meeting (Figure 1).

Figure 1. *Example of professional advisors required for a farm succession team meeting*

During the meeting the advisor can take on the role of meeting facilitator, main note-taker and provide guidance on the agri-scheme aspects. The individual circumstances of each family member can be examined from a tax, legal and farm scheme perspective to ensure that the transition can be completed to the maximum advantage of the family members. A clear plan of action can then be created with follow-on appointments set up with the solicitor, accountant and agricultural advisor in sequence over the following months to complete the transfer.

Farm apprenticeships: a new approach to agricultural education

Alison Sinnott[1,2], Marcella Phelan[1], Emma-Louise Coffey[1,2] and Frank Murphy[1]

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Summary

- Teagasc will be introducing two new apprenticeship programmes in September 2023; the Farm Technician Apprenticeship and the Farm Manager Apprenticeship.
- The current Advanced Certificate in Dairy Herd Management and new apprenticeship programmes will support the next generation of dairy farmers in the development of their skills and technical knowledge.

Introduction

As the dairy industry navigates through current and future sustainability challenges, the need for skilled people to work on farms is more essential than ever before. The Irish dairy industry is reliant on skilled farmers who have the ability to cope with such changes as well as managing financials, people and day-to-day farm tasks. Subject to QQI validation and legislation approval, and in addition to existing courses, Teagasc will introduce two new apprenticeship programmes in September 2023 for people interested in pursuing a career in agriculture. Both programmes are inclusive of all agricultural sectors (including dairy, pigs, poultry, drystock and tillage).

Advanced Certificate in Dairy Herd Management

The current Level 6 programme will continue to provide graduates with the knowledge and technical skills required to operate dairy herds. Following one year in agricultural college, students typically spend a further 16 weeks in college and 16 weeks of practical learning placement with a host farmer in Ireland or abroad. Course content is a combination of technical and farm business planning modules. Successful completion of the Level 6 programme will see individuals join the dairy industry as a skilled operative or go on to complete the Farm Manager Apprenticeship.

Apprenticeship learning experience

The main component of both apprenticeship programmes is two years of work-based learning employment, where apprentices are based on one specialist farm in Ireland, in their sector of choice. Apprenticeship employers must be screened and approved by both Teagasc and SOLAS. During these two years, there are approximately 10 weeks of course days per year where apprentices further develop a broad range of skills in technical farming and farm business planning. Course days will be delivered at the coordinating Teagasc College, industry locations, and online. It will incorporate both formal (lectures) and informal (discussion groups and skills practicals) training, delivered by an integrated team of highly specialised Teagasc staff, including researchers, college teachers and specialists. Guest lecturers will also be invited, such as key industry stakeholders and successful commercial farmers.

Farm Technician Apprenticeship

The Higher Certificate Level 6 Farm Technician Apprenticeship provides individuals with the knowledge and technical skills required to operate within farming systems. Individuals who successfully complete the Farm Technician Apprenticeship will be skilled in compliance with industry standards and regulatory measures. Learners will be equipped with skills to manage the daily operations (e.g. animal and grassland management) as well as recording and administrative activities, farm planning and business performance evaluation. Progression from the Level 6 programme includes the Teagasc Farm Manager Apprenticeship.

Farm Manager Apprenticeship

The Ordinary Bachelor Level 7 Farm Manager Apprenticeship will be the gold standard for farm management and farm ownership training in Ireland. The programme aims to equip trainee farmers with management skills to successfully run farm enterprises. Successful completion of this course will see individuals take responsibility for all farming activities including work organisation, income and expenditure, strategic planning, compliance, safety, health and welfare management, and human resource management.

Joining Apprenticeship Programmes

Entry requirements for the Farm Technician Apprenticeship will be published once approved. For entry into the Farm Manager Apprenticeship, individuals must have a Level 6 Advanced Certificate in Agriculture or have completed the Farm Technician Apprenticeship. An individual may then apply for employment on an approved employer's farm. Following this, both employer and apprentice will approach Teagasc to express interest in part-taking in the apprenticeship programme. The employer will pay a salary of at least minimum wage to the apprentice for the duration of the apprenticeship programme.

Conclusion

The next generation of farm owners and managers should avail of every accessible training opportunity in order to acquire knowledge, skills and experience to secure the long-term future of their dairy business. Experience with excellent farmers reinforces learning experiences and offers a network of people and mentors that can make a significant positive contribution throughout a future farmers' career.

Building resilience into sustainable dairy farming

Abigail Ryan
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Summary

- Resilience is the ability to withstand or to recover quickly from various challenges.
- Participants thought that most of their group meeting is too focused on technical information, and not on subjects such as risk management and resilience.
- Planning and prevention strategies to mitigate risks associated with reducing resilience issues were highlighted as important by participants.
- Building support networks such as family, friends and discussion group members is important to manage and strengthen resilience.

Introduction

Resilience is the strength that people are able to call on in times of need to carry them through life and work without the whole system falling apart. To build meaningful resilience it must be practiced regularly, and should be seen as an investment, similar to other skills such as grassland, stock and people management. Individual farmer resilience is influenced by numerous variables such as the farmers own health, network, financial security and job satisfaction.

The 4 S's of resilience

The 4 S's of resilience are Supportive, Strategy, Sagacity and Solution-Seeking behaviours. Using the 4S model helps strengthen resilience.

- *Supportive* is where you build a strong network of people such as family/friends, discussion group members, advisors, etc. for support or guidance.
- *Strategy* is building a defence mechanism to make the farm business robust, examples include doing the weekly grass walk, preparing a business plan, and choosing the right genetics to guarantee herd sustainability.
- *Sagacity* is about learning from challenges in the past, such as lessons learned from your own business or a discussion group member.
- *Solution-Seeking behaviourism* involves exploring solutions, and could involve learning new skills and engaging more with the farm network team.

There are many on and off farm situations that will increase or decrease farm resilience from day to day. Building resilience is about understanding how best to manage each problem and maintain a positive attitude. Examples such as calf health, TB restrictions, prolonged periods of very dry or wet weather, workload management, personal health, family challenges are some areas that can be triggers to supress or build resilience according to farmers. Learning how to include resilience practices and or technologies to avert these risks can further enhance the farm business.

Farmers need to develop their dairy farm system so that they are flexible to respond to certain uncertainties. Discussions on key aspects such as how workload and time is managed, including who will do each task, the correct stocking rate for the farm and assessing farm facilities can identify actions or strategies that may help the farm bounce back quickly or eliminate the risk completely.

Results of the case study survey

In 2023, 40 dairy farmers were surveyed to understand their own resilience. Farmers were members of one of two discussion groups, which either expanded or converted their farms to dairy since the abolition of milk quotas. The majority of participants were reaching and surpassing the best industry key performance indicators. The average herd sizes of the two groups were 381 cows (expansion group) and 245 cows (dairy conversion). The average milking area stocking rate was 3.2 cows/ha in both groups. In 2022, the dairy expansion and dairy conversion discussion group grew 12 and 12.6 tonnes grass DM/ha, respectively.

Main findings of the Survey

- Unanticipated durations of wet or dry weather had the biggest effect on their resilience over the past year.
- The other top resilience testing issues were calf management, long hours worked in spring, labour issues and the stress of future policy changes.
- Since conversion/expansion 87% of farmers had strengthened their support team.
- From 1st February to the end of April 58% had three days off, while 25% of respondents had no day off.
- When participants found things stressful, they called a family member/friend or a discussion group member. Worryingly, 9% said they did not contact anybody.
- There was no one size fits all for the factors that strengthened the farmers' resilience. Suggestions included building a strong network, looking after themselves, knowing the right system for their farm, building cash and feed reserves, improving facilities and experience.
- A high percentage (87%) of the two groups had a social network for their off-farm interests.

Conclusion

Resilience is another skill required to make dairy farms more robust. More training in developing resilience skills is required to create fully sustainable farm businesses. The question is can the Irish discussion group model deliver on resilience training for members. It was clear that more discussion is required on resilience to create a fully sustainable farm business. Discussion group training can build awareness among group members about resilience and allow members to identify if resilience is weakening on farms. It is important for each farmer to realise his or her own resilience capacity as expansion or dairy conversion may not be for everyone.

Potential roles for spouses/partners within the farm business

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Summary

- Farmers' partners bring a diversity of backgrounds, skills, knowledge and perspectives and in most cases are beginning to see how they can strengthen and develop their role within the business.
- Taking part in a management course changed how the partners viewed the farm, moving towards seeing the farm as a jointly operated business rather than something that their spouse did and one in which they could play a pivotal role regardless of their technical farm knowledge.

Introduction

Most farmers partners have off-farm careers when 'marrying into' the farm, yet they play an important role in terms of financial contributions and work on the farm. The importance of farm couples working together to determine the direction of their joint life and business is increasingly recognised as a critical factor in the success of a family farming business. Despite the importance of their role, a previous Irish study found that there is poor engagement among farm women with advisory services for a number of reasons including: the feeling that women wouldn't be taken seriously; that they are unwelcome; lack of self-confidence; lack of knowledge and training; and isolation. The aim of this study was to understand the role of farmers' partners within the family dairy farm business.

The research undertaken for this study was focused on farmers' partners participating in the pilot learning initiative - an online training course developed by two independent consultants that was specifically designed to engage dairy farmers' partners/spouses. A questionnaire survey of the participants was conducted at the start of the programme. The questionnaire was anonymous, but participants were asked to give contact details if they were willing and interested to take part in a follow-up interview.

Results

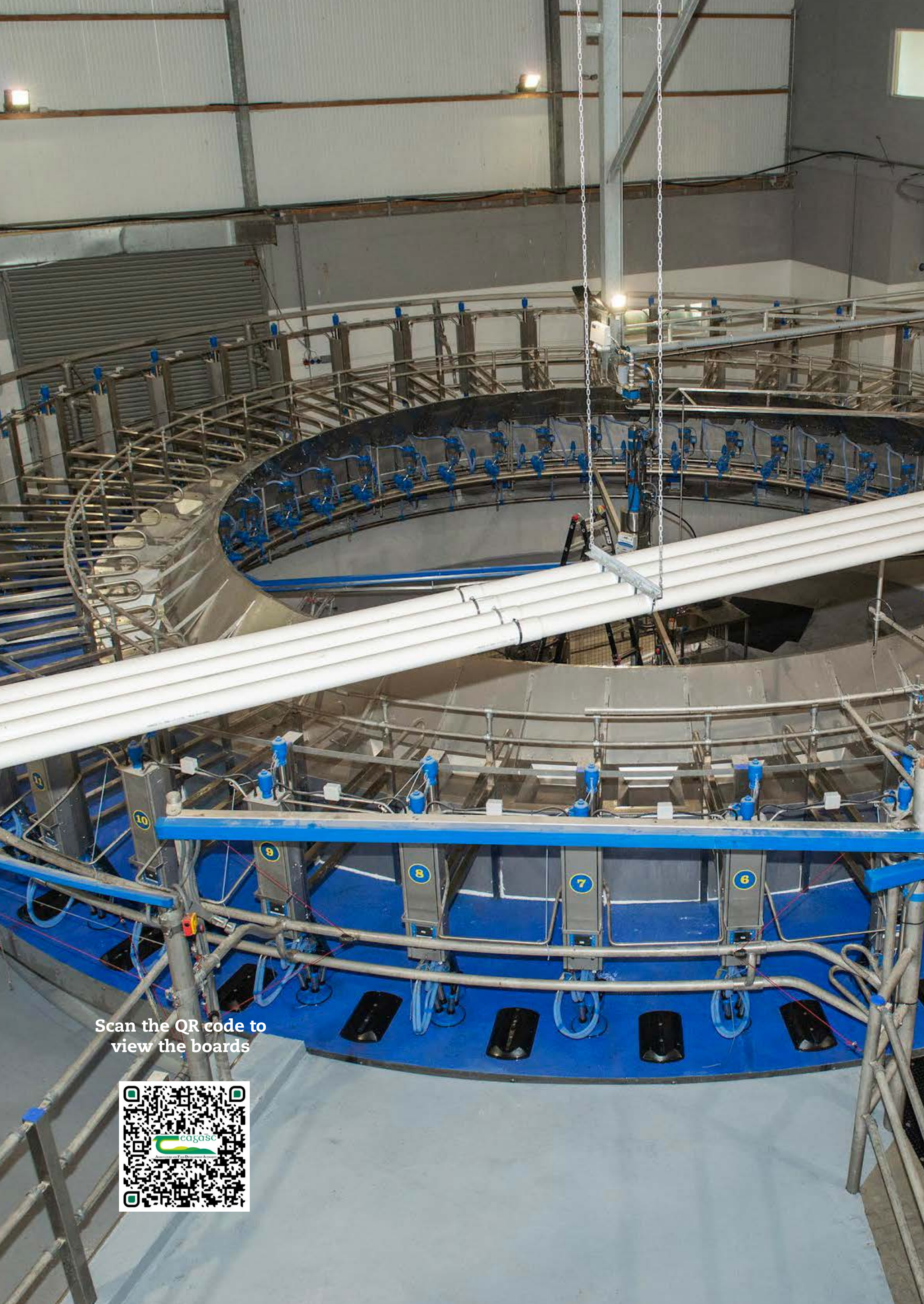
Twenty-one participants completed the survey; they were all female with a diversity of backgrounds and backstories. The majority of participants were from a non-farming background, with 37% from a rural area, 36% from an urban area while 27% were from a farming background. Sixty-four percent of the participants had a part-time or full-time off-farm job in a variety of careers, including teaching, science, law, banking, childcare, and environmental services. Their off-farm incomes were contributing to household expenses, savings and investment and farm expenses. Participants included young, recently married women with no children, women with small and school-age children and older women with grown-up children. Their (partners') dairy farm businesses were larger than the average Irish dairy farm. All of their farms employed non-family labour with a mix of part-time and full-time employees. The participants' individual length of involvement on their farms varied from newly being involved to being involved more long-term. When asked to describe their current role on farm, participants identified a wide range of roles but mainly focused around business rather than physical/technical tasks. Many of the participants were involved in more than one task, highlighting the diverse role that farm partners play in the business. Administration and business tasks included farm planning, decision making, ordering supplies, dealing with DAFM schemes, farm accounts (including liaising with banks and accountants) and paperwork tasks (e.g., calf registrations, record keeping and form filling). Human resource management tasks included ensuring health and safety, coordinating/feeding staff, dealing with callers, and payroll. Calf rearing and milking were the physical tasks some completed regularly, while other physical farm tasks they completed occasionally included repairs and maintenance, grassland management, operating machinery and animal care.

Analysis of the interviews revealed similar trajectories in terms of role development. They all 'married in' to the farm business and before marriage considered the farm and farming to be 'his job' while they had their own separate careers. Some who came from farm backgrounds felt that this prepared them better for the realities of dairy farm life. Other interviewees recalled their shock at the busyness of the calving season and the realisation that in-laws often had expectations of them in terms of bookkeeping and family care responsibilities. For some, the arrival of children meant the juggling of many responsibilities as well as a struggle regarding their professional identity. In the majority of cases, women carried the responsibility for childcare and domestic tasks. Many spoke about questioning what their role was on the farm in light of competing demands on time and giving up their off-farm jobs – a 'crossroads' as one interviewee called it. A pivotal point in the majority of cases was a decision to take part, as a couple, in a strategic management course facilitated by the same consultants who developed the partners' programme. The outcome of this was an overarching reorientation by the partners towards seeing the farm as their family business rather than something that their spouse did and in which they had just a peripheral role. For example, an interviewee had reached the stage where she confidently identified herself as 'a farmer', having developed a key role in calf care, human resource management and administration while also initiating a farm tourism project within the business.

This study highlighted the importance of training, advisory and networking support for farmers' partners at the different stages of developing their roles within the farm. However, the design and facilitation of such support needs careful consideration as the skillsets and the learning needs are varied. The interviewees in this study placed the highest value on peer learning for building confidence, learning the language of dairy farming, and exploring roles that they would like to develop. They also highlighted the importance of space to discuss the sensitive challenges inherent in family farms with regard to finances, partnerships and succession.

Conclusions

This examination of the experience of farmers' partners who were involved in a learning initiative reveals that their roles within the farm are evolving. They are bringing a diversity of backgrounds, skills, knowledge and perspectives, and in most cases are beginning to see how they can strengthen and develop their role within the business. This case study suggests that bespoke learning initiatives specifically designed for farm spouses/partners can enhance their role within the farm business.



Scan the QR code to view the boards

Infrastructure Village

Design and performance of land drainage systems

Pat Tuohy[1] and Owen Fenton[2]

[1]*Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork;*
[2]*Teagasc, Johnstown Castle, Environment Research Centre, Wexford*

Summary

- Two main types of drainage system exist: a groundwater drainage system and a shallow drainage system. The optimum system and its design depend entirely on soil drainage characteristics.
- With appropriate drainage, grass production has been shown to increase by between 4 and 7 t DM/ha per year.

Introduction

The objective of any form of land drainage is to remove excess water from the soil, to lower the watertable, and to reduce the period of waterlogging. This can have potential benefits such as lengthening the growing and grazing season, improving utilisation of grazed grass by livestock and improving accessibility of land to machinery. Drainage of poorly drained mineral soils has positive effects on greenhouse gas emissions by reducing losses of nitrous oxide, while drainage is linked to carbon loss on carbon-rich soils, such as peats. Drainage works should therefore be focused on mineral soils. A number of drainage techniques have been developed to suit mineral soil types. There are two main categories of land drainage:

Groundwater drainage system: A network of deeply installed field drains exploiting permeable layers.

Shallow drainage system: Where the permeability is low at all depths a shallow system, such as mole or gravel mole drainage, improves soil permeability by cracking the soil and encourages water movement to a network of field drains.

A number of test pits (at least 2.5 m deep) should be excavated within the area to be drained. These test pits should be dug in areas that are representative of the area as a whole. As the test pits are dug, observe the faces of the pits, establish the soil type and record the rate and depth of water seepage into the soil test pit (if any). Visible cracking, areas of looser soil and rooting depth should be noted as these can convey important information regarding the drainage status of the different layers. The depth and type of drain to be installed will depend entirely on the interpretation of soil characteristics.

Groundwater drainage system

In soil test pits where there is strong inflow of water or seepage from the faces of the pit walls, layers of high permeability are present. If this scenario is evident on parts of your farm, it would be best to focus on these areas first as the potential for improvement is usually very high. The installation of field drains at the depth of inflow will facilitate the removal of groundwater assuming a suitable outfall is available. Conventional field drains at depths of 0.8-1.5 m below ground level have been successful where they encounter layers of high permeability. However, where layers with high permeability are deeper than this, deeper drains are required. Deep field drains are usually installed at a depth of 1.5-2.5 m and at spacings of 15-50 m, depending on the permeability and thickness of the drainage layer. Field drains should always be installed across the slope to intercept as much groundwater as possible, with main drains (receiving water from field drains) running in the direction of maximum slope.

Shallow drainage system

Where a test pit shows no inflow of water at any depth, a shallow drainage system is required. These soils with no obvious permeable layer and very low hydraulic conductivity are more difficult to drain. Shallow drainage systems are those that aim to improve the capacity of the soil to transmit water by fracturing and cracking it. These include mole drainage and gravel mole drainage. Mole drainage is suited to soils with high clay content that form stable channels. Mole drains are formed with a mole plough comprised of a torpedo-like cylindrical foot attached to a narrow leg, followed by a slightly larger diameter cylindrical expander. The foot and trailing expander form the mole channel while the leg creates a narrow slot that extends from the soil surface down to the mole channel depth.

The success of mole drainage depends on the formation of cracks in the soil that radiate from the tip of the mole plough at shallow depth. Gravel filled mole drains employ the same principles as ordinary mole drains but are required where an ordinary mole will not remain open for a sufficiently long period. This is the case in unstable soils having lower clay content. The mole channel is formed in a similar manner but the channel is then filled with gravel, which supports the channel walls. The gravel mole plough carries a hopper that controls the flow of gravel. During the operation the hopper is filled using a loading shovel or a belt conveyor from an adjacent gravel cart. Gravel moles require a gravel aggregate within the 10-20 mm size range to function properly.

Performance analysis

Performance analysis of drainage systems installed on Heavy Soils Program (HSP) farms allows examination of the impact of the type of drainage system, soil type and seasonal variations in soil moisture on drainage system performance. All of the systems installed reduce the overall period of waterlogging and control the water table, thereby improving the conditions for both the production and utilization of the grasslands they drain. Drained sites increased grass production by between 4 and 7 t DM/ha per year. Deeper drain systems with direct connectivity to groundwater discharge greater volumes of water and maintain a deeper water table compared with shallow drainage designs. The differences in drainage capacity observed between the different drainage design types is dictated largely by the hydraulic capacity of the soil within a catchment and connectivity to different water bodies. This work is allowing a more complete understanding of the capacity of individual drainage systems, and providing useful information on appropriate drainage design practices for poorly drained soils.

Land drainage publications

The Teagasc Manual on Drainage - and Soil Management is available via the Teagasc website.

Evaluation of land drainage system materials

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Summary

- This work showed a large variance between the sizes indicated by the quarries and the true gradation of the aggregate.
- A clean aggregate less than 20 mm in size would offer best results in the majority of soils.

Introduction

Subsurface drainage in agriculture plays an important role in the removal of excess surface and subsurface water from poorly drained soils. Drainage of mineral soils together with optimised soil fertility and appropriate management, facilitates productive grasslands. The removal of excess water has many benefits, including increased trafficability and crop yield, reduced surface runoff and improved soil structure. A typical subsurface field drainage system consists of a network of corrugated or smooth perforated pipes surrounded by an envelope material, which is typically stone aggregate in Ireland. The performance and lifespan of land drainage systems is highly variable and poorly understood, and is dependent on, amongst other factors, the quality and suitability of the materials used in field drains, and on keeping such drains well maintained.

Survey and Particle Size Distribution (PSD) analysis

A recent survey sought information on the types, size, lithology of stone aggregates and location of quarries throughout the country. The most popular stone sizes as indicated by the quarries were, 10 mm, 20 mm, 20 – 40 mm and 50 mm. The survey was followed by a Particle Size Distribution (PSD) analysis on seventy four samples, from sixty quarries, collected throughout the country. The results from this work showed a large variance between the sizes indicated by the quarries and the true gradation of the aggregate. This is indicated in Figure 1. The variance in a Q 50 mm aggregate can be seen visually with variance in size and lithology. The four most popular sizes from the survey were grouped and the results showed, the variance increased with increasing aggregate size. The sizes indicated by the quarries can be highly variable and may not accurately reflect actual material grading. A large proportion of available aggregates are larger than the 10 to 40 mm grading range currently recommended and an effort should be made to select a more suitable smaller aggregate material for drains.

Aggregate size criteria based on flow and filtration performance

The suitability and performance of aggregate sizes currently used for drainage systems in Ireland are mostly based on preference and availability. When design criteria, based on international specifications, are applied to a range of soil textures commonly seen in heavy soil farms, an aggregate size smaller than what is currently in use in Ireland is required. Testing of a range of aggregate sizes currently in use (up to 62 mm) was carried out to establish efficacy and determine a suitable aggregate size for heavy soil textures. This experiment indicated that aggregates < 20 mm in size performed best from both a filtration and hydraulic perspective. Increased filtration performance was observed in aggregates < 10 mm in size. The adoption of more appropriate aggregate size range specifications would optimise performance and extend the lifetime of drainage systems.

Figure 1. *A selection of Q 50 mm aggregates*

Conclusion

The current system of quarry aggregates being identified by a single size, or of a specified grading range, does not give a fair reflection of the true gradation of aggregate being sold. The sizes of aggregates currently in use are larger than what is recommended, and the suitability and preference of the current sizes of aggregate for Irish mineral soils does not conform to established international aggregate specifications which advise a smaller aggregate size than what is currently in use. Aggregates < 20 mm in size showed best results under performance testing, while those < 10 mm in size offered additional benefits. Such specifications are smaller than aggregate sizes generally used currently.

Planning for good grazing infrastructure

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Summary

- Ensure farm roadway network is appropriate for herd size and soil type.
- Upgrade water supply to paddocks. Achieve a good flow rate to troughs with large pipe bores and "full flow" type ballcocks.
- Good fencing is an important aid to grassland management.

Grazing infrastructure

Improved grassland management relies upon robust grazing infrastructure; suitably sized and shaped paddocks with multiple access points serviced by roadways of sufficient quality and adequate drinking water. It is vital to consider the quality of your grazing infrastructure and acknowledge where deficits have arisen in recent years. Maximum grazing efficiency will not be achieved unless all grazing infrastructure is sufficient.

Paddocks

Paddock size will have to be changed as herd size increases. The size of the paddock should be based on either two or three grazings of the planned number of cows in the herd. During mid-April to August, a three grazings per paddock system is preferred as this maximises pasture intake and milk production. The guideline paddock area is 1.3 ha per 100 cows for two grazings and 2.0 ha per 100 cows for three grazings (with a target pre-grazing cover of 1,400 kg DM/ha). For a 21 day rotation in mid-summer, this means that 21 (two grazings) or 14 (three grazings) paddocks are required. Ideally paddocks should be square to rectangular in shape, with the depth no more than three times the width. As a general rule, the distance from the roadway to the back of the paddock should be between 50-100 metres on heavy land, 100-170 metres on medium land and 170-250 metres on light land. The upper limits are more applicable to larger herds. Use multiple access points to paddocks on heavy land and during wet weather (e.g. cows enter through one access point and leave the paddock through a different access point).

Roadways

Design, construction and maintenance of farm roadways have a big impact on cow flow, walking speed and lameness. Does your current farm roadway system service all of the potential grazing area, and is it in good condition? If the current roadway system is inadequate, it needs to be upgraded and/or extended. Essential elements of a good roadway are adequate width for the herd, a smooth surface, adequate crossfall (with a fall to width ratio of 1:25 to 1:20), raised above the grazing area with sweeping bends at corners and junctions. The main roadway should be wide enough for good cow flow (e.g. 100 cows - 4 metres wide; 200 cows – 5 metres wide). New farm roadways must be laid in good weather and with dry soil conditions. Construction costs can vary, from €24 to €40/metre, depending on the cost of materials, the width, depth of material and the construction method. Cow tracks (spur roadways) are a cost effective way (€8-€11 per metre) to improve access, particularly on heavy land and to long paddocks. Cows like to walk with their heads down to see where to put their front feet. The hind foot is also placed on ground that the cow has seen. When cows cannot place their feet safely, they will slow down. They also slow down due to a poor roadway surface or if forced to move on from behind. If forced to move on from behind, cows become bunched and stressed and they lift up their heads and shorten their stride.

Water system

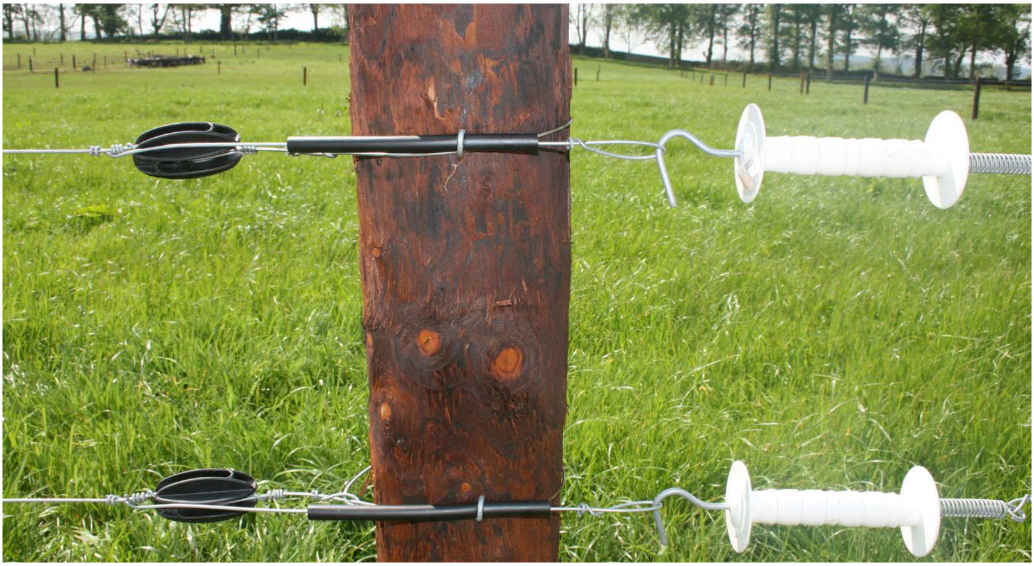
Ask the following questions when assessing your current water supply to the paddocks:

- Are pipe sizes adequate?
- Are ballcocks restricting flow?
- Are water troughs big enough and correctly located?
- What water flow rate is needed for your herd?

A flow rate of 0.2 litres per cow per minute and a trough volume of about 5-7 litres per cow is generally recommended. For example, a flow rate of 20 litres per minute and approx. 600 litre troughs per 100 cows. Don't be tempted to solve water supply problems with very big troughs; focus on flow rates and larger pipe sizes instead. Farms vary widely in terms of cow numbers, pipe length, farmyard location and topography, so take all these factors into account when deciding on pipe size and system layout. The aim is to minimise pressure loss due to friction in water pipes so that enough pressure is available to overcome elevation changes and maintain a good flow rate in troughs. Err on the high side with pipe size bore. A ring main (loop system) is a cost effective way to enhance water flow rates and ensure an even flow rate to troughs. Main pipe size bores should typically be 25 mm, 32 mm or 40 mm and branch pipe bores to individual troughs should be 20 mm, 25 mm or 32 mm. Use "full flow" type ballcocks in all new troughs. These ballcocks typically have 9-12 mm jets, providing a good flow rate even with low pressures at the ballcock. A standard high pressure ballcock jet (3 mm diameter) is very restrictive even where pressure at the ballcock is high. Position troughs to minimise walking distances to water and to avoid unnecessary smearing of grass. Keep troughs away from gaps and hollows. Troughs should be level and have no leaks. Isolate, monitor, locate and repair leaks. Troughs on roadways will slow cow movement and make roadways dirty. Allow trough space for at least 5% of the herd to drink at once. Assess costs in advance; costs can amount to €300 per hectare for new installations.

Paddock fencing

Good fencing is an essential element of any paddock grazing system. A specialised fencing contractor will be more skilled and better equipped to erect top quality fencing. Plan the location of fences carefully based on a paddock plan on the farm map, and plan the grazing system to aid grassland management. It should be easy to quickly set up access to paddocks between grazings. Good maintenance is essential.



Management of farm roadway runoff

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Summary

- A risk assessment model has been developed for potential environmental impact of farm roadways on receiving waters; however further development is required as more farms with more variable inputs are encountered.
- High levels of legacy P have been measured in farm roadway surface material, representing a high pollution risk where connectivity to surface waters exists.

Introduction

Despite generally declining soil phosphorus (P) balances, the impairment of fresh waters due to P and nitrogen (N) emissions from agricultural landscapes remains a key environmental issue. Relatively small but critical source areas within agricultural catchments tend to contribute disproportionally to suspended sediment, dissolved nutrients (N & P) and harmful bacterial loads (*E. coli*) in receiving waters. Farm roadways, which typically retain excessive nutrient concentrations, particularly P, have been little investigated with respect to their role in nutrient transport to receiving waters. These roadways, many of which have not been mapped to date, may contain all components (source, mobilisation, transport, hydrological connectivity, delivery, and impact) of the nutrient transfer continuum (NTC), and contribute significant non-point nutrient losses within catchments. In addition, source P loads from within the farm roadways themselves are considered a highly concentrated source of legacy P and likely a large contributor to catchment scale P emissions via surface and subsurface pathways. The study aims were to a) evaluate pollution risk potential of a selection of typical farm road networks and b) investigate storage and potential release of legacy P from farm roadway material.

On-farm study

Pollution risk potential

A semi-quantitative risk assessment model was developed and tested based on all components of the NTC and a relative impact score was assigned to each parameter based on a visual assessment. Seven dairy farms were assessed using the model which generated a risk score classification system from 'very low' to 'very high'. A 3-interval (low, moderate, high) 30-year average rainfall classification system was used.

Legacy P in farm roadway material

Material from farm roadways at Johnstown Castle was bulk sampled from 17 locations at regular intervals to 1 cm depth using a hand-held corer. All samples were oven dried (40°C), sieved (2 mm) and tested for Morgans P (Pm) and Mehlich 3-P (M3-P).

Results

Pollution risk potential

Approximately three per cent of roadways surveyed were classified as high or very high and in need of mitigation measures for existing climatic conditions. This increased by 60% for 'high' and 242% for 'very high' classifications in the scenario of increased (high) rainfall

(1957-≥3523 mm per annum), representing climate change (Figure 1). A farm roadway visual assessment booklet (Available from the Teagasc website) has been developed to help identify sections of roadway that may need improvement.

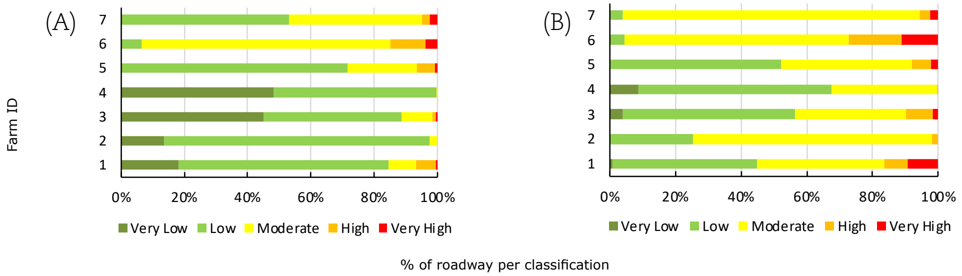

Figure 1. *Distribution of risk score classifications across seven farms (A) under existing climatic conditions and (B) under the high (future) rainfall scenario*

Legacy P in farm roadway material

Morgans P and M3-P for roadway material (Table 1) far exceeded the agri-environmental thresholds for soil (8 mg/L and 75 mg/kg, respectively) and represent a significant source of soluble and available P.

Table 1. *Measured farm roadway material P concentrations at the Johnstown Castle farm*

Sampling date	Morgans P (Pm) (mg/L)	Mehlich3-P (M3-P) (mg/kg)
September 2021	44.3 ± 21.77	155.0 ± 57.52
October 2021	55.1 ± 31.58	162.8 ± 88.05

The high P concentrations measured were consistent with repeated deposition of sources over time leading to an accumulation of significant amounts of available and labile P. This high P source load represents a high risk of pollution if connected directly or indirectly to receiving waters.

Conclusions

Farm roadways are a source of event and legacy P loads which can enter receiving waters via surface and subsurface pathways. A model to assess the risks of farm road pollution has been developed; however further development is required as more farms and more variable inputs are encountered. High P loads, on average 5-7 times those of a soil P index 4, were measured in the granular road material at a dairy farm, representing a significant pollution risk if connected to surface waters.

Acknowledgements

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Assessing roadway condition and associated cow flow

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Summary

- Roadway widths on-farm are sub-optimal for herd requirements, with only four per cent being the optimal width (or greater) relative to herd size.
- With regard to surface condition, just 14.2% of roadways on-farm are optimal.
- Roadway width and surface condition significantly affect cow flow.

Introduction

Irish dairy farming can maintain its global competitive edge by prioritizing low-cost grass-based milk production and continuing with compact spring-calving systems. The temperate climate allows for high-quality pasture production over a long growing season; pasture-based diets offer environmental benefits and improved animal welfare, making them more preferable to consumers. The efficient utilization of pasture is critical for profitability, and farm roadways are essential for rotational grazing systems. However, Irish dairy farmers face challenges with suboptimal roadway conditions that affect herd movement between paddocks and the milking parlour. The impact of varying roadway width and congestion points on herd movement was assessed in a recent study using commercial farms.

Table 1. *On-Farm roadway survey results*

Herd size (cows)	<100	100-149	150-199	200-249	≥250
Number of herds	11	18	8	5	13
Sample size of roadways (n)	130	260	124	87	292
Length of sections examined (m)	87	129	114	157	185
Mean roadway width (m)	2.97	2.94	3.30	3.6	3.89
Range roadway width (m)	1.7-6.0	1.2-5.0	1.8-7.7	2.5-5.3	1.9-10.0
Roadway width relative to herd size	0.76	0.70	0.69	0.74	0.62
Mean surface condition score	2.46	2.75	2.81	2.64	3.06
Public crossings	10	20	20	4	41
Mean total farm CPM	35.6	36.6	41.0	43.7	55.4

On-farm study

This study aimed to evaluate the current condition of farm roadways on Irish dairy farms. The study included farms with herd sizes ranging from 30-760 cows, which were contributing grassland management data to the Pasturebase Ireland platform. A total of 55 farms were selected based on their herd size and geographical location. The on-farm assessment of farm roadways took place from May to July 2021. A roadway quality metric was developed to evaluate the condition of farm roadways, which was based on three independent variables assessed on each section of the roadway; roadway width, surface condition score (Ranging from 1: inadequate for animal movement to 5: optimal), and the presence of a congestion point on a roadway (Table 1). The roadway quality metric was validated by assessing cow-flow on a range of roadway types on the Dairygold Research Farm. The impact of varying roadway width, surface condition and degree of congestion on cow-flow was evaluated. This information was used to estimate mean cow flow on each farm, defined as cows moved per minute (CPM). The findings of this study will provide valuable insights for farmers to improve their roadway infrastructure, which is crucial for efficient farm management and animal welfare.

Impact of roadway condition on cow flow

The study examined the impact of roadway width (RW) and surface condition (SC) score on herd movement; 893 roadway sections on 55 farms were assessed, many RW were suboptimal for herd size requirements. Farm roadways should be at least 3.5 m wide (for a 50 cow herd) with another 0.5 m allowed for each additional 50 cows. In practice roadways were, on average, 70% of the recommended width relative to herd size and only 4.0% of farm roadways were the optimal width (or greater) relative to herd size across all farms. Larger herd sizes tended to have wider roadways. The research found that RW and SC significantly affected the number of cows moved per minute (CPM), passing a given point on a farm roadway, with wider and better surface roads resulting in higher CPM (Table 2). Interestingly, congestion points did not have a significant impact on CPM, whereas public road crossings had a significant negative effect on CPM due to the additional time required for the herd to cross. A public road crossing was found to reduce CPM by 32.7% on average. With regard to surface condition, the study found that just 14.2% of roadways were in optimal condition for animal movement, with 24.4% being totally inadequate. Factors that positively affected SC included RW, congestion points, and the presence of a grass verge. The study suggests that farmers can evaluate their own roadway network in terms of roadway width and surface condition to calculate the maximum potential CPM and assess which aspects require upgrading.

Table 2. *Measured Cow flow (cows per minute) with varying roadway width and surface condition*

	Surface condition index				
Width (m)	1	2	3	4	5
1	12.4	13.8	15.2	16.6	21.3
1.5	13.4	15.6	21.5	25.1	32.1
2	14.4	17.4	27.8	33.6	42.9
2.5	15.5	21.2	34.0	42.2	53.6
3	16.5	25.0	40.3	50.7	64.4
3.5	17.5	28.8	46.6	59.3	75.2
4	18.5	32.6	52.8	67.8	86.0
4.5	19.6	36.4	59.1	76.3	96.8
5	20.6	40.2	65.4	84.9	107.6

Conclusion

Farm roadway infrastructure has not adapted to meet increased herd demands on commercial dairy farms. Roadway width and surface condition have a significant impact on cow throughput on farm roadways, with wider roadways and improved surface condition leading to increased cow throughput. Farmers should ensure that farm roadways are an optimal size for their herd size and in good condition to improve overall cow flow.

Optimising the management of poorly drained soils

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Summary

- The Heavy Soils Programme was developed to act as a test bed for strategies that could be implemented to improve the efficiency and performance of farms dominated by poorly drained soils.
- Farm output in terms of milk solids/ha has increased by 85% (850 to 1,574 kg/ha) since the start of the programme.
- Grass growth has increased steadily from 10.6 Tonnes DM/ha in 2011 to 13.2 Tonnes DM/ha in 2022.

Introduction

The initial development of the Heavy Soils Programme was encouraged by a number of factors, namely; a number of years of extreme summer rainfall, particularly 2009 and 2012; an appetite for more detailed research with regard to the management of heavy soils and land drainage and the impending removal of quota restrictions which would incentivise the need for sustainable use of all resources, including land. Of the 3.18 million ha of managed grassland nationally, it is estimated that 0.96 million ha (30%) are imperfectly or poorly drained. Farms on such soils are subject to shorter grazing seasons, due to a need to limit damage to soils/swards, and lower productivity, profitability and resource efficiency than those on free draining soils. The level of volatility associated with such soils will depend on the proportion of such soils on a given farm and weather in a given year. Generally profitability on such soils is closely related to weather and as such can be extremely volatile. It was decided in 2011 to establish the Heavy Soils Programme to develop a network of farms on poorly drained soils to act as a test bed for strategies and management practices that could be implemented to improve the efficiency and performance of farms dominated by such soils. The objective of the Heavy Soils Programme is to demonstrate methods to sustainably improve grassland productivity and utilization, decrease volatility in these parameters and sustain viable farm enterprises on poorly-drained soils. Initially the major focus areas were land drainage design and implementation and grassland management. Overtime this has evolved with soil fertility, fodder reserves, and farmyard & grazing infrastructure requiring greater consideration as the project developed.

Farm performance and development

Since the beginning of the programme, herd size has increased by approximately 52% from the 2011 level, with a corresponding increase in milking platform stocking rate from 2.12-3.03 cows/ha. Output in terms of milk solids/ha has increased by 85% (850-1,574 kg/a) (Table 1).

Annual grass production has shown a steady increase over the period of the programme. An on-going review of poorly performing paddocks allows for investment to be planned with regards to improvements. HSP productivity and financial performance has been built on investment in land drainage, soil fertility, farm infrastructure and reseeding. These strategies developed through on-farm research have facilitated increases in efficiency and scale. These gains have shown that management strategies can be applied which overcome limitations associated with challenging soils. All heavy soils programme information, regular programme updates and links to other resources is available from the dedicated website www.teagasc.ie/heavysoils.

Table 1. *Average farm output and financial performance*

Year	Milk solids	Gross output		Total cost		Net margin	
	Kg/Ha	(€/Ha)	(c/Litre)	(€/Ha)	(c/Litre)	(€/Ha)	(c/Litre)
2011	850	3,236	35.6	1,838	20.3	1,398	15.3
2012	869	3,092	35.4	2,143	24.7	948	10.7
2013	940	3,689	40.0	2,332	25.4	1,357	14.6
2014	935	3,725	39.3	2,134	22.4	1,591	16.9
2015	1,091	3,245	32.0	2,145	21.2	1,100	10.8
2016	1,068	2,865	28.3	1,911	19.7	954	8.6
2017	1,289	4,508	38.4	2,355	20.1	2,153	18.4
2018	1,404	4,530	35.9	2,961	23.3	1,571	12.6
2019	1,338	4,250	35.7	2,676	22.4	1,574	13.3
2020	1,405	4,406	36.2	2,591	21.1	1,815	15.0
2021	1,565	4,761	44.6	2,754	25.8	2,007	18.8
2022	1,574	6,907	65.3	3,440	32.2	3,479	33.1

Figure 1. *Example soil profiles in heavy soils programme farms in Stradone and Kishkeam*

Improving soil fertility on poorly drained soils

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Summary

- Liming is critical in improving nutrient availability & efficiency.
- The response of soil pH to lime application is reduced as soil clay content increases.
- 70 kg surplus phosphorus (P)/ha is required to increase soil test P by 1 mg/l on heavy mineral soils.
- Granulated lime is 5.9 times more expensive than ground lime.
- Herbage production difference between P Index 1 and 3 is 1 t DM/ha.

Introduction

Poor soil fertility is a major limiting factor on output potential of farms in Ireland, particularly farms dominated by fine particle size and/or high organic matter content (peat soils). Lime application aids the increase of nutrient availability and efficiency, it assists the growth of ryegrass and clover, and it accelerates the activity of nitrogen fixing bacteria and earthworms which in turn improves soil physical structure. Of the soil samples analysed in Ireland in 2020, only 21% were optimum in soil pH, P and K, in comparison to 15% of paddocks on the 'Heavy Soil Programme' (HSP) monitor farms. The HSP was established in 2011 in order to assess the overall potential of these soils.

Phosphorus can pose a major risk to water quality, particularly when used excessively or when managed poorly. Due to the risk legacy P poses to water quality and the large variation of P input required to optimise plant P availability, a soil specific approach is required to minimise the accumulation of excessive P in soil, reduce its environmental impact and increase P use efficiency. Controlled studies have been developed to isolate soil specific responses to lime and P application on heavy soils.

Liming

Soil acidity, lime application rate, lime type and effects on nutrient availability, soil structure and herbage production have been assessed. Achieving optimal soil pH (≥6.3) is crucial to ensure soil functions are optimised. Equivalent rates of ground and granulated lime application are required to achieve similar changes in soil pH on these particular soils. One t/ha of each lime product increased soil pH by 0.15 and 0.21 pH units, respectively. For a similar increase in soil pH, granulated lime proved 5.9 times more expensive than ground lime. The lower the clay content the greater the increase in soil pH (Figure 1). Liming increased soil test P and herbage production and showed no negative effect on soil physical structure. Increasing soil pH by one pH unit increased herbage production by 1.3 t DM/Ha.

Phosphorus

The effects of P application on the HSP farms with regards to soil fertility, agronomic potential and their potential risk to the environment have been assessed. Results show that liming and counteracting soil acidity is fundamental to increasing P availability and also reducing P loss potential. Similar to pH, P availability is largely influenced by the level of clay content in the soil and the concentration of iron and aluminium cations; 50 kg P/ha was required to achieve sufficient soil P concentration to support healthy plant growth and also increased soil test P by 0.45 mg/l. Organic soils (>20% OM) pose a major threat to water quality if excessive P is applied. Achieving optimum soil P index (Index 3) will increase herbage production by 1 t of DM/ha (Figure 2).

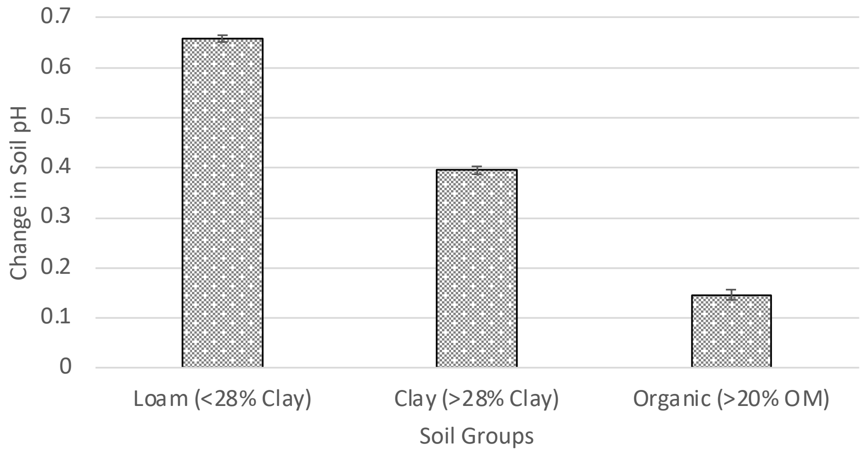

Figure 1. *Change in soil pH applying five tonne lime/ha across soil groups*

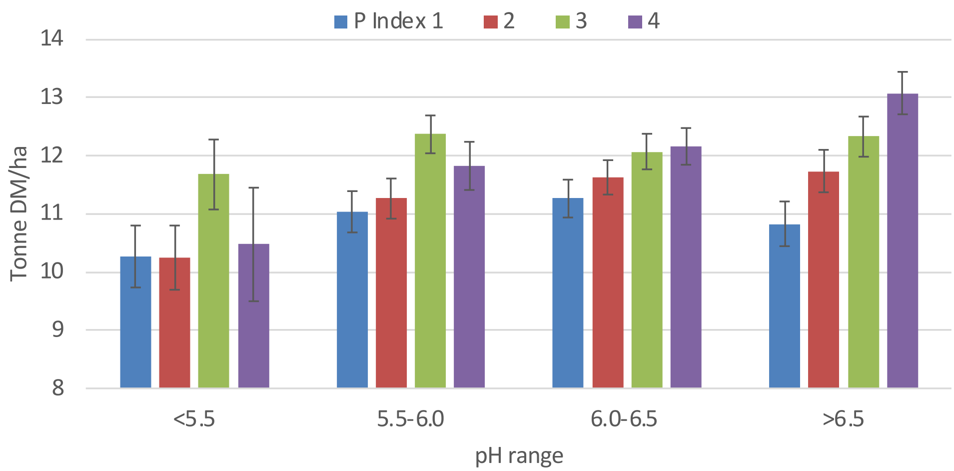

Figure 2. *Effect of soil pH range and soil P index on herbage production*

Conclusion

Currently in Ireland, standard P recommendations for mineral soils do not take into account the variability in soil type response and soil specific requirements. A more strategic approach is required to increase soil fertility and productivity on heavy soils. Soil texture and chemical composition influence the fate and efficiency of applied P. Liming to achieve optimum soil pH (≥6.3) is fundamental to buffer the soil and increase herbage production. Heavy mineral soils have a large affinity for P and therefore improving soil test P status can be very slow.

Survey of milking equipment and milking management practices on Irish dairy farms

Alice Walsh, Pablo Silva Bolona and John Upton

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Summary

- A detailed survey on the prevalence of milking technology and milking management practices was carried out on commercial dairy farms.
- The most prevalent parlour types were swing-over herringbones (59%) and herringbones with recording jars (21%).
- The most common milking equipment technological add-ons for herringbones and rotaries, respectively, were in-parlour feeders (87%, 100%), automatic washers on the bulk tank (75%, 92%) and automatic cluster removers (64%, 100%).
- This dataset will be used to investigate associations between milking technology and bulk tank SCC.

Introduction

Recent expansion of dairy herd size has posed challenges with regard to milking times, milking technique and mastitis control strategies. There is a gap in knowledge with regard to the level of proliferation of parlour technologies within Irish dairy herds and how these technologies impact milk SCC. This research looks at various farm management strategies and milking equipment technologies on independent Irish dairy farms that may be of importance in influencing bulk tank SCC.

Materials and methods

An online survey was distributed by 15 milk processors to all of their suppliers in June 2022. Its purpose was to assess milking management practices, dry period management practices and parlour facilities in Irish dairy herds. The survey comprised 66 questions and was divided into five sections; general contact information, farm-, parlour-, and cow-specific management questions and farmer-specific questions.

Results

Survey respondents (474 in total) were geographically distributed across the 4 provinces of the Republic of Ireland, with a total of 24 out of 26 counties represented. Of these, 269 respondents were from Munster, 39 from Connaught, 137 from Leinster and 29 from Ulster. Twenty two per cent of herds were managed as part of a partnership.

Farm-specific information

The most prevalent parlour types amongst respondents were swing-over herringbones (59%) and herringbones with recording jars (21%). Most respondents milked twice per day (94%). Rotaries and automatic milking system (AMS) parlours accounted for 3% and 2.5% of survey respondent parlours, respectively.

Parlour-specific information

In terms of servicing, 68% respondents had their parlour serviced once per year, 16% had it serviced twice per year, 4% serviced more than twice per year and 7% serviced less than once per year. Liner changes occurred most commonly once (34%) or twice (44%) per year. Cluster disinfection occurred in 32% of herds. Of these, 12% used an automated system of cluster disinfection whilst 20% conducted manual disinfection. A list of parlour technological additions and their prevalence are outlined in Figure 1.

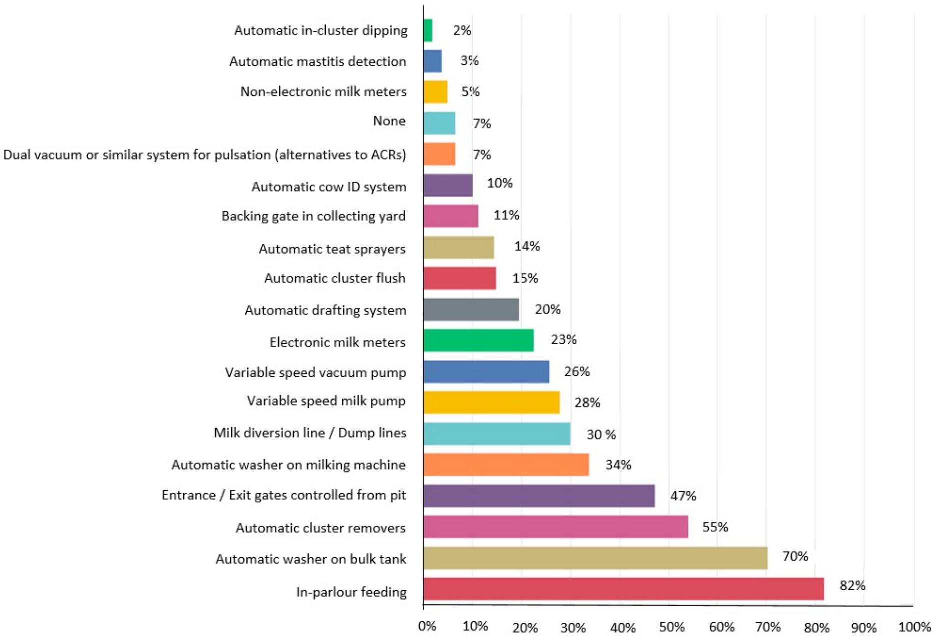

Figure 1. *Prevalence (%) of various parlour technologies on respondent farms*

Cow-specific information

Clots identified in the milk filter were an indication for foremilking on 47% of respondent farms, as were freshly calved cows (40%), clinical mastitis cases (36%) or increases in bulk tank SCC (31%). Seven percent of respondents reported that they never conducted foremilking. In terms of pre-milking preparation, 27% of respondents did not report doing any udder preparation at all. For those that did, a dry wipe was most commonly carried out (31%). Pre-spraying was implemented on 16% of farms and pre-dipping on 6% of farms. Post-milking teat disinfection most commonly involved spraying with a disinfectant solution, with 74% of farms using this method. Post-milking dipping occurred on 5% of farms and automatic in-cluster dipping on <1% of farms. No post-milking teat disinfection occurred on 15% of farms.

Conclusion

A detailed survey on the prevalence of milking technology and milking management practices showed that the most prevalent parlour types were swing-over herringbones and herringbones with recording jars. The most common milking equipment technological add-ons for herringbones and rotaries were in-parlour feeders, automatic washers on the bulk tank and automatic cluster removers. These data will be used in subsequent analysis to investigate associations between milking technology and bulk tank SCC.

Acknowledgements

The authors would like to acknowledge Animal Health Ireland (AHI) and the Irish Cattle Breeding Federation (ICBF) for their contributions towards the survey.

Effect of milking permission and concentrate supplementation in an automatic milking system on milk yield per cow

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Summary

- Free milking permission (MP; permission to milk after 6-8 h of previous milking) and high concentrate supplementation (CS; 3.5 kg/cow per day) increased the number of milkings/cow per day and the milk yield/cow per day.
- Milk yield/cow per day over the experimental period was similar for the cow groups on restricted MP (permission to milk after 12-14 h of previous milking) and high CS compared with free MP and low CS (0.5 kg/cow per day).

Introduction

A significant issue for the future sustainability of the family dairy farm is over-demand on the farm family's time and flexibility leading to a perceived less than satisfactory quality of life. Currently, the conventional milking process is considered a causative factor, accounting for more than 30% of the demand for labour on Irish dairy farms. Automatic milking (AM) is a technology with the potential to address these issues. The system works with cows voluntarily presenting themselves to be milked and the AM robot deciding and performing the task. However, some challenges of the AM system operating in a grass-based system include achieving a high number of milkings/robot per day, establishing the optimum herd size for the robot, achieving high grass intake, thus maximizing the grass proportion of the cow diet. The objective of this study was to examine the effects of milking permission (MP) and concentrate supplementation (CS), individually and their interaction, in order to optimize the operation of an AM system within a grass-based scenario.

Materials and methods

We conducted an experiment at the Dairygold Research Farm (Fermoy, Co. Cork, Ireland) between May 1st and September 17th 2022. Sixty-eight spring-calving dairy cows were selected. Cows were milked using one Lely AM robot. Cows were blocked on parity (2.9±0.1), days in milk (47.2±3.5) and milk yield (24.2±0.5). Cows were randomly assigned to one of four groups. The treatments consisted of two levels of MP and two levels of CS. Free and restricted MP represented permission to milk after 6-8 h and 12-14 h of the previous milking, respectively. This was achieved by changing the settings of the robot to decide if a cow was due for milking or not. Low and high CS levels were 0.5 kg and 3.5 kg of concentrate/cow per day, respectively. Cows grazed on an ABC grazing system appropriate to AM; post-grazing height averaged 4.1 cm.

Results

The impact of MP and CS on milkings/cow per day and milk yield/cow per day are shown in Table 1 and Figure 1. Both variables were affected by MP and by CS level. Cows with a free MP and high CS had a higher number of milkings/cow per day and milk yield/cow per day. Milking duration/milking and average milk flowrate/milking were higher in cows with a restricted MP. The milk yield/cow per day over the experimental period was similar for the cow groups on the restricted MP/high concentrate treatment and those on the free MP/low concentrate treatment. The cow groups on the free MP/high concentrate and restricted MP/low concentrate treatments had the highest and lowest milk yields, respectively.

Table 1. *Main effects of milking permission[1] (free and restricted) and concentrate[2] level (low and high) on cow and milking parameters*

	Milking permission[1]		Concentrate level[2]	
	Free	Restricted	High	Low
Milkings per cow/day, n	2.1	1.4	1.9	1.6
Milk yield per cow/day, kg	19.2	17.6	19.9	16.9
Milking time/milking, min	4.8	6.1	5.42	5.45
Average milk flowrate/ milking, l/min	2.43	2.55	2.51	2.47

[1]Milking permission: free and restricted MP represented permission to milk after 6-8 h and 12-14 h of the previous milking, respectively; [2]Concentrate supplementation level: low and high concentrate supplementation level represented 0.5 kg and 3.5 kg of concentrate/cow per day, respectively.

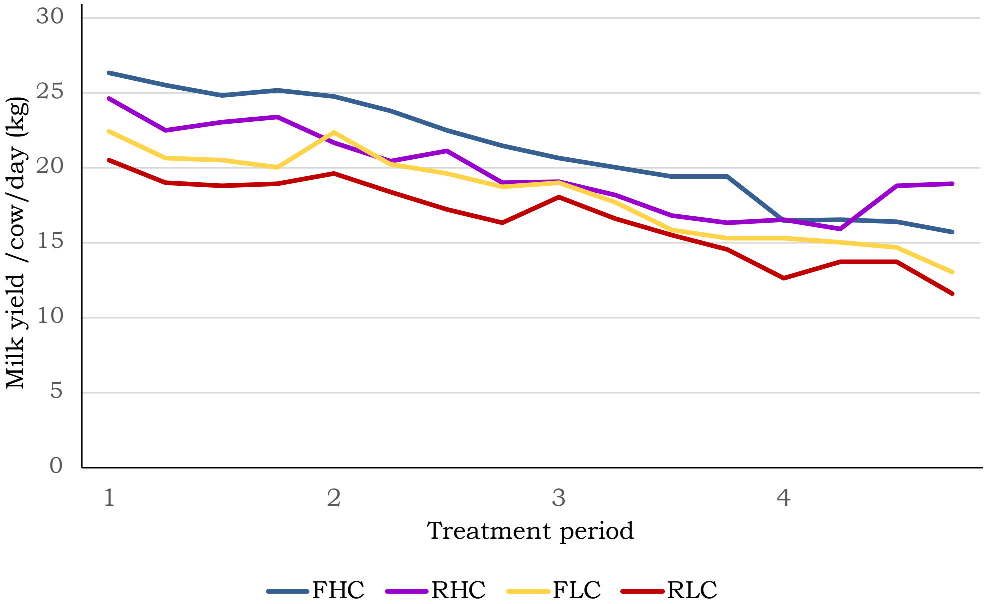

Figure 1. *Milk yield per cow/day (kg) across the different trial periods (P1= 9 May to 5 June 2022, P2= 13 June to 10 July 2022, P3= 18 July to 14 August, P 4= 22 August to 19 September 2022) for each treatment group (FHC= free milking permission, high concentrate; FLC= free milking permission, low concentrate; RHC= restricted milking permission, high concentrate; RLC= restricted milking permission, low concentrate)*

Conclusions

Free MP and high CS each, individually increased milk yield/cow per day. When the treatments were combined, the milk yield/cow per day over the experimental period was similar for the cow groups on the restricted MP/high concentrate treatment and those on the free MP/low concentrate treatment. The cow groups on the free MP/high concentrate and restricted MP/low concentrate treatments had the highest and lowest milk yields, respectively. As concentrate costs can be reduced with the free MP/low concentrate treatment, this is likely to be a more economical option than having additional cows to fill the extra available time on the robot with restricted permission.

Relating measurement of hind leg movement during milking to cow comfort on various milking machine settings

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Summary

- The three pillars of successful milking are milking gently, quickly and completely.
- Optimising milking machine settings can positively impact on all three.
- Significantly more rear leg stepping occurred during daily milking where the automatic cluster remover activated at 0.2 kg/min compared with 0.8 kg/min.

Introduction

Since the abolition of milk quotas Irish dairy herd size has expanded to an average size of over 90 cows. The challenge of milking larger numbers of cows has been met more through expanding milking facilities as opposed to adding additional labour. Where this results in more milking clusters without extra milkers, automatic cluster removers (ACRs) have been usefully employed. They have dual benefits to milkers and cows in eliminating the cluster removal process from the milkers workload together with preventing overmilking of the cow where increased vacuum levels act on the teat-end during low/no milk-flow. Choosing the correct ACR threshold (milk flow-rate at which the cluster is removed) is important for reasons including yield, milking time and udder health. With animal health and welfare now more prominent in farming, including in the new CAP, optimising cow comfort during the milking process becomes increasingly relevant. This paper describes a method for assessing cow comfort during milking on two different ACR thresholds based on measurement of stepping activity during milking as measured by IceTag accelerometers.

Measurement of stepping/kicking during milking

Forty-four cows included in this study were milked with two different ACR thresholds. These were pre-programmed into the milking software and, as cows entered the milking parlour they were identified by their transponder collar, with the designated ACR threshold automatically applied. Half were initially milked with an ACR threshold of 0.2 kg/min (ACR0.2) with the remainder at 0.8 kg/min (ACR0.8). After two weeks each crossed over to the other ACR setting for a further two week period.

Each cow had a 3-dimensional accelerometer fitted to a rear leg for the duration of the study. This measured leg movement and included a step count feature that could detect leg movements that did not necessarily involve forward movement. The time of each cluster attachment and the duration of milking was logged by the milking equipment. This time stamping enabled movement data from the relevant time period to be extracted from the downloaded accelerometer data. In addition to calculating leg movement over the entire milking period, a value was also calculated excluding the minute when the cluster was attached. This was done to mitigate against other sources of agitation the cow might experience during the cluster attachment process, separate from any discomfort experienced due to increased vacuum acting on the teat-ends resulting from declining milk-flow towards the end of milking. Teat condition was also assessed through touch after milking once per week to check on any obvious effect that the milking process may have had on the teat tissue.

Results and discussion

There was no significant difference in milk yield or SCC between both ACR thresholds but cows daily milking time reduced by 74 seconds (12%) on ACR0.8.

During daily milking the step count of 11.7 on ACR0.2 was significantly higher than 10.1 on ACR0.8 (Table 1). This was also the case when analysing only PM milkings. For PM milkings, excluding minute of cluster attachment reduced step count by 35% on ACR0.2 and 37% on ACR0.8 when compared to the total for the entire PM milkings, yet a significant difference remained between treatments. Due to the 16:8 h milking interval, AM milkings were much longer (386 s AM vs 271 s PM, ACR0.2). A trend towards greater leg movement on ACR0.2 during AM milkings was not significant.

ACR0.2 resulted in significantly lower mean milk flow-rates. Lower milk flow-rates tend to increase vacuum under the teat, potentially impacting cow comfort. Shorter milking intervals between AM and PM milkings resulted in lower udder fill and also reduced milk flow-rate (32% lower on ACR0.2). Under low udder fill conditions, rear leg movement, as an indicator of cow comfort, reduced significantly when the ACR threshold increased from ACR0.2 to ACR0.8.

No significant differences in post milking teat condition were apparent between the two ACR thresholds. However all teat condition scoring happened after the AM milking sessions, so not finding differences in post milking teat condition between both ACR settings is consistent with the lack of difference in stepping found during AM milking.

Table 1. *Average steps/kicks recorded during milking on both ACR settings*

	ACR0.2*	ACR0.8	ChiSq (P Value)
Steps during milking per day	11.7	10.1	0.02
Steps per milking AM	5.74	5.41	0.35
Steps per milking PM	5.75	4.96	0.01
Steps during milking per day excluding minute of cluster attachment	5.96	4.83	0.01
Steps per milking excluding minute of attachment AM	4.16	3.68	0.05
Steps per milking excluding minute of attachment PM	3.72	3.11	0.01

**ACR0.2 – cluster removed after flow reduced to 0.2 kg/min, ACR0.8 - removed after 0.8 kg/min*

Conclusions

Significantly more rear leg stepping occurred during daily milking with ACRs activated at 0.2 kg/min compared with 0.8 kg/min. A significant difference was found for rear leg movement during PM milkings between both ACR thresholds. No significant difference was found between thresholds for rear leg movement during AM milking, corresponding with similar post-milking teat condition assessments. There was a much shorter interval before PM milking, resulting in lower udder fill and reduced milk flow-rates at PM milking. Hence, teat-end vacuum may exert greater force on teat-ends if milking continues to a milk flow rate of 0.2 kg/min. Removing the cluster earlier (0.8 kg/min) can improve cow comfort, reducing kicking and stepping activity during milking, while reducing milking time and without impacting milk yield.

Acknowledgements

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Milking and operator efficiency of herringbone and rotary parlours

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Summary

- Milking efficiency was documented on Irish dairy farms using herringbone and rotary milking systems through the use of video cameras, infrastructure surveys and farm milk yield data. The metrics of 1) cows per hour (cows/h), 2) cows per operator per hour (cows/op/h) and 3) litres of milk harvested per hour (L/h) were used to evaluate farm performance.
- The average milking efficiency on farms using herringbones was 94 cows/h, 70 cows/op/h and 1,015 L/h. In comparison, average milking efficiency on rotary farms was 170 cows/h (+81%), 132 cows/op/h (+89%) and 1,534 L/h (+51%).
- For farms using herringbone (H) and rotary (R) milking systems, with two operator systems, more cows were milked per hour (+19% H, +33% R) and more litres of milk were harvested per hour (+21% H, +21% R) but less cows were milked per operator per hour (-35% H, -12% R) when compared to one operator parlours.

Introduction

Milking efficiency is often defined as the number of cows milked per hour, cows milked per operator per hour or litres of milk harvested per hour. Achieving high levels of milking efficiency is dependent on the successful engagement of factors related to milking system infrastructure, automation and management. Ireland's dairy herd has increased by 46% from 2011-2022 with recent statistics showing that the average Irish dairy farm is currently around 93 cows. Milking is a significant task and accounts for approximately 30% of a dairy farmers daily workload. This paper will describe the milking efficiency values of a sample of Irish dairy farms with respect to infrastructure (system size and type), levels of automation and operator efficiency.

Materials and methods

A sample of 17 farms using herringbone (H) and 10 farms using rotary (R) milking systems were selected for study participation. Farmers were chosen for inclusion in this study based on their willingness to participate in data recording, share farm data and manage dairy farms that are representative of future Irish dairy farms. Data were collected using video cameras, infrastructure surveys and national milk yield databases. Recordings were taken over two periods to account for seasonality: period one from 28/07/2020 to 23/10/2020 and period two from 12/04/2021 to 19/05/2021.

Table 1. *Milking assistance automations, their descriptions and applicability to herringbone and rotary farms*

Automations	Descriptions	H[1]	R[2]
Auto gates	Allows cows entry/exit to milking parlour	A[3]	N/A[4]
Backing gate	Moves cows from holding yard to parlour	A	A
Custer removers	Removes cluster when milking finished	A	A
Feeders	Allocates feed to cow bail	A	A
Rapid exit	Bails lift : whole row walks under and out	A	N/A
Row lift	Bails lift : cows exit conventional direction	A	N/A
Teat spray	Post-milking teat spray application	N/A	A

[1] *Herringbone,* [2] *Rotary,* [3] *Applicable,* [4] *Non Applicable*

Milking efficiency was evaluated through three distinct metrics: 1) cows milked per hour (cows/h), 2) cows milked per operator per hour (cows/op/h) and 3) litres of milk harvested per hour (L/h). Milking efficiency KPIs were calculated using 'total process time' (defined as time from arrival of cows to the holding yard until cleaning of facilities was completed), as opposed to the 'cups-on to cups-off' metric used in some studies, in order to account for time dedicated towards setting up the parlour before milking as well as cleaning of the facilities after milking. Automations identified on herringbone and rotary farms are listed and described in Table 1.

Results

Herringbone

The average herd size on farms using herringbone milking systems was 180 cows, average system size was 20 clusters, average number of operators present was 1.4 and the average number of rows per milking was 10. The average milking efficiency on farms using herringbones was 94 cows/h, 70 cows/op/h and 1,015 L/h. 81% of farms using herringbone milking systems had cluster removers, 56% had auto gates, 50% had row lifts, 38% had feeders, 19% had backing gates and 13% had rapid exits. One-operator farms had system sizes of 18 clusters with an average of two automations and achieved an average milking efficiency of 88 cows/h, 84 cows/op/h and 940 L/h. In comparison, two-operator farms had system sizes of 23 clusters with an average of three automations and achieved an average milking efficiency of 105 cows/h (+19%), 55 cows/op/h (-35%) and 1,136 L/h (+21%) (Figure 1).

Rotary

The average herd size on farms using rotary milking systems was 425 cows, average system size was 50 clusters, average number of operators present was 1.5 and the average number of rotations at milking was 10. 100% of farms using rotary milking systems had feeders and cluster removers and 60% had teat spray and backing gates. The average milking efficiency values on farms using rotary's was 170 cows/h, 132 cows/op/h and 1,534 L/h. One-operator farms had system sizes of 48 clusters, an average of three automations and achieved an average milking efficiency of 147 cows/h, 142 cows/op/h and 1,396 L/h. In comparison, two-operator farms had system sizes of 55 clusters, an average of three automations and achieved an average milking efficiency of 196 cows/h (+33%), 125 cows/op/h (-12%) and 1,690 L/h (+21%) (Figure 1).

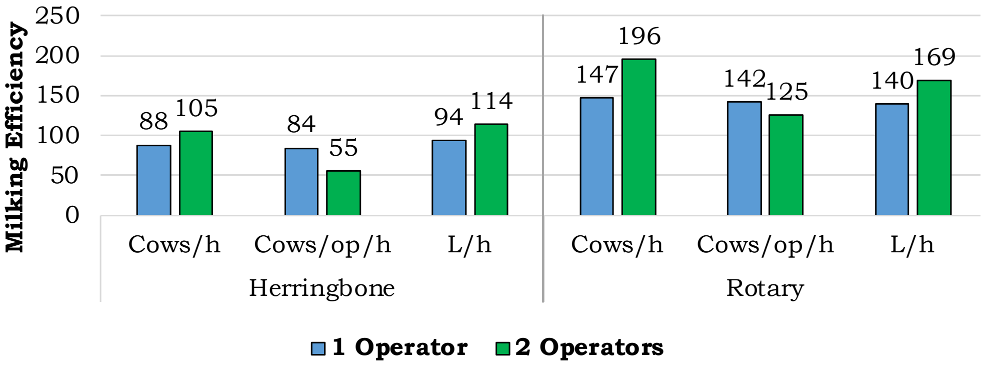

Figure 1. *Milking efficiency values for one operator and two operator parlours on herringbone and rotary farms. L/h has been scaled down by a factor of 10*

Conclusions

On average, farms using rotary milking systems achieved higher levels of milking efficiency (+81% cows/h, +89% cows/op/h, +51% L/h) than farms using herringbone milking systems. For farms using herringbone and rotary milking systems, two-operator parlours achieved more cows/h (+19% H, +33% R) and more L/h (+21% H, +21% R) yet less cows/op/h (-35% H, -12% R) when compared to one-operator parlours. The results of this study show that on average, there were only marginal efficiency gains in cows/h and L/h for farms using herringbone and rotary milking systems by adding a second operator, which also resulted in a detrimental effect on the key operator metric of cows milked per operator per hour. Hence, one-operator milking parlour installations can maximise milking efficiency and labour utilisation at milking.

Key requirements for calf sheds on dairy farms

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Summary

- The five key requirements for a calf shed are:
  - Good ventilation to ensure air is fresh with no draughts.
  - Adequate space: It is recommended to provide 2.0-2.3 m^2 pen area per calf.
  - Dry/good drainage: Young calves spend up to 70% of their time lying down so they need a dry bed.
  - Warmth: Extra bedding is recommended especially for young calves when temperatures are low (<10°C).
  - Clean and cleanable: Floors and walls should be easily cleaned.

1. Fresh air

Good ventilation removes stale, damp air, which helps ensure that viruses and bacteria cannot survive for long outside the animal. Fresh air is also required to limit dust and ammonia, which can irritate the respiratory tract and make the animal more vulnerable to respiratory disease. The recommended air inlet should be two to four times the required outlet. The outlet area should be a minimum of 0.04 m^2/calf. A capped ridge outlet is recommended with flashing, as required, to prevent wind driven rain getting in.

Air inlets can be provided by 'Yorkshire boarding' (Figure 1) or vented sheeting. Yorkshire boarding has two staggered lines of vertical timber so it reduces air speed, water entry and the likelihood of draughts. Specification S101 from the Department of Agriculture, Food and the Marine (DAFM) stipulates that the minimum length of the boarding is 1.5 metres, that the laths are 25 mm thick, a maximum width of 75 mm with gaps of at least 25 mm. The two lines of laths are 25-50 mm apart.

Space boarding can be satisfactory on the sheltered side of a calf house in a suitable site. If in doubt use Yorkshire boarding because wind direction can change and calves are sensitive to draughts. A draught is essentially excessive air movement (air speed >0.5m/s) at calf level.

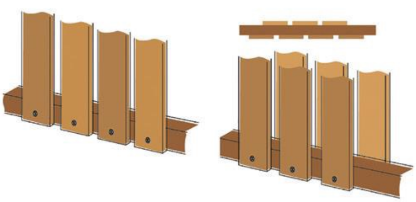

Figure 1. *Space boarding on left and Yorkshire boarding on the right*

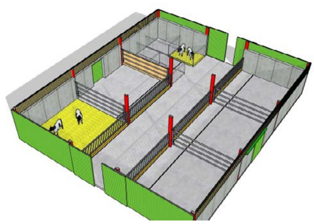

Figure 2. *Calf house with penning*

2. Space

It is recommended to provide 2m^2 - 2.3 m^2 pen area per calf. Each large pen in Figure 2 is 4.8m x 4.6m =22m^2 divided by 2.3 m^2 = 9 calves/pen, the centre passageway is not included in this calculation.

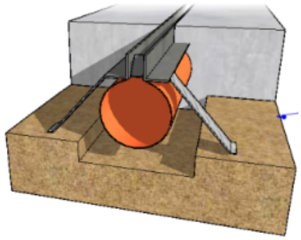

Figure 3. *A 'split drain', this can be constructed without the use of angle iron, contact your adviser for details. Cast iron 'Acco' drains are an alternative option.*

3. Dry with good drainage

Calves spend a lot of their time lying down (up to about 70% for young calves) so they need a dry bed. All calf houses should be built with a damp proof course to prevent rising dampness.

A slope of 1:20 in the calf pen area is recommended (Specification S124 DAFM). A split drain as shown in Figure 3 has the advantage that it will get urine and associated smells out of reach of calves quickly. This drain should be positioned approximately 0.8 m inside the feed barrier. In large pens, typically where automatic calf feeders are used, there is merit in having this drain approximately three metres within the pen. This area will however have to be cleaned at least daily, preferably with a 'hand yard scraper' or a scraper mounted on a skid steer or quad since any use of water within the building should be kept to a minimum to keep down humidity.

4. Warmth

A young calf is comfortable between 10 and 26°C ('thermoneutral zone') whereas the equivalent for a month old calf is 0 to 23°C. Deep beds of straw are effective in protecting calves from the cold so extra bedding is recommended for young calves in cold weather. Calves require 15-20 kg straw as bedding per week or one 150 kg round bale of barley straw to rear each calf. An extra feed of warm milk will also help calves cope with low temperatures.

5. Clean and cleanable

Floors and walls should be easily cleaned. Floors can be laid in bays of not more than 4.5m by 6m to avoid the need to make contraction joints. Ensure concrete is well compacted and properly cured to avoid plastic shrinkage cracks etc.

Natural light

Natural light is conducive to good animal health and provides for a good working environment. 15% of the roof area as translucent sheets is recommended (as listed on DAFM S.102).

Mistakes & challenges in calf housing

- Inadequate space: aim to provide at least 150m^2 of calf pen area for a 100-cow herd.
- Eave heights over 4 m, calves do not generate enough heat to shift a big volume of air above them.
- Excessive ventilation.
- Yorkshire boarding with excessive space between the two lines of timber leading to draughts and rain entry.

Improving milking efficiency

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Summary

- Cluster removers eliminate over-milking and provide consistency of milk-out.
- Increasing the ACR threshold from 0.2 kg/min to 0.8 kg/min reduced daily milking duration by 14% over a 31-week period.
- Increasing the ACR threshold to 0.8 kg/min did not affect milk yield, SCC or the amount of milk left behind in the udder after milking.

Introduction

Milking is the main chore on dairy farms and typically consumes over 30% of total labour input. With high labour costs and problems accessing skilled labour, the recent trend has been to install milking parlours with a greater number of clusters to be handled by one operator. Automatic cluster removers (ACRs) are a useful automation to facilitate one operator to manage a greater number of milking clusters, they also offer consistency around the end-point of milking and can eliminate over-milking of cows. Over-milking should be avoided to keep teats in good condition and to maintain cow comfort during milking. Much work has already been conducted providing strong support for significant reduction in milking duration without impact on milk yield through increasing the flow-rate at which the ACRs detach the milking cluster (ACR threshold). However, in practice many farms have not adopted this labour saving technology on the basis that it may increase milk SCC. Typically the ACR threshold is set at a flow-rate of 0.2 kg/min (i.e. completely milking the cow out). The objective of this study was to increase the ACR threshold from 0.2 kg/min to 0.8 kg/min in steps of 0.2 kg/min and document the effects on milk yield, milking duration, average milk flow-rate, strip milk (milk left behind after cluster removal) and SCC over a 31-week period.

Materials and methods

Four treatments, consisting of ACR thresholds increasing from 0.2 kg/min to 0.8 kg/min in steps of 0.2 kg/min (ACR0.2 ACR0.4, ACR0.6, ACR0.8), were deployed for 31 weeks to cows at the Teagasc Research Centre at Moorepark. A mid-line 30-unit Dairymaster herringbone, swing-over milking system was used to milk the cows on the trial twice per day. The milking system utilised simultaneous pulsation (i.e. 4x0 pulsation) and was fitted with automatic cluster removers and weigh-all milk meters. The standard farm ACR threshold was 0.2 kg/min with a three second time delay. The milking cluster weight was 2.8 kg and was fitted with 916SL milking liners. The milking parlor software was modified to apply a pre-defined ACR threshold to a specific cow regardless of when she presented for milking. Cows were managed in a pasture-based system and were milked twice per day with a 16:8 h milking interval. Cows were an average of 81 days in milk at the beginning of the study. Average parity was three ranging from one to eight. Each experimental group had 27 cows at the beginning of the study. Strip milk was recorded on four separate occasions over the course of the study. This was carried out by reattaching the cluster to the cow after it had been removed by the ACR, adding a 2.5 kg weight to the cluster, and removing the unit once milk flow had ceased. The strip milk yield was then recorded from the milk meter. The strip milk data of 64 randomly selected cows spread evenly across all four treatments were collected.

Results

The milking duration for ACR0.8 was significantly shorter, by 95 s (14%), than ACR0.2 (Figure 1). Similarly, the average flow rate for ACR0.8 was significantly larger, by 0.26 kg/min (16%), than ACR0.2. There was no treatment effect on milk yield or strip milk, i.e. increasing the ACR threshold did not affect the milk yields of the cows or the amount of milk left behind in the udder after milking. There was no significant effect of treatment on SCC. The SCC values were 71,700, 67,000, 69,900 and 67,700 cells per ml for the ACR0.2, ACR0.4, ACR0.6 and ACR0.8 treatments respectively. We found a significant effect of week on milk SCC, whereby the SCC of the cows on the experiment increased as lactation progressed in a similar way across all treatments. There were 10 cases of clinical mastitis among the cows on the study. There were two cases on ACR0.2, one case on ACR0.4, four cases on ACR0.6 and three cases on ACR0.8. *Strep. Uberis* was identified in four cases, *Staph. Aureus* was identified in three cases and in three cases no bacteria was identified.

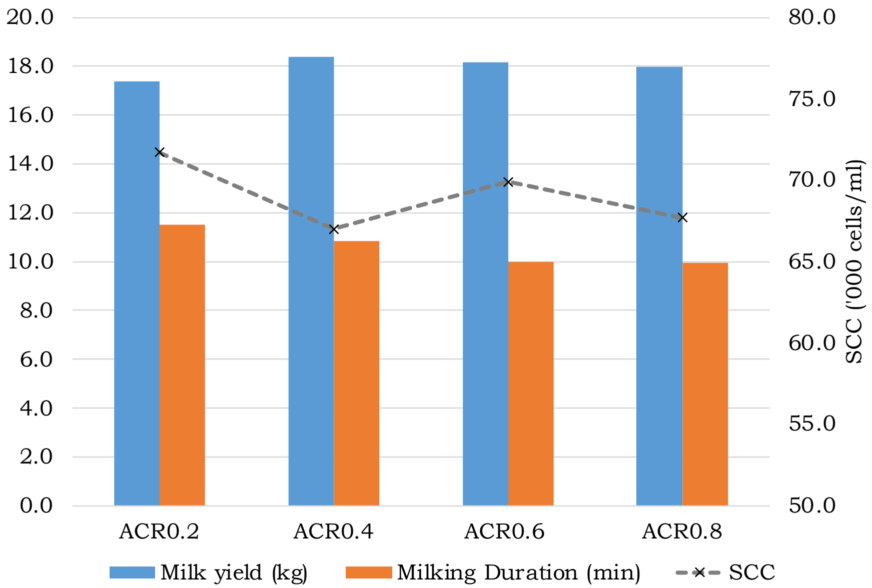

Figure 1. *Results for milk yield, milking duration and SCC across ACR thresholds*

Conclusions

We did not find a significant effect of increasing the ACR threshold from 0.2 to 0.8 kg/min on milk SCC in this long term study. We found a significant effect of week on milk SCC, whereby the SCC of the cows on the experiment increased as lactation progressed. We can also conclude that increasing the ACR threshold from 0.2 kg/min to 0.8 kg/min reduced daily milking duration by 14% without any significant reductions in milk production or significant increase in strip milk in this pasture based study.

Acknowledgements

This publication has emanated from research conducted with the financial support of Science Foundation Ireland (SFI) and the Department of Agriculture, Food and Marine on behalf of the Government of Ireland through VistaMilk under Grant Number [16/RC/3835] VistaMilk. Further financial and technical support was provided by Dairymaster.

Effect of milking efficiency and herd size on energy efficiency

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Summary

- Farms using rotary milking systems in this study achieved higher energy efficiency than the farms using herringbone milking systems.
- Annual energy costs of farms using herringbone and rotary milking systems in the largest 25% of herds were €497 and €1,412 lower respectively, than the smallest 25% of farms for equivelent milk production volumes.
- The annual energy costs of farms using herringbone and rotary milking farms in the highest 25% of herds, in terms of milking efficiency, were €464 and €4,793 lower respectively, than farms in the lowest 25% of herds based on their milking efficiency for equivelent milk production volumes.

Introduction

Increased dairy herd size since the removal of milk quotas in 2015 has led to increased energy demand and improved levels of milking efficiency (cows milked per hour) on Irish dairy farms. Energy efficiency was defined as the amount of Watt-hours consumed per kg of milk sold (Wh/kg_{Milk}). The objective of this study was to examine the effect of herd size and milking efficiency on energy efficiency and energy costs (€/year) on Irish dairy farms across herringbone and rotary milking parlours.

Materials & methods

Energy data were recorded using energy meters installed on 26 dairy farms (16 herringbone, 10 rotary). The energy meters were installed for two distinct seven-day periods of observation coinciding with peak and late lactation. The milking procedure was observed via video recordings and these data were subsequently analysed to extract the milking efficiency key performance indicators (e.g. the number of cows milked per hour, cows/h). In addition, surveys of the energy-consuming infrastructure on these farms were undertaken to identify the parlour technologies in place. Milk production and herd data were acquired for each farm from the ICBF database.

These data allowed the energy efficiency and milking efficiency of the farms to be determined. The energy efficiency of the first quartile of the farms (Q1), was then compared to the fourth quartile (Q4). Where $Q1_h$ = smallest 25% and $Q4_h$ = largest 25% by herd size. Similarly, the energy efficiency of Q1 and Q4 farms by milking efficiency was determined, where $Q1_m$ farms represented the lowest 25%, and $Q4_m$ farms represented the largest 25%, by milking efficiency. This comparison was used to investigate if farms with larger herds were more energy efficient than smaller herds and whether energy efficacy was affected by milking efficiency. Results of this analysis are presented in Table 1.

Table 1. *Average energy efficiency (Watt-hours consumed per kg of milk sold; Wh/kgMilk) and energy costs of Q1 and Q4 groups, in terms of herd size and milking efficiency (cows/h), for farms using herringbone (H) and rotary (R) milking systems*

Parlour Type		Ranked by herd size				Ranked by milking efficiency		
		Herd Size	Wh/kg Milk	€/1000kg Milk		Milking Efficiency (cows/h)	Wh/kg Milk	€/1,000kg Milk
H	$Q1_h$	113	32	4.33	$Q1_m$	56	33	4.31
	$Q4_h$	314	29	3.92	$Q4_m$	126	29	3.92
R	$Q1_h$	297	27	3.67	$Q1_m$	113	38	5.25
	$Q4_h$	551	20	3.01	$Q4_m$	192	20	3.01

Results - infrastructural survey

Herringbone

The average herd size for the herringbone group was 193 cows ($Q1_h$ = 113 cows, $Q4_h$ = 314 cows). The herringbone farms achieved an average milking efficiency rate of 82 cows/h ($Q1_m$ = 56 cows/h, $Q4_m$ = 126 cows/h). The average number of milking clusters was 18 units, (range 6 to 36 units).

Rotary

The average herd size for the rotary group was 404 cows, ($Q1_h$ = 297 cows, $Q4_h$ = 551 cows). The rotary farms achieved an average milking efficiency of 152 cows/h ($Q1_m$ = 113 cows/h, $Q4_m$ = 192 cows/h). The average number of milking clusters was 50, (range 44 to 64).

Results – energy efficiency

The farms using rotary milking systems achieved higher energy efficiency (30 Wh/kg_{Milk}) than farms using herringbone milking systems (33 Wh/kg_{Milk}). The average milk production of the herringbone milking systems was 1.2 million kgs of milk annually. Annual energy costs for herringbone milking systems were €497 less with the largest herds ($Q4_h$) than with the smallest herds ($Q1_h$) equivelent milk production volumes. Similarly, annual energy costs were €463 less for the farms using herringbone milking systems with the highest rates of milking efficiency ($Q4_m$) than the farms with the lowest milking efficiency ($Q1_m$) equivelent milk production volumes.

The average milk production of the farms using rotary milking systems in this study was 2.1 million kgs of milk annually. On farms with rotary milking systems annual energy costs were €1,412 less for the largest herds ($Q4_h$) than the smallest herds ($Q1_h$) equivelent milk production volumes. Similarly, annual energy costs on farms using rotary milking systems were €4,793 less with the highest rates of milking efficiency ($Q4_m$) compared with the lowest rates of milking efficiency ($Q1_m$) equivelent milk production volumes.

Conclusion

Farms using rotary milking systems achieved higher energy efficiency (30 Wh/kg_{Milk}) than farms using herringbone milking systems (33 Wh/kg_{Milk}). The annual energy costs of farms using herringbone and rotary milking systems in $Q4_h$ were €497 and €1,412 lower respectively, than farms in $Q1_h$ equivelent milk production volumes. Similarly, annual energy costs of farms using herringbone and rotary milking systems in $Q4_m$ were €464 and €4,793 lower, respectively, than farms in $Q1_m$. Therefore, farms with larger herd sizes and higher rates of milking efficiency achieved the best levels of energy efficiency.


151-OY-131

Health and Safety

Health and safety management on dairy farms

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Summary

- Dairy farms have high levels of both fatal and injury causing farm workplace accidents.
- There are strong legal duties in place requiring management of safety, health and welfare on dairy farms.
- Completion and implementation of a Risk Assessment Document is a key step to managing farm health and safety.

Introduction

Injury or ill health causes tragedy, pain and suffering. These also impact negatively on the farm as a business due to loss of production, poor productivity and reduced levels of motivation. One fatality or serious injury is one too many. Farm workplace deaths have shown a welcome decline during 2021 and 2022 with 12 and 13 occurring, respectively, compared to an average of 21 for the previous decade (HSA data). Twenty five percent of dairy farms had an injury causing a farm accident in the past five years. Dairy farms have higher levels of both fatal and serious workplace injuries than other farm enterprises so their health and safety management requires particular attention.

Legal duties of dairy farmers and employees to implement SHWW

Farm owners/managers have legal duties to manage safety, health and welfare under the Safety, Health and Welfare at Work (SHWW) Act 2005 and associated regulations. Employees also have duties to comply with this legislation. Non-compliance with these legal duties leaves persons liable to criminal prosecution.

An employer has the predominant duty of protecting the safety, health and welfare of their employees and all affected by work activities. This includes providing and maintaining: a safe place of work, safe machinery, equipment, safe systems and organisation of work. The employer must provide information, instruction and training to staff on workplace hazards and risks. Where a risk cannot be eliminated or reduced sufficiently, suitable personal protective equipment (PPE) must be provided, used and maintained. Emergency plans such as arrangements to contact emergency services, first aid and fire precautions must be prepared and updated. An employer must seek competent advice if they do not know the solution to a safety, health or welfare problem.

Employees have the following duties: co-operate with their employer; take care to avoid injury to themselves and others; report any defects or system of work that might be a hazard and use all items of equipment or PPE in a safe manner. Employers and employees must safeguard persons who are not their employees such as members of the public. Self-employed farmers must apply the legal requirements to themselves and all who live or work on the farm.

Complete a risk assessment

A Risk Assessment and a Code of Practice have been prepared for the Agricultural sector under the 2005 Act and these are available on the HSA and Teagasc websites (www.hsa.ie and www.teagasc.ie). Teagasc and accredited consultants provide half-day training on completing the Risk Assessment Document which is a requirement for TAMS grant payment. Completion of the Risk Assessment document is also a requirement for Quality Assurance Schemes.

Employing staff

Due to on-going expansion, increased labour input is required on dairy farms. Excellent standards of safety, health and welfare along with time management, farm buildings, equipment and facilities provide an attractive workplace for staff. The Teagasc Farm Labour Manual is available online from www.teagasc.ie.

Farm building construction

Safety, Health and Welfare at Work (Construction) Regulations apply to farm constructions. An advisory booklet 'Build in Safety' prepared by FBD Insurance, the HSA and Teagasc is available from FBD Insurance, HSA and Teagasc websites.

ATV regulations

New quad bike or all-terrain vehicle (ATV) regulations (SI No. 619 of 2021) come into force on 20th November 2023. These regulations apply to all work sectors including agriculture. The regulations require the operator of the ATV to have successfully completed an ATV safety training course provided by a registered training provider to a QQI standard or equivalent. They must also carry out a risk assessment before use and wear PPE while operating the machine. Farmers with an ATV should consider measures now to ensure compliance with the regulations. It is important to note that the regulations apply to all ATVs, whether new or old.

Preventing accidents associated with tractors and vehicles rolling

The HSA report titled 'A Review of Work-Related Fatalities in Agriculture in Ireland 2011-2020' reported 39 work-related fatalities involved vehicles striking people during the 10 year period. Of these, 23 occurred when parked vehicles rolled because the handbrake was faulty or insufficiently engaged. This means that over one in ten of all work-related fatalities involving vehicles in agriculture were caused by parked vehicles rolling out of control and striking people. Vehicle operators must ensure their vehicles are in safe working order and that they are safely parked, paying particular attention to having the handbrake applied properly.

Protection from cow at calving

The same HSA report stated that 32% of farm fatalities in the last 10 years involving livestock were associated with cows with calves and over half of non-fatal injuries were associated with livestock handling. Farmers are advised to have a well thought out written procedure for calving that is visible to everyone working on the farm. Procedures and facilities must be regularly risk assessed. It is important that everyone involved in calving and caring for calves are cautious around freshly calved cows. Never enter a group pen to carry out a task without planning an escape route. Keep a barrier between you and the cow, and keep pen stocking rates to manageable cow numbers.

Conclusions

Active and on-going management of farm safety, health and welfare is a vital component of operating and managing a progressive dairy enterprise. Further information and guidance on all aspects of farm safety, health and welfare is available at www.hsa.ie and at https://www.teagasc.ie/rural-economy/farm-management/farm-health--safety/

Physical and mental health status of farmers, and services available to farm families

Anne Marie McAuliffe
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Summary

- Maintaining a mentally and physically active lifestyle helps to improve longevity.
- Services are available in Ireland to assist anyone struggling with feelings of isolation and loneliness.

Introduction

According to a recently published report from the Health and Safety Authority, older people (>65 years) are particularly vulnerable to fatal accidents on farms. The over 65 age group accounted for 46% of all farm fatalities in the period between 2011 and 2020.

Embrace Farm

Embrace Farm is an organisation that helps farm families that have experienced grief or loss from fatal farm accidents, serious injury, suicides, trauma or fatal illness. They provide both emotional and practical supports through their peer-to-peer groups and "Encircle" Programme for farm families that seek help with grief and loss. Founded in 2014 by Brian and Norma Rohan, following the passing of Brian's father Liam in a farm accident on their farm in Laois, Embrace Farm currently supports almost 400 families nationwide. If you or anyone close to you needs support please contact them on www.embracefarm.com or call 085-7709966.

Irish Heart Foundation

Recent research conducted by Teagasc has shown that farmers experience more health issues compared with people that work in other occupations. This affects farm income, and the future sustainability of farming. Male farmers are less likely to go to their GP's for regular check-ups compared with men employed in other sectors. They understand the importance of maintaining high standards of animal health and welfare for productivity and longevity, but often don't place sufficient emphasis on their own health. The farmer is the most important cog in the wheel, therefore good cardiovascular health is essential for maintaining your ability to farm into the future. Eighty percent of premature heart disease is preventable. The Irish Heart Foundation has identified eight healthy heart habits:

- Manage your blood pressure
- Be active
- Control your cholesterol
- Eat healthier-reduce salt and sugar
- Quit smoking
- Manage your stress
- Maintain a healthy weight
- Reduce alcohol intake

We know a substantial proportion of farmers are at risk from heart disease. Previous research conducted by the HSE found that 97.5% of farmers had two or more risk factors for cardiovascular disease.

The 'Farmers Have Hearts' programme provides free heart health checks at marts around the country. As part of this initiative, Irish Heart Foundation nurses will measure:

- Blood pressure
- Cholesterol
- Glucose
- Pulse
- Body mass index
- Waist circumference
- Carbon monoxide (only relevant to smokers)

For more information and to view their upcoming schedule visit www.irishheart.ie.

Aware

Farming life has inherent stressors, with long working hours, increasing costs and regulations and fluctuating incomes. Recent years have also brought increasing pressures in the form of unpredictable and detrimental weather conditions that have further impacted upon production, income and future planning for individual farmers. Social isolation, which can be part of rural life, can also further compound the stresses of the farming lifestyle. Aware is an organisation that can offer support through these challenges. Mental health, like physical health, should not be taken for granted. We all need to work at it to get the most out of life. Aware offer free online programmes, as well as other supports, to build mental resilience, reduce stress and improve sleep (www.aware.ie).

Alone

Loneliness and isolation are two big issues affecting farmers as they age. Almost a third of older Irish people currently experience loneliness, and this figure is expected to be greater in the farming community. Organisations are available to offer coordinated supports which will help farmers age with dignity in their own homes. One such organisation is Alone. Their service offers help to resolve all types of difficulties for the older person, to resolve issues such as housing, health, entitlements, and financial concerns. They provide practical supports such as technological solutions and assistive technologies that create an infrastructure to empower older people to use technology, enabling the user to manage their social connection, health, safety and security. Alone encourages engagement with local events and activities to support older adults to age happily and securely in their own homes and with close links to their communities. (www.alone.ie).

Conclusions

Implementing small but consistent habits can help to protect your physical and mental health. Lifestyle measures such as stopping smoking, maintaining a healthy weight and diet, managing stress, regular exercise, talking about your personal issues and checking for and treating conditions such as high blood pressure and cholesterol can all help.

Acknowledgements

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Vistamilk

VistaMilk Science Foundation Ireland Research Centre

TJ McAuliffe, Francis Kearney and Elena Hayes
Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork and VistaMilk SFI Research Centre

Summary

- The mission of the VistaMilk Science Foundation Ireland (SFI) research centre is to be an agent of sustainable growth for the Irish dairy and Agri-Tech industry through scientific leadership in fundamental and translational research for digital pasture-based dairying.
- Research at VistaMilk spans all the way from soil, through to the pasture, the cow, the milk processor and the human gut with a particular focus on how digital technologies can be exploited to help deliver on its mission. Many of the exciting projects funded by VistaMilk are reported elsewhere in this booklet.

Introduction

The long-term viability of healthy food is conditional on both applied and fundamental scientific excellence deployed across a responsible agri-food system that is focussed on people's needs, solutions to imminent challenges and problems, and taking advantage of opportunities across the soil to human spectrum – a *soil to sustenance* approach. The required transformational change in the food system will only be achieved through co-designed trans-disciplinary research developed in conjunction with stakeholders and end-users, encompassing the soil-to-gut pathway. VistaMilk has developed a transformational research programme to grow a fully inter-connected and responsible food system that positively impacts the environment, while respectful of societal values and, yet, sufficiently profitable to deliver a viable livelihood for primary producers and rural communities.

In delivering on its vision, VistaMilk pools domain expertise across a range of areas and technologies to create a truly unique collaboration to benefit the Agri-Tech and Agri-Food industries. The outcomes of the integrated centre have already begun to positively impact the environment, animal well-being, consumer health and the economic status of its key stakeholders.

VistaMilk's future vision will advance the construction of a set of digital twins, each representing a module in the soil-to-gut pathway but with the ability for upstream and downstream communication and interaction – a system-of-systems. Such an integrated collection of independent systems for the dairy sector will enable whole system scenario modelling of a multitude of features and perturbations such as climate change adaptation, policy, farm advice, and research/hypothesis generation, the scale of which has never before been achieved. The outcome is informed direction and policy on how best to tackle Ireland's unique challenges.

VistaMilk has three overarching strategic goals: sustainability, food security and prosperity and societal enrichment (Figure 1). The research programme focuses on new methods and technologies in soil, pasture, cow and food. These research themes are underpinned by several enabling technologies delivered by the different research partners.

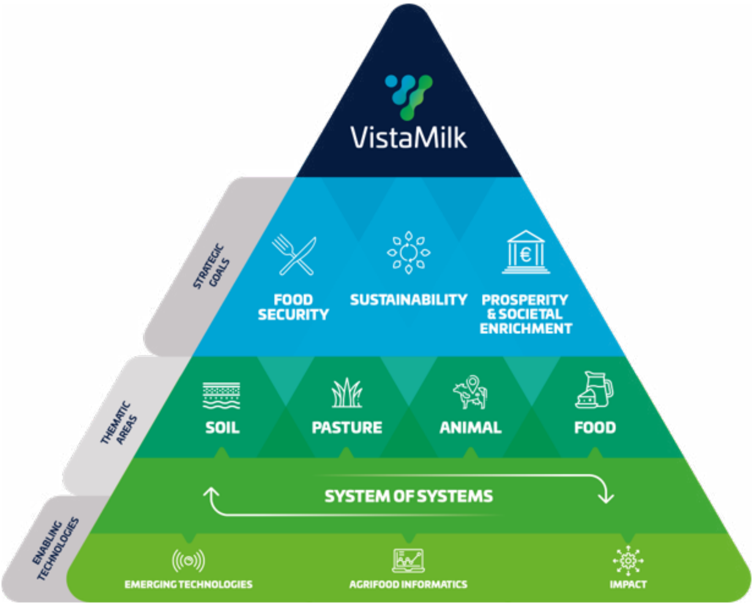

Figure 1. *VistaMilk strategic goals and research programme*

Sample highlights of the research programme to-date

Image analyses to predict sward composition. Current methods to estimate sward composition (grass, clover, weed composition), herbage mass and sward height are labour intensive and time consuming. A large experiment was undertaken which used machine learning methods to predict sward composition with an accuracy of 95%. The research is continuing to now predict herbage mass and sward height. It is intended to develop this into an APP enabling farmers and advisors to use the technology in the field; outputs will enter the PastureBase Ireland application.

Carbon Index. A world's first carbon index was developed to rank dairy males and females based on their expected lifetime carbon output using the carbon models developed in the VistaMilk platforms. The carbon output associated with an incremental change in the traits within the national dairy cow breeding index was generated and used to rank animals. The index was launched in November 2022.

Methane. VistaMilk pioneered the research on methane emissions in grazing dairy cows in Ireland. Individual cow enteric methane data now exists on >300 grazing cows. Considerable inter-animal variability in enteric methane was identified. Results from dairy cows clearly demonstrate that while genetically elite dairy cows produce the same methane emissions as their national average contemporaries, the 8% greater milk solids output in the former translate to improved methane efficiency of milk solids production. Research is on-going on the usefulness and practicality of feed additives in the diet of dairy cows to reduce emissions – favourable results have already been observed.

Conclusions

VistaMilk outputs will enable evidence-based policy formation and provide a robust advisory role for government. Outcomes will generate the knowledge and tools to deliver a sustainable and balanced human diet by creating highly nutritious dairy products with added health benefits, complementary to other dietary choices.


Image Credit: Bord Bia

Teagasc Food Research Programme

Trend analysis of seasonal changes in milk composition from a pasture-based dairy research herd

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Summary

- Breeding strategies, driven by the economic breeding index (EBI), have focused on increasing the solids content of milk, with a particular focus on fat and protein. This is largely because milk solids are processed into cheese, butter, protein-based ingredients and lactose, the primary Irish dairy exports.
- Milk composition from 2012 - 2020 was analysed, and results showed that fat and protein has increased yearly since 2012, while lactose increased until 2017 and began to decrease from 2017 - 2020.
- Seasonal factors such as grass growth, temperature and rainfall influence milk composition, impacting total solids content and thus, the quantity of dairy products manufactured.

Introduction

The dairy industry is Ireland's largest agricultural exporter, worth over €4bn to the Irish economy. Milk production increased in recent years due to the abolition of milk quotas in 2015. Milk volume per cow has increased by 14% from 2009 - 2018; however, there was a 21% increase in fat and protein production in the same time frame. The introduction of an economic breeding index (EBI) allowed farmers to choose high-potential bulls based on specific genetic traits to enhance the genetic merit of their daughters entering the dairy herd. This resulted in the targeted increase in individual milk component's such as protein and fat. As farmers are paid based on the yield of fat and protein in milk rather than milk volume, increasing total solids (**TS**) is economically beneficial for the farmer and processor. Solids then can be converted into a diverse range of dairy products, for example, skim, whole milk, protein concentrates/ isolates and hydrolysates, caseinates, nutritional formulations, cheese and butter.

Materials and methods

Milk composition data (fat, protein, lactose and total solids) from a spring calving Holstein Frisian dairy research herd at Teagasc Moorepark from 2012 - 2020 were analysed. Grass growth data was collected for the same period, and weather data were obtained from the Met Éireann weather station in Moorepark.

Results

Fat and protein increased over the period studied. Within a lactation period, trends for each year were consistent with fat decreasing from early to mid-lactation and increasing from mid to late-lactation. There was a high standard deviation within stages of lactation for fat, indicating that content is less consistent and is influenced by external factors, such as the cows diet.

Protein was much more consistent within stage of lactation compared to fat. Trends of protein composition over a lactation period were consistent for each year. Protein increased from early to late lactation. However, while total protein remained consistent, Non Protein Nitrogen (NPN) varied year on year. There were inverse correlations between NPN and grass growth, indicating that diet also influences NPN. The relationship between grass growth, rainfall and temperature can be seen in Figure 1. The high levels of rainfall during the summer of 2012 resulted in low grass growth. The lack of rainfall and high temperatures during the summer of 2018 also resulted in lower grass growth. This affected the milk composition as cows were supplemented with either silage or concentrate feed. In 2018, the milk solids decreased during July, which correlates with the lowest levels of grass available.

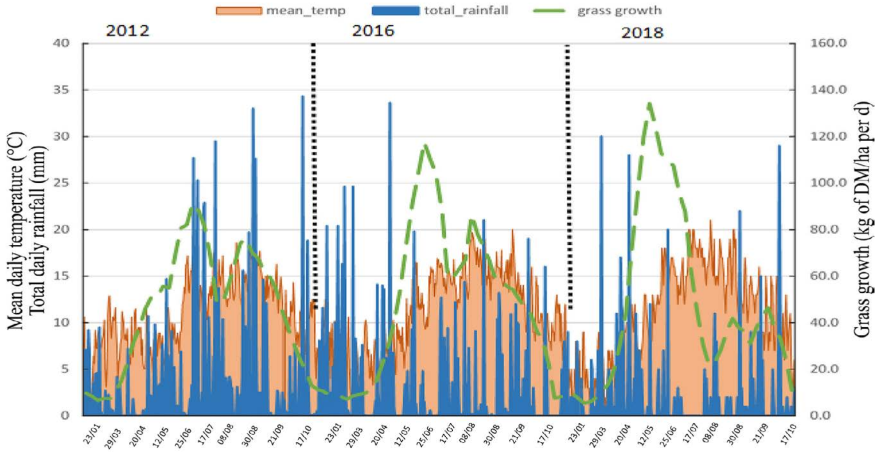

Figure 1. *Seasonal variation of grass growth (dashed green line), average temperature (orange), and total rainfall (blue) from January to October for 2012, 2016, and 2018*

While these factors impact the gross milk composition, they also affect the ratio of components in milk. Figure 2 shows an increase in fat and protein over the years, suggesting that the standardisation required for milk products, such as skim milk powder, in 2019 is higher than in 2013. This has implications for a dairy processer due to the need to add lactose or milk permeate in the case of skim milk powder production to standardise its protein content across the season.

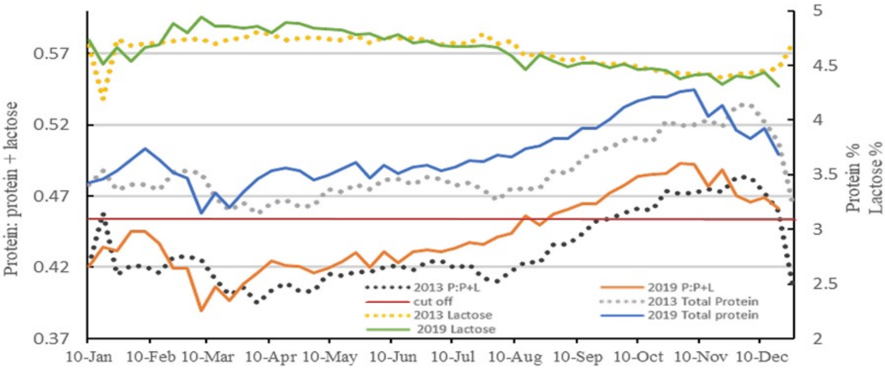

Figure 2. *Total protein, lactose, and ratio of protein to protein plus lactose (P:P+L) for 2013 and 2019. The area above the red cut-off line indicates the ratio that processors need to start standardizing milk powder with lactose*

Conclusion

Milk composition from pasture-fed cows changed significantly between 2012 and 2020, primarily driven by increases in fat and protein concentration. Compositional changes, particularly P:P+L ratio, affect the level of standardization required to meet target specifications during the manufacture of skim milk powder. In addition, adverse weather conditions that correlated with a reduction in grass growth led to seasonal changes in milk composition.

Acknowledgements

This study has emanated from research conducted with the financial support of Science Foundation Ireland (SFI) and the Department of Agriculture, Food and Marine on behalf of the Government of Ireland under grant number [16/RC/3835] - VistaMilk (Ireland).

Milk kefir: The future of fermented milk

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Summary

- Milk kefir is a fermented milk product with a long history of safe consumption and has gained considerable interest due to its proposed health benefits. An in-depth knowledge of microorganisms associated with kefir, will greatly improve current and future research efforts into the health benefits of consuming kefir.
- 64 kefir grains were sourced from 25 different countries and used to produce kefir milks in order to study the composition of microbes in kefir.
- We have detected 46 microbial species persisting in the kefir microbiome. The majority of organisms are bacterial species, with eukaryotic species accounting for <2% of the total microorganisms in the kefir microbiome.
- *Lactococcus lactis* was consistently detected across all kefir milk samples regardless of timepoint or geographical location of the kefir grains. Such a result suggest *Lactococcus lactis* is universal to the kefir microbiome and should be considered in regulatory guidelines concerning milk kefir production.

Introduction

Milk kefir is fermented milk, produced from the inoculation of milk with kefir grains that comprise a specific and complex mixture of microorganisms that live in a symbiotic association. Kefir originates from the Caucasus and Tibet, and has a long history of safe consumption. Recently, kefir and its associated microorganisms have raised interest in the scientific community due to numerous scientific studies, many conducted *in vitro* or in animal models reporting promising results in terms of improved health. For example, regular consumption of kefir and its associated microbes has been associated with improved digestion and tolerance to lactose, as well as having an antibacterial effect, hypocholesterolaemic effect, anti-hypertensive effect, and anti-inflammatory effect. To further explore the health promoting aspects of kefir, it is necessary to first understand the combination of microbes responsible for its production and how they differ across different grains. Such research is particularly important given that health benefits are not universal across kefir products, but are associated with specific grains and, thus specific microbes.

Testing

A kefir collection initiative was launched in Teagasc Moorepark, aiming to collect kefir grains from all over the world. In total 64 kefir grains were sourced from 25 different countries, representing six of the seven continents. All kefir grains collected were fermented in duplicate in full fat cow's milk for 24 hours. During these fermentations, the resulting fermented milk was collected at eight and 24 hours for shotgun metagenomics sequencing. A series of computational pipelines were carried out using the Teagasc high performance computing (HPC) cluster to provide an insight into microbes contained within milk kefir.

Results

Analysis of kefir milk samples through shotgun metagenomics sequencing detected 46 microbial species, the majority of which were bacterial species, with eukaryotic species such as *Saccharomyces cerevisiae* and *Kluyveromyces marxianus* accounting for <2% of the total microorganisms across kefir samples. Initially relatively high bacterial diversity decreased over time, with a small number of species becoming dominant by eight and 24 h. Specifically, at 0 h, or immediately before the grains were added to the milk, the bacterial species present at a proportion of ≥1% transitioned from *microbes* consistently detected in pasteurised milk, such as *Thermus thermophilus* and *Pseudomonas lundensis* to microbes such as *Lactobacillus kefiranofaciens, Lactobacillus helveticus and Lactococcus lactis*. Fermentation time influenced the frequency of the dominating species, for example in certain kefir milks, between eight and 24 h, the proportions of *Lactobacillus kefiranofaciens, Lentilactobacillus kefiri* and *Lactobacillus helveticus* decreased, whereas the relative abundance of *Lactococcus lactis* increased. We consistently detected *Lactococcus lactis* across all kefir milk samples produced in this study. Species detected in ≥10% of samples (the defined threshold of prevalence for this study) and thus considered to be typically found microbes in milk kefir included *Acetobacter cibinongensis, Acetobacter fabarum, Lactiplantibacillus plantarum, Lactobacillus gallinarum, Lactobacillus kefiranofaciens, Lactobacillus Helvetius Lactococcus garvieae, Lactococcus lactis, Lentilactobacillus kefiri, Lentilactobacillus parakefiri, Leuconostoc mesenteroides,* and *Pseudomonas helleri*.

Conclusions

In this study, we combined shotgun DNA sequencing to measure microbes involved in the production of kefir milk, providing the most in-depth information into the microbial population of kefir and how they transition over the course of 24-hour fermentations. Our analysis, raised awareness into the commonly found microbial species in milk kefir, key microbial species that drive the fermentation process and provided evidence that *Lactococcus lactis* is universal to all kefir milk products, and should be considered in regulatory guidelines concerning milk kefir production.

Acknowledgements

We thank the fermented food producers for kindly supplying samples.

Transforming the dairy industry using Industrial Internet of Things: an exploration of applications and benefits

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Summary

- Industrial Internet of Things (IIoT) connects devices, software, and networks to gather real-time data and monitor industrial processes.
- Sensors and advanced analytics are key components of IIoT.
- IIoT can be used to monitor milk quality, automate milk processing, and evaluate equipment performance in the dairy industry.

Introduction

Industrial Internet of Things (IIoT) is an innovative technology that merges devices (e.g. sensors and machines), software, and networks to support real-time data gathering and remote monitoring of industrial processes.

Applications of IIoT in the dairy supply chain

IIoT sensors and devices can be embedded into milking machines to collect data on milk quality (e.g. somatic cell count), temperature, and volume. Dairy processors can also use IIoT sensors and devices to automate processes and improve process efficiencies. Processors can collect data using sensors installed to monitor in-room environmental parameters (e.g. temperature, humidity), or in-pipe product properties (e.g. pH, fat, and protein), at different stages of the process. In addition, sensors can be used to collect data on equipment effectiveness, energy consumption, or be integrated within a predictive maintenance programme to evaluate changes in performance of unit operations.

Implementation of IIoT in the Teagasc pilot plant for real-time data visualisation and analysis

The IIoT platform has been successfully installed in the Teagasc Moorepark pilot plant to enable real-time process monitoring and historical data access in one centralised location. This has been achieved through the utilization of existing unit operations, coupled with additional wireless sensors. The following unit operations have been integrated into the platform; heat treatment, membrane filtration, evaporation, and spray drying. The system has been designed to facilitate real-time data acquisition from legacy systems, integration to one centralised location (historian), data analytics, and visualization, during processing (Figure 1). The objective of this platform is to identify outliers and trends during processing and to create a repository for real-time and historical data. It also captures important process parameters, such as temperature, viscosity, and moisture, and calculates and visualizes individual unit operation energy and water usage.

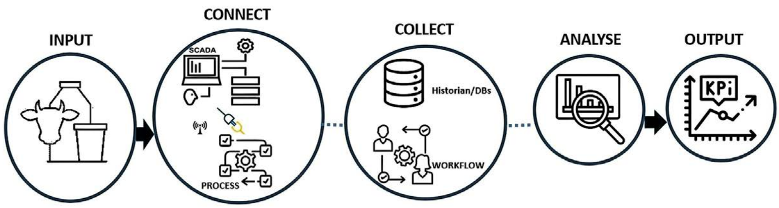

Figure 1. *Workflow used as part of the IIoT platform in the Teagasc pilot plant*

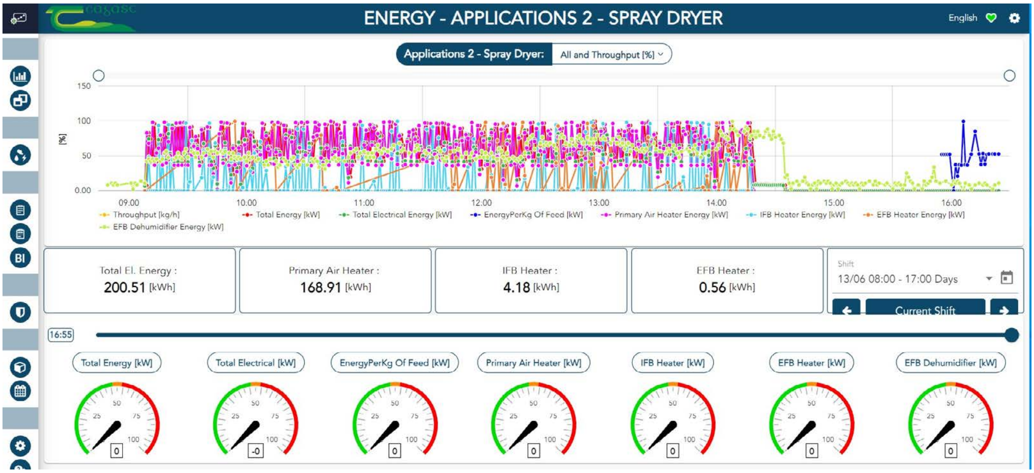

Figure 2. *Work Area Performance System (WAPS) dashboard for energy monitoring of the spray dryer*

The Work Area Performance System (WAPS) is a dashboard developed to support various functionalities, such as monitoring of planned and unplanned downtime in the process, digital workflows, energy monitoring, real-time visualization, advanced analytics, and reporting (Figure 2). It uses both wired connectivity and wireless sensors to gather data from the PLC-controlled machines and manual workstations. The data is then recorded as a time-stamped event in the historian. The sustainability and utilities dashboards monitor the energy and utilities consumption for each production unit over a specific period. The condition monitoring module displays the process variables such as temperature, mass flow, and steam-in pressure. The WAPS system provides users with a comprehensive overview of the pilot plant's performance, enabling the user to make data-driven decisions during milk processing.

Conclusion

Overall, implementation of IIoT in the dairy industry is advantageous as it allows real-time process monitoring and data analysis, which can lead to increased process efficiencies, enhanced productivity, and improved safety for employees. It can also help reduce downtime and equipment failure. Furthermore, optimizing resource utilization and minimizing waste can result in overall cost savings. Teagasc's implementation of the IIoT and the WAPS dashboard system has enabled the pilot plant to collect, analyse, and visualize critical data in real-time, thereby enhancing the plant's productivity and efficiency.

Acknowledgement

This research was funded by Teagasc, the Irish Agriculture and Food Development Authority.

Factors influencing milk composition

Jonathan Magan and John Tobin
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Summary

- Milk composition is altered by animal and management factors.
- Early and late-lactation milk presents some challenges for dairy processors.
- There is potential for further differentiation of Irish milk by selecting for specific genetically driven protein profiles.

Introduction

The most significant differences in overall milk composition are observed between individual cows within a herd. This variation is typified by considerable differences in the concentration of total solids, protein, fat, lactose and individual protein components between cows, but is effectively controlled by the process of bulk milk assembly from an entire herd and, subsequently, multiple herds at processor level, resulting in average values for each component. Despite this, the following factors discussed are sufficient to influence the composition of assembled bulk milk.

Breed

The major milk components (particularly fat and protein content) vary considerably between breeds. While milk yield is highest for Holstein and Holstein x Friesian cows, (with average % fat and protein values of 3.8% & 3.4%, respectively in mid-lactation milk), milk with increased average total solids content is produced by breeds such as Jersey (~5% fat & 4% protein), Fleckvieh (~4.1% fat & 3.5% protein) and Ayrshire (~4% fat & 3.4% protein), which may be included or crossbred within Holstein/Friesian herds to increase milk solids yields. Despite this, overall annual Holstein milk solids yield is greater than most other breeds, due to increased volumes being produced over the course of an entire lactation.

Genetics

The variation in milk composition seen between individual cows is primarily governed by their distinct genetic profile. Genetic selection for fat and protein, in particular, is practiced to meet the requirements of milk-quality-based payment schemes. However, finer milk compositional factors, such as individual proteins within the total protein fraction of milk, are also genetically determined and offer considerable scope for tailored dairy products with specific functional properties and associated economic merit. The protein content of milk is influenced by various factors; however, only genetics have a major impact on protein composition. Milk is made up of two major families of protein, casein and whey. Casein comprises around 80% of the total milk protein and consists of proteins which exist as large suspended colloidal structures called micelles. Whey proteins make up the remaining ~ 20% of the total milk protein content and are present in the serum fraction of milk. There have been 53 variants of individual casein and whey proteins identified, which are both genetically determined and possess unique functional characteristics. Current research focuses on specific protein variants within the Teagasc herds and the value these variants could bring to Irish dairy produce by tailoring milk to meet the needs of consumers.

Milking interval

In general, the interval between an evening milking and the following morning milking is longer than that between a morning and evening milking of the same day. A disparity between the total volume of milk produced by the cow and the amount of fat deposited within the milk throughout the shorter milking interval results in higher fat content at evening milk. Recent work carried out at Moorepark has also identified that, in addition to reduced milking time and labour costs, full-time once-a-day milking resulted in lower milk yield, milk solids yield and % lactose and higher levels of provitamin beta-carotene, higher percentage protein and fat, and, consequently, increased cheese yield per unit volume of standardised milk.

Age and health status

Milk yield and the efficiency of milk synthesis in the mammary gland is also influenced by the age and health status of the cow. Typically, milk fat and milk solids non-fat will decrease over the course of five lactations. The most significant health factor relative to milk production is the incidence of sub-clinical mastitis, caused by a variety of streptococcal, staphylococcal and coliform microorganisms. Mastitic infection typically results in reduced milk and milk solids yield, reduced milk lactose, fat and casein contents and increased levels of serum proteins, enzymes, chloride and sodium ions. These changes render mastitic milk unsuitable for processing into end-products and incur high costs to both processors and farmers.

Seasonality and stage of lactation

Irish milk production is characterised by a seasonal production pattern, intended to synchronise the collective calving and lactation cycle of the herd with the pattern of grass growth throughout the year. Pasture-based production systems such as these account for approx. 10% of global milk production, making the Irish dairy industry somewhat unique in a global context. However, this also presents a challenge to processors, due to the variation in milk composition and volume which occurs throughout the lactation period. Approx. 85 – 90% of Irish milk is derived from spring-calving herds, which leads to considerably higher volumes of milk available in mid-lactation, relative to the early and late-lactation periods. Coinciding with reduced milk yield and lactose content, late-lactation milk contains higher protein, fat, whey protein, enzymes, and calcium and sodium ions, along with increased pH, making it unsuitable for heating processes and cheese manufacturing. Butter production is also limited in late-lactation, due to increased levels of saturated fats and a decline in milk fat globule size, which results in harder, less spreadable butter. Table 1 shows compositional variation in milk from a spring-calving, pasture-based herd at Moorepark.

Table 1. *Change in compositional variables (%) of Holstein-Friesian milk throughout lactation from a seasonal grass-based system (adapted from O'Callaghan et al., 2016)*

%	Early-lactation	Mid-lactation	Late-lactation	Yearly average
Total solids	13.60	13.56	14.58	13.95
Protein	3.33	3.51	3.89	3.65
Fat	4.56	4.46	4.90	4.65
Lactose	4.98	4.92	4.75	4.87
Casein	2.66	2.78	3.31	2.95
Whey	0.48	0.54	0.65	0.56

The considerable volume of mid-lactation milk available for processing during the summer months has led to a focus on the production of long shelf-life products such as butter, cheddar cheese and powders. The remaining 10 – 15% of Irish milk limits the effect of lactational changes through the inclusion of autumn-calving programmes and consistent supply of mid-lactation milk.

Conclusion

Milk composition is influenced by a variety of factors at farm level and between individual cows. For spring-calving production systems, the seasonal impacts of lactation stage and changing diet represent the most significant factors driving the variability seen in bulk milk throughout the year. The specific effects of differences in dietary factors are discussed in the following article on grass-fed milk.

Grass-fed milk: The impact of diet on milk composition

Jonathan Magan and John Tobin
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Summary

- Lactational changes in milk composition are augmented by changes in diet throughout the year.
- Pasture feeding results in higher percentage total solids, protein and fat and lower milk yield and percentage lactose.
- Pasture-based milk production creates unique compositional differences, compared to indoor systems, especially relative to the fatty acid profile and carotenoid contents.

Introduction

The most substantial factors influencing bulk milk composition in Ireland are the effects of lactation stage and diet. The variation in milk composition which occurs throughout the lactation cycle of a spring-calving dairy herd is further augmented by changes in the diet of the herd throughout the year, as influenced by the developmental stage of the grass sward throughout grazing cycles and the feeding of silages and concentrates during the winter months. Unique aspects of milk composition can be attributed to a grass-based diet and recent studies on this topic are discussed below. The effect of different feeding regimes on milk composition has been widely investigated in various countries, with a range of effects observed, including a greater dependency of milk protein content on dietary energy levels, rather than dietary crude protein, of which overfeeding results in increased non-protein nitrogen content in milk. Similarly, overfeeding of dietary fat will depress milk fat content by inhibiting cellulolytic microorganisms in the rumen, as is also observed for low roughage diets.

Materials and methods

An extensive analysis programme based on the comparison of perennial ryegrass only (GRS) and perennial ryegrass/white clover (CLV) pasture systems practiced in Ireland with a conventional, indoor, total mixed ration (TMR) based system, common in other regions, was carried out at Moorepark between 2015 and 2020. A wide range of dairy products derived from each system were analysed for major and fine compositional factors, with a range of effects observed.

Results

Milk yield and lactose content was greater for the TMR system, whereas total solids, fat and protein were greater for the pasture-based systems. Figure 1 shows the average percentage total solids, fat, protein and lactose content of raw milk from the GRS, TMR and CLV systems.

As seen throughout previous dietary studies, the fatty acid profile of milk was the fraction which was most significantly affected by feed type. The concentration of several saturated fatty acids such as palmitic acid were significantly higher in products from the TMR system, which led to increased butter and cheese hardness and lower butter spreadability.

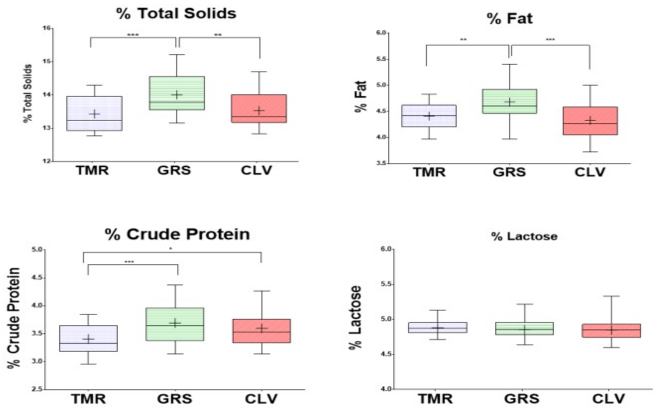


Figure 1. *Percentage total solids, fat, crude protein and lactose of raw milk from total mixed ration (TMR), perennial ryegrass (GRS) and perennial ryegrass/white clover (CLV) systems (O'Callaghan et al., 2016)*

Long chain polyunsaturated fatty acids such as conjugated linoleic acid, which is associated with a number of anti-inflammatory health effects, were present in higher concentrations in pasture-derived products (particularly GRS), including a more favourable ratio of omega-3 to omega-6 fatty acids, relative to TMR products, shown in Figure 2 below.

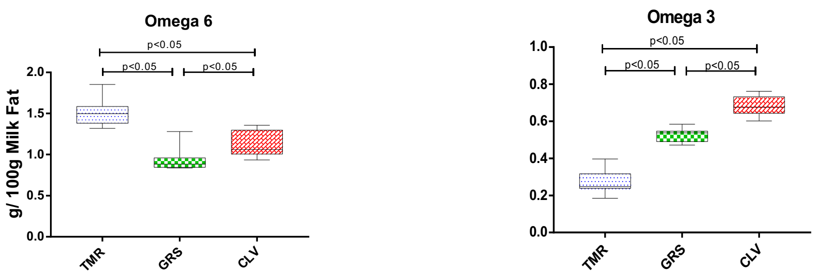


Figure 2. *Differences in omega-6 and omega-3 fatty acid balance between raw milks from total mixed ration (TMR), perennial ryegrass (GRS) and perennial ryegrass/white clover (CLV) systems (O'Callaghan et al., 2016)*

The TMR system was also associated with higher concentrations of vitamin B3 (niacin) and B3-amide (niacinamide) in milk powder products, whereas the pasture-based systems resulted in greater concentrations of vitamins B1 (thiamine), B2 (riboflavin) and B7 (biotin). Furthermore, the higher beta-carotene and vitamin B2 content of pasture-derived (particularly GRS) milk was responsible for the characteristic yellow colour of Irish butter and cheese, with colour differences also visually apparent in whole milk powders. Mineral supplementation within the TMR diet lead to increased transfer of trace elements such as selenium, copper and iodine into milk and subsequent products. Significant differences in sensory profile between products derived from each system were also determined using consumer and trained sensory panels, as influenced by a range of volatile compounds which were associated with each particular feed type, including para-cresol and toluene.

Conclusion

In the context of Irish milk production, milk composition is complex and constantly changes over time. However, this variability leads to a number of characteristics unique to Irish dairy products, which set them apart from those derived from conventional indoor systems worldwide.

Diversity and Inclusion at Teagasc

DIVERSITY & INCLUSION
Let's grow together

Diversity and Inclusion Vision

Teagasc is committed to being an organisation that recognises the value of diversity among its staff, and where all staff feel included and valued, irrespective, and indeed because, of their uniqueness. We support and value our staff for who they are and the work they contribute to the organisation. We strive for diversity in our sector, through our stakeholder groups and external engagements, amongst our full and part-time students, and across our farmer clients.

Teagasc wants to promote an understanding of diversity of thinking, which embraces a broad range of ideas and reaches out to all areas in the organisation and beyond to the wider sector. This understanding of diversity will unlock the value derived from differing perspectives in terms of increasing innovation, promoting Teagasc as a better place to work, and improving problem-solving behaviours throughout the agri-food sector.

Diversity and Inclusion in Action

Teagasc has an active Diversity and Inclusion working group who monitor progress on our Diversity and Inclusion Strategy and action plans. Our strategy is sponsored from the top and we are working hard to ensure that diversity is manifested across management structures in all Directorates. We welcome a diverse range of staff to all levels of the organisation. Almost half of our staff are female, we have staff from over 40 different countries across the globe, we have put new initiatives in place to openly support the LGBTIQA community and we provide accommodation to staff with disabilities.

Diversity and Inclusion commitment to our Staff

- Ensure all staff are part of the Diversity and Inclusion Strategy at Teagasc and reinforce words with solid actions for the common good of all in the organisation
- Maintain a work environment that respects all individuals and promotes real inclusion at every opportunity throughout the organisation
- Reinforce a just and honest culture with the Teagasc Authority and Senior Management Group setting the example, where staff members are treated fairly, promoting trust and drawing the line between acceptable and unacceptable behaviours.

Grassland Decision Support Tool

Agriculture and Food Development Authority

PastureBase IRELAND

Tools include

- **Grass Wedge & Projected Wedge**
- **Spring & Autumn Rotation Planners**
- **Grass & Fodder Budgets**
- **Fertiliser & Slurry Recording**

Additional features

- **Farm Mapping Tool**
- **Soil Test Imports**
- **Nitrogen Planner & NUE % Calculator**
- **Forecast & Actual Weather Data**

Grassland Decision Support Tool

PastureBase Ireland (PBI) is the first choice on-line grassland management platform for thousands of farmers nationwide. A range of new tools and reports have been developed in recent years and PBI continues to expand its functionality to meet the needs of farmers. Each year the number of farmers using the application is increasing while the measuring intensity continues to increase.

The Grass Wedge

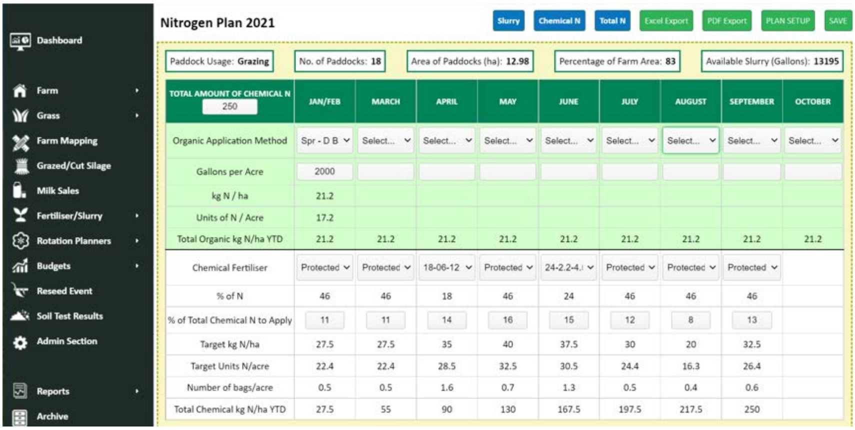
The Grass Wedge is the primary tool within PBI and is used for the day to day running of any grassland farm. The Grass Wedge displays the grass available in each paddock. The red demand line is determined by the number of stock, the grazing area, the grass intake of each animal and the rotation length. The Grass Wedge identifies grass surpluses and deficits as they arise. Paddocks can be easily removed from the Grass Wedge and cut for surplus bales in order to keep with the targets. Likewise, in a deficit situation, grass intake can be reduced and supplement added to the diet. The Grass Wedge can be downloaded or printed for you advisor or farm staff to make decisions.

Farm Mapping Tool

The objective of the Farm Mapping Tool is to give farmer a visual aid to make informative decisions. The user friendly tool allows farmers to map each paddock on their farm and calculating the area of each paddock. Once mapped, information for example grass covers, daily growth, soil fertility data, fertiliser records etc can be displayed on the map for each paddock. The farm map can be downloaded or printed to enhance communication and aid decision making between your advisor, farm staff and agricultural contactors.

Nitrogen Planner

In the Nitrogen Planner paddocks are allocated to a particular use, for example; a paddock can be used for grazing or grazing + 1 cut of silage or grazing + 2 cuts of silage etc. From this information monthly chemical nitrogen targets are determined. When the farmer selects the fertiliser product they wish to apply, the rate of application is calculated. The nitrogen plan also takes into account the application of slurry on paddocks. As the year progresses actual fertiliser and slurry records are added to PastureBase Ireland and compared with monthly targets.



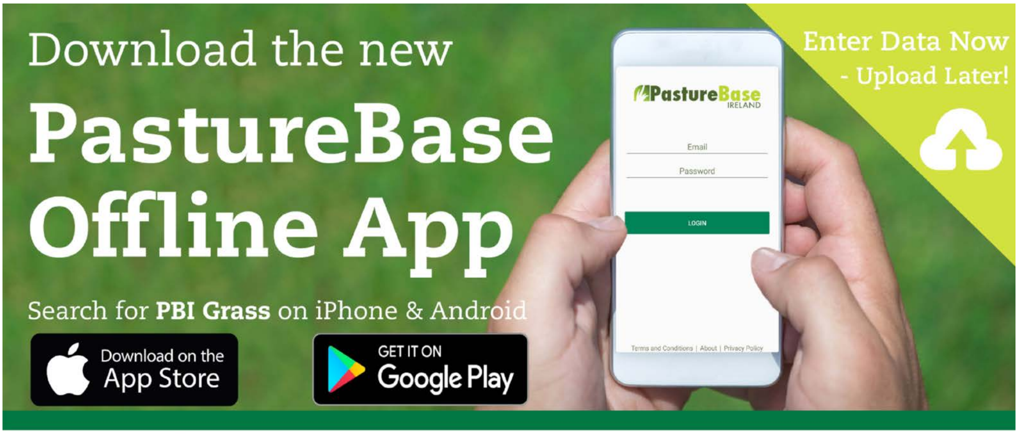
TOTAL AMOUNT OF CHEMICAL N 250	JAN/FEB	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
Organic Application Method	Spr - D B	Select...	Select...	Select...	Select...	Select...	Select...	Select...	Select...
Gallons per Acre	2000								
kg N / ha	21.2								
Units of N / Acre	17.2								
Total Organic kg N/ha YTD	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2
Chemical Fertiliser	Protected	Protected	18-06-12	Protected	24-2.2-4.!	Protected	Protected	Protected	
% of N	46	46	18	46	24	46	46	46	
% of Total Chemical N to Apply	11	11	14	16	15	12	8	13	
Target kg N/ha	27.5	27.5	35	40	37.5	30	20	32.5	
Target Units N/acre	22.4	22.4	28.5	32.5	30.5	24.4	16.3	26.4	
Number of bags/acre	0.5	0.5	1.6	0.7	1.3	0.5	0.4	0.6	
Total Chemical kg N/ha YTD	27.5	55	90	130	167.5	197.5	217.5	250	

Nitrogen Use Efficiency

Nitrogen Use Efficiency (NUE) calculator measures how efficiently nitrogen in slurry, feed and fertiliser converts to milk and meat. The calculator will also determine the farm gate nitrogen surplus on the farm. Improving NUE and reducing nitrogen surplus will have a large economic and environmental benefit.

Forecast & Actual Weather Data

Research from the Agricultural Catchment Programme has shown large year-to- year variation in nitrogen losses to the environment. This is mostly influenced by year-to-year variation in meteorological conditions. The use of precision N application strategies, taking cognisance of meteorological conditions will improve N use efficiency and reduce losses to the environment. Teagasc now issues precision nitrogen management advice weekly through PBI. This is based on predicted weekly grass growth information using Met Eireann meterlogical data to increase nitrogen use efficiency on grassland farms throughout Ireland.



Teagasc
Agriculture and Food Development Authority

PastureBase IRELAND

PBI has an offline app which is available for download from the App store and Google play store. Search for 'PBI Grass'. All farmers currently using PBI should download the app right now. The app is also free to download. Grass covers, graze dates, fertiliser application, livestock number/intakes as well as milk data can be quickly recorded while undertaking the task in the paddock whether mobile coverage is poor or not available.

The main benefits from measuring grass

- **Minimise costs for dairy, beef and sheep production.**
- **Maximise the proportion of grazed grass in the diet.**
- **Increase nitrogen use efficiency.**
- **Adopt greater precision in terms of nutrient management.**
- **Graze more grass in the spring and autumn, shorten the winter period.**
- **Achieve target average farm cover at key times during the year.**
- **Identify and correct poor performing paddocks.**

You cannot manage something you do not measure!

Measuring grass enables the grassland farmer to make better informed and more effective grassland management and grazing decisions.

PastureBase Ireland, Animal & Grassland Research and Innovation Centre,
Teagasc, Moorepark, Fermoy, Co. Cork.

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Teagasc
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The Dairy Edge
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Notes

We Need Your Feedback!

Your feedback is important to us and we constantly strive to make our open days bigger & better!

Open the camera on your phone & scan the QR Code to access the survey!

One lucky person will receive a €250 One4All Voucher!

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