Animal & Grassland
Research and Innovation
Centre

Moorepark

Irish Dairying

Delivering Sustainability

Tuesday 14th – Thursday 16th September, 2021

Teagasc
Agriculture and Food Development Authority

MOOREPARK '21
IRISH DAIRYING – DELIVERING SUSTAINABILITY

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The Signpost Programme is a collaborative partnership of farmers, industry and State Agencies, working together for climate action.

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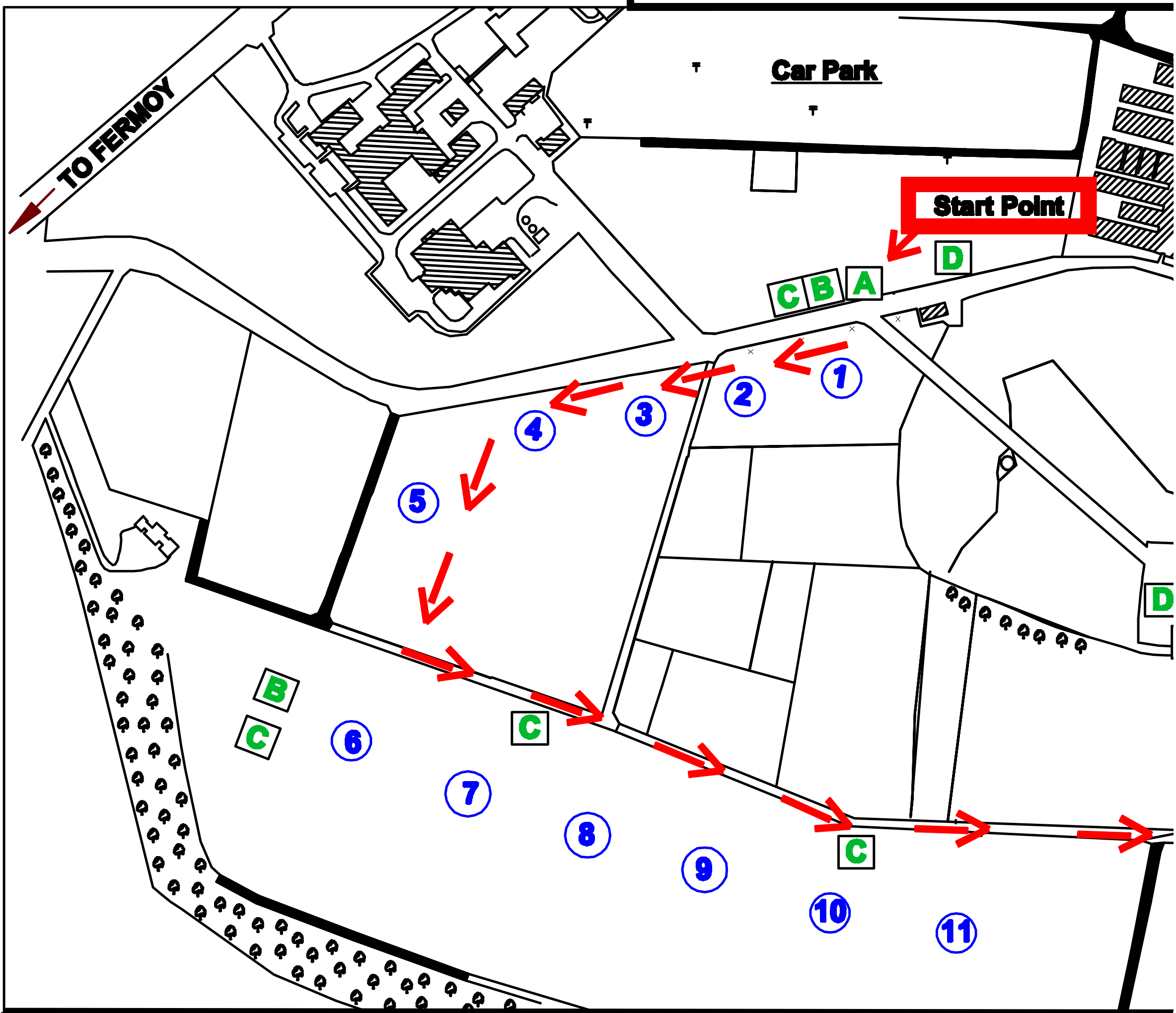

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1. Delivering on Sustainability
2. Profitable Milk Production Systems
3. Grazing Management to Increase Nitrogen Use Efficiency
4. Sustainable Breeding - What are the options?
5. Grass10
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7. Signpost Farm Programme
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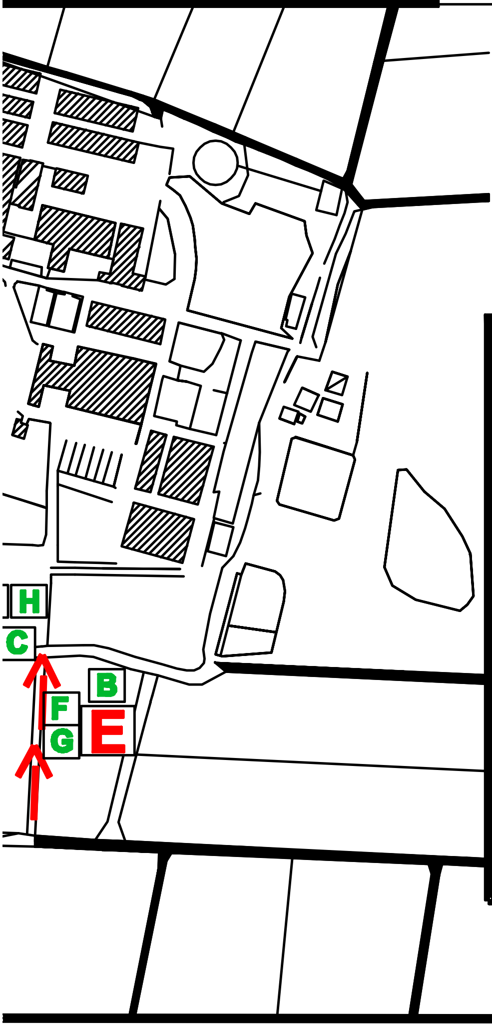

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MOOREPARK '21

IRISH DAIRYING – DELIVERING SUSTAINABILITY

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MOOREPARK '21

IRISH DAIRYING – DELIVERING SUSTAINABILITY

Tuesday, Wednesday and Thursday

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INTRODUCTION

Introduction: Irish dairying — Delivering sustainability

Pat Dillon

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Current situation

The Irish dairy industry has been transformed since the abolition of milk quotas in 2015. Exports of Irish dairy products and ingredients have increased from an average of €1.8 billion for years from 2007–2009 to over €5.2 billion in 2020.World milk supply is forecast to expand by just 1% in 2021, which is less than previous forecasts and long term historical growth rates. China continues to drive current global trade for dairy products. Currently, higher feed prices are keeping dairy farmers margins under pressure in high input systems. Dairy commodity prices are trading at elevated values compared with last year.

Increase in milk production

Milk production in Ireland has increased from an average of 4.93 billion litres (average of 2007–2009) to 8.29 billion litres in 2020. This is equivalent to a 68% increase in milk production or an 87% increase in milk fat and protein production, exceeding the 50% increase forecasted by in Food Harvest 2020 strategy document. In 2020, dairy cow numbers had increased by 454,267 (43%) compared with the average of 2007 to 2009 (1,057,583). Over this period, milk production per cow has increased by 15%, increasing from 4,666 litres/cow (average of 2007–2009) to 5,485 litres in 2020; the combined yield of milk fat and protein per cow has increased by 27%, increasing from 334 kg to 425 kg/cow. Therefore, over this period 50.5% of the increase in milk fat and protein production came from an increase in cow numbers with the remaining 49.5% coming from increased milk solids production per cow.

Increased dairy farm competitiveness and productivity

Cele *et al.* (2021) compared the competitiveness of dairy farmers in Ireland with those of our main EU competitors, which included Belgium, Denmark, Germany, France, Italy, The Netherlands and UK. The analysis compared the period before quota abolition (2012–2014) (pre-quota) with the period immediately after quota abolition (2015–2017) (post-quota). In Ireland post quota, milk solids yield per cow increased by10.2% (394–435 kg), milk solids per ha increased by 15.6% (791–915 kg/ha), milk price per 100 kg reduced by 13% (€36.1–€31.4), dairy herd size increased by 9% (67.3–73.5 cows) and farm net income increased by 18% (€61,808-€73,092). Post-quota in the other seven EU countries; milk solids yield per cow increased by 3.8% (556–578 kg), milk solids per ha increased by 4.2% (1,245–1,297 kg/ha), milk price per 100 kg reduced by 12% (€36.2 – €31.8), dairy herd size increased by 3% (90.2–92.1 cows) and farm net income reduced by 14% (€63,594 – €54,459). Post-quota Irish dairy farmers had the lowest total costs (€3.78) and total cash costs per kg of milk solids (€2.39). In contrast, dairy farmers in Italy and Denmark had the highest total cost (€5.13) and total cash cost (€3.79) post quota removal. Consequently, Ireland was ranked first as the most competitive country post-quota for both total costs and total cash costs per kg of milk solids.

McCormack *et al.* (2020) developed a methodology to estimate the Total Factor Productivity (TFP) of the Irish dairy industry at farm level. TFP is a measure of productive efficiency of an industry. TFP takes into account all of the land, labour and intermediate resources utilised in the dairy farm production and compares these with the total output of milk and livestock. If the total quantum of output produced is growing at a faster rate than the total quantum of input used, this is called an improvement in TFP. Kelly *et al.* (2021) reported that the TFP of specialist Irish dairy farmers increased by 24% over the period 2010–2018. Over this period, total inputs increased by 14%, while total outputs increased by 39%.

Adoption of key technologies

Over the last eleven-year period (2010–2020), mean calving interval on Irish dairy herds has reduced from 401 days to 387 days, six-week calving rate has increased from 52%-65%, and mean calving date has advanced from 9 March to 27 February. The proportion of cows calving in the months of January to April has increased from 79% in 2010 to 84% in 2020. A compact calving pattern is essential to maximise profitability on a grass-based system. It allows the herd feed requirements to match the grass growth curve. Average grass utilisation on Irish dairy farms has increased from 6.7 tonnes DM/ha in 2010 to 8.0 tonnes DM/ha in 2019; this was associated with an increase in the whole farm stocking rate from 1.80 LU/ha to 2.03 LU/ha. The annual rate of gain in EBI (for cows calving) has been €11.37 over the past 10 years with no sign of deceleration.

Environmental challenges

The Irish dairy industry has been the fastest growing dairy-sector in the EU during the last 10 years, which has contributed greatly to improve economic prosperity in rural Ireland. At the same time, however, the industry is also a major focal point for discontent among both national and international industry commentators who perceive that this expansion is being achieved at the cost of accelerated climate change via growing agricultural emissions, reduced water and air quality (ammonia emissions) and reduction in biodiversity. In the future, dairy farmers must operate farming systems that are financially profitable while at the same time environmentally sustainable and socially acceptable.

Climate change

As part of the new Climate Action and Low Carbon Development Bill, Ireland has set a target for a reduction of 51% in GHG emissions by 2030 and being climate neutral by 2050. Sectoral emission reduction targets have not yet been defined, but it's assumed that agriculture will have to deliver greater than the 10–15% reduction that was proposed in the previous Climate Action Plan in 2019. This will be challenging given that the national herd has increased by 13.4% over the 2010–2020 period (a 44.6% increase in the dairy cowherd and a reduction of 15.4% in the suckler cowherd (based on December CSO data). Agriculture in Ireland accounted for 35.3% of GHG emissions in 2019, which is high compared with the EU27 average of 10.1%. This is due to Ireland's relatively low population density, little heavy industry and a high share of agriculture in its economic activity. Livestock account for approximately 90% of total agricultural GHG emissions, with methane from enteric fermentation accounting for over 57.9% of these GHG emissions in 2018. Lanigan *et al.* (2018) projected that, in the absence of mitigation strategies, GHG emissions from agriculture would continue to increase during the period to 2030 due to increased agriculture activity. With the adoption of mitigation measures, however, a reduction of 15% was possible. The Teagasc Marginal Abatement Cost Curve indicates that with a linear uptake of mitigation measures between 2021 and 2030 would result in a mean abatement potential 1.85 Mt of carbon dioxide equivalents per year or 3.06 Mt by 2030.

The reliance of our dairy production system on grazed grass, and the selection of animals to suit pasture-based systems, have had favourable effects on the emissions intensity of milk production. Buckley and Donnellan (2020) reported that emissions intensity has reduced over time. Herron *et al.* (2021) reported that the current emissions intensity of Irish milk production is slightly less than 1.0 kg CO_2 eq per kg of Fat and Protein Corrected Milk. Lahart *et al.* (2021) reported that GHG emissions are decreased by 1% per unit of product for every €10 increase in EBI. Increasing stocking rate was associated with reduced emissions per unit of product, while increasing concentrate supplementation had the opposite effect. Continued improvements in grazing management and EBI of the national herd, use of low emission slurry spreading, use of protected urea plus greater reliance on clover to supply biological fixed N instead of chemical N will continue to improve the emissions intensity of Irish milk production.

The current standard for determining how GHG warms the planet, which is GWP100, does not reflect the differing characteristics of biogenic methane compared with other GHG's such as CO_2 and N_2O. Based on new scientific information, biogenic methane is a potent GHG but it has a relatively short life cycle of 12 years, and therefore it is possible that the amounts that are being emitted can be equal to the amount being destroyed. Therefore, the most appropriate metrics will be important to develop strategies to achieve climate neutrality by 2050.

Water quality

Water quality is regulated in Ireland by the EU Water Framework Directive, which requires at least 'good' water quality in all water bodies (rivers, lakes, groundwater and transitional coastal waters). In Ireland, this must be achieved by 2027. Irish water quality statistics are better than most EU countries; 53% of Irish waters are at good or high status compared with 44% in the EU; and 92% of groundwater is classified as good compared with 80% in the EU. The EU Nitrate Directive has been implemented in Ireland since 2007, and regulates agricultural practices such as stocking rate, fertilizer use, manure storage requirements, and timing of manure and fertilizer application. The current Nitrate Action Programme (4^{th}) and associated Nitrate Derogation will expire at the end of this year.

In December 2019, the EU announced the European Green Deal agenda. This was followed by the Farm to Fork Strategy in 2020, which set a requirement to reduce nutrient losses by 50% and fertilizer inputs by 20% by 2030. Subsequently, the DAFM published "Ag Climatise — A Roadmap towards Climate Neutrality". This set a target to reduce chemical nitrogen from a peak of 408,000 tonnes in 2018, to 350,000 tonnes in 2025 and 325,000 tonnes in 2030, representing a 10% and 20% reduction, respectively. The latest EPA Water Quality report in 2020 indicated some improvements in biological quality of rivers; 57% of rivers and 46% of lakes in either good or high quality status. However, nutrient levels in rivers, groundwater, and estuaries in the south, southeast and east of Ireland are too high and these must be reduced. The EPA has carried out an analysis of the annual nitrogen load reduction required for each catchment to achieve a standard of 2.6 mg/l N in the downstream estuary (EPA, WFD, River Basin Management Plan, and June 2021). The report highlights the challenge in the south and east of the country where water quality is declining and agriculture pressures are higher.

Increased stocking rates in pasture-based systems are associated with increased usage of chemical fertilizer and supplementary feed importation, increased nutrient surpluses and reduced nutrient use efficiency resulting in increased losses to ground water and the general environment. Where feed and fertilizer use are held constant, however, and additional pasture utilisation is achieved to support extra stock, the risks of nutrient loss during intensification are much reduced. The Teagasc report on 'The Impact of Nitrogen Management Strategies within Grass Based Dairy Systems' highlights the importance of adhering to current regulations with regards to observance of the closed period and not exceeding maximum levels of chemical N application in minimizing losses to the environment. It also highlights the benefit of precision N application strategies, taking cognizance of meteorological conditions, especially in early spring and periods of poor grass growth during the main grazing season. The current River Basin Management Plan (2018–2021) took a new approach to protect the environment, including a collaborative Agriculture Sustainability and Advisory Support Programme (ASAP). This partnership between the State and the dairy industry consists of 30 Sustainability Advisers to promote best farming practices in 190 areas that were selected for action (reaching up to 5,000 farmers). Initial positive results from this initiative have been reported.

Ammonia

The National Emission Ceilings Directive (NECD) regulates ammonia emissions in the EU and Ireland. Ammonia emissions in Ireland are predominately from agriculture (~99%), and have been exceeding the NECD ceilings of 116 kilotonnes since 2017. Ireland has been set a ceiling of 114.73 kilotonnes over the period 2020–2029, and reducing to 111.85 kilotonnes by 2030. The adoption of mitigation measures outlined in the Teagasc Ammonia Marginal Abatement Cost Curve developed by Buckley *et al.* (2020) should meet these targets.

Biodiversity

The EU Habitats Directive prescribes a list of habitats and species considered important at European scale that must be protected. The EU biodiversity strategy aims to have at least 10% of agriculture area under high-diversity landscape features. High Nature Value farming systems occupies about a third of farmland in Ireland and is mostly distributed along the western seaboard. A third is classified as Low Nature Value farming systems and this is mostly distributed in the eastern part of the country with the remaining classified as Medium Nature Value farming systems. More intensively managed livestock systems are associated with lower levels and diversity of semi-natural habitats. The area of semi-natural habitat has declined by 42%, 15.6% and 6.1% in extensive, intermediate and intensive farming systems, respectively. A recent survey of intensively managed farms found that the median wildlife habitat area of 5% in tillage, 6% in intensive beef and 6.6% for intensive dairying. The target is that by 2027, 10% of farmland in dairy farms will be under high-diversity landscape features.

Conclusion

The structure of the Irish dairy industry has changed significantly following EU milk quota abolition. This expansion has increased the competitiveness of Irish dairy farming. The application of key technologies in relation to farm system, grazing management and use of high EBI genetics were critical to achieving profitable expansion at farm level. Challenges in the future relate to greenhouse gas emissions, water quality, ammonia emissions and biodiversity. The Irish pasture-based system confers environmental advantages in terms of manure recycling, soil organic matter carbon content, feed self-sufficiency, GHG emissions per kg of product and landscape diversity. There are demanding domestic and international policy and environmental targets, however, which will require the system of farming to adapt. These changes should build on Ireland's 'green' reputation, gain market share in expanding high value international markets and improve the living standards of practicing dairy farmers.

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DELIVERING SUSTAINABILITY

Delivering on sustainability

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Summary

- On average dairy cows in Ireland have access to pasture for 71% of the year and are managed on farms that operate at low stocking rates (<2.1 livestock units (LU)/ha) with relatively low milk yield per cow
- Cow locomotion/lameness is the key dairy cow welfare consideration on farm
- Calf mortality in Ireland is low when compared internationally. There is an increasing requirement to develop integration strategies between the dairy and beef industries in order to maximise opportunities for animal welfare, the environment and economics
- Total Irish agricultural greenhouse gas emissions currently are similar to 1998. Irelands dairy carbon footprint is one of the lowest in the world with plans to reduce it further through increased productivity and efficiency, movement to urea based fertilisers, and reduced crude protein concentration of bought in concentrate
- Ammonia emissions reduced by 7.2% between 2018 and 2019. Achieving Irelands ammonia emissions target reduction is dependent on the widespread use of protected urea, reduced N fertiliser and the uptake of low emissions slurry spreading technologies
- The most recent water quality report from the EPA (Water Quality in 2020) shows an increase in ecological water quality in Ireland compared to the previous report. Further gains will be possible based on management changes at farm level based on a focus of reducing N surplus and increasing N use efficiency
- Water use on Irish dairy farms is substantially below most other countries in the world due to the abundance of rainfall, low purchased concentrate and lack of irrigation in the production systems
- Habitat areas cover approximately 7.5% of the land area on dairy farms with specific plans required to increase the quantity and quality of these areas om all farms
- Irish dairying is a significant net contributor to the production of human digestible protein.

Introduction

The Irish dairy sector has gone through a transformational change over the past 10 years with a 77% increase in milk output and 43% increase in cow numbers in the period 2007–2009 to 2020 (CSO, 2021). This increase follows a period of stagnation in the dairy industry due to the EU milk quota regime which was introduced in 1984 to stabilise market support expenditure. Ireland's grass-based milk production systems provide a comparative economic advantage due to lower costs of milk production globally. Dairy production in Ireland has a higher margin, even when accounting for unpaid land, labour and capital, than countries such as the UK, Netherlands, France, Germany and Denmark even though the milk price received by Irish farmers is less.

The expansion achieved in the Irish dairy industry is reflective of the pent up capacity as a result of milk quotas as well as the technology developments that had occurred (grassland and genetics) on farms over the proceeding 15–20 years. While this rapid expansion is now stabilising at farm level, the next phase for the dairy industry will be dependent on policy change, with an expectation of steady growth in the industry in future years.

In order to evaluate an industries performance it is important to look at its overall sustainability. There are three pillars to sustainability 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, 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 as importantly, are the environmental and resource considerations for the farm (e.g. GHG emissions, nutrient use efficiency, etc). For this paper a number of the aspects around social and environmental sustainability will be discussed. Economic sustainability is discussed in the first paper in this Open Day proceedings.

Topics discussed include cow welfare, calf welfare, greenhouse gas (GHG) emissions, ammonia (NH_3) emissions, water quality, water use, biodiversity and land use planning.

1. Cow welfare

Dairy cows in Ireland have, on average, access to grazed grass for 71% of the year and are free to roam around an assigned paddock/paddocks. Irish pasture-based systems, with average milk yields of 430 kg milk solids (MS)/cow, have one of the lowest milk yields per cow in Europe. Irish animals are generally not exposed to production type diseases and issues that are common in countries where milk production per cow is maximised. In general, in Ireland profitability is not maximised where milk production per cow is maximised but is where grass utilisation per hectare is maximised (Hanrahan *et al.*, 2018). In Ireland, the key animal welfare considerations are around lameness and Somatic Cell Count (SCC). Somatic Cell Count is a good indicator of mastitis based diseases on farm. Data from the Animal Health Ireland (AHI) *CellCheck* program shows that the average SCC levels in dairy herds has declined over the past 10 years with average SCC now close to 175,000 cells/ml (AHI, 2021).

In terms of lameness; a recent analysis of 11,742 cows across 68 pasture-based dairy farms in the Munster region shows that just over 30% of cows studied had mild suboptimal mobility, 6% of cows had moderate suboptimal mobility, and less than 1% of cows had severe suboptimal mobility (Figure 1. O'Connor *et al.*, 2019). The category of mild suboptimal mobility requires detection by a trained individual. This compares favourably with most international comparisons.

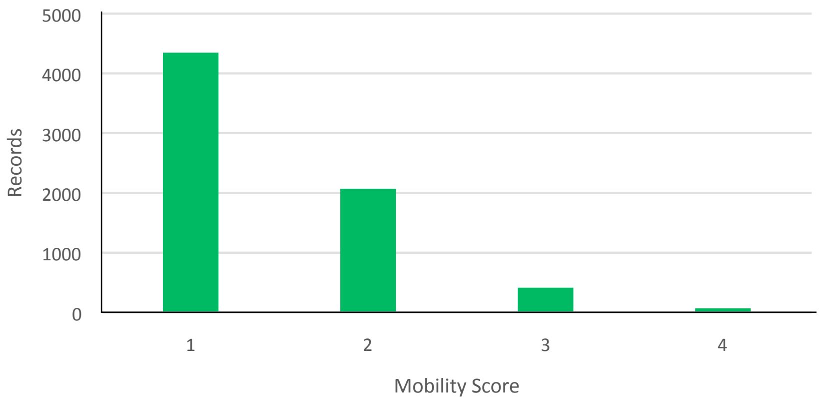

Figure 1. *Mobility score on 62 commercial dairy herds in Ireland*

Finally, in relation to dairy cow welfare, herd age profile is ever increasing, with the average number of calvings per cow increasing from 3.3 years in 2014 to 3.6 years in 2020 (ICBF, 2021). The target is for the average parity within the herd to increase to 4.5 in the target system. Clearly, there is a considerable amount of work required to achieve this target in areas of breeding and management, which will result in reduced GHG emissions per unit of product, increased productivity and profitability of the herd as a whole, while at the same time increasing the age profile of the herd.

Key to all of these improvements has been developments in the Economic Breeding Index (EBI). The EBI was launched in 2001 and has economic based traits that select for a balance of characteristics in the animal, from health, longevity, fertility and production.

The index is identifying animals that have a broad balance of characteristics rather than just production, which was the case in the past. Within the dairy industry as a whole, the key to continued dairy cow welfare improvements will be a focus on farm management, infrastructure and breeding.

2. Calf welfare

As mentioned earlier there are now approximately 43% more dairy cows in Ireland compared to the period 2007–2009. Incidentally, dairy cow numbers are approximately the same as they were in 1984 when milk quotas were first introduced. These additional cows are increasing the numbers of dairy origin calves entering the beef industry. While difficult to compare, overall calf mortality in Ireland compares favourably with other countries. For example, calf mortality at three months of age in the UK was 6.0%, it was 7.8% up to 55 days of age in the Netherlands, while the figures from Ireland at 28 days of age were 3.6% over the period 2017–2019.

In Ireland, the additional calves provide a significant opportunity for the beef industry to reduce GHG emissions and production costs associated with beef production. Within this context there is a need for the dairy industry to embrace technologies like sexed semen and the Dairy Beef Index. There is also a requirement for leadership within the industry around incentivising earlier age at slaughter and introducing beef pricing strategies that reward carcasses based on the yield of different meat cuts, as well as the costs to process the carcass. The live export of calves is extremely important at satisfying a market demand while reducing the livestock pressures in Ireland. A key component of calf transport centres on animal welfare, which will need to be underpinned with strategies that minimise animal discomfort and stress. While calf mortality in Ireland is low as previously stated, there is a need to ensure that this is maintained at farm level, through appropriate technologies and investment. There is a real need for joined up strategies between the beef and dairy industry to develop profitable beef systems that are early maturing (lower emissions) and can provide a reward to both the dairy and beef farmers, while helping to decarbonise agriculture.

3. GHG emissions

The Climate Action and Low Carbon Development (Amendment) Bill 2021, will 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'. Ireland's GHG emissions from agriculture in 2018 were similar to 1998 with emissions in 2019 declining by 4%, the first decline since 2014 (Figure 2. EPA 2021). Agricultural emissions declined between 1998 and 2011 followed by increases as dairy cow numbers have increased.

Cattle numbers peaked in 1998 at 7.6 million (Figure 3; CSO, 2021). Between 1998 and 2011, cattle numbers dropped as cow numbers declined due to increases in milk yield per cow. Between 2011 and 2017, average cattle numbers increased from 6.2 million to 7.0 million. Since 2017, there has been a decline in cattle numbers. In 2020, average cattle numbers were below 1998 by approximately 800,000.

Climate action plan

For the dairy industry, which exited milk quota just over six years ago, the development of carbon budgets will be watched with concern. Clearly, there is a need for agriculture to play its part in GHG emissions reductions. However, in reality anything over a 15% of mitigation (without further research advances) for agriculture, will be extremely difficult to achieve without affecting activity. Within the dairy industry under the milk quota system where there was fixed output, there tended to be stagnation in terms of vibrancy, in terms of investment and most importantly in the introduction of young people to the industry. Clearly, this must be avoided; and the focus of the policy should be to decouple GHG emissions from production and not to cap production. Presently there is a dearth of proven technologies to reduce GHG emissions at farm level. However, there is currently significant investment in GHG emissions reduction technologies at research level, which will increase the possible mitigation strategies. Ireland's competitive position from a GHG emissions perspective means that mitigation strategies that reduce milk production in Ireland have a huge global marginal abatement cost, because in effect GHG emissions will be increasing (decreasing in Ireland and increasing to a greater level internationally) to meet market demand as has been pointed out in a number of studies. Unfortunately, this level of robust scientific information is discounted within the largely unscientific discussions that often happen between vocal groups.

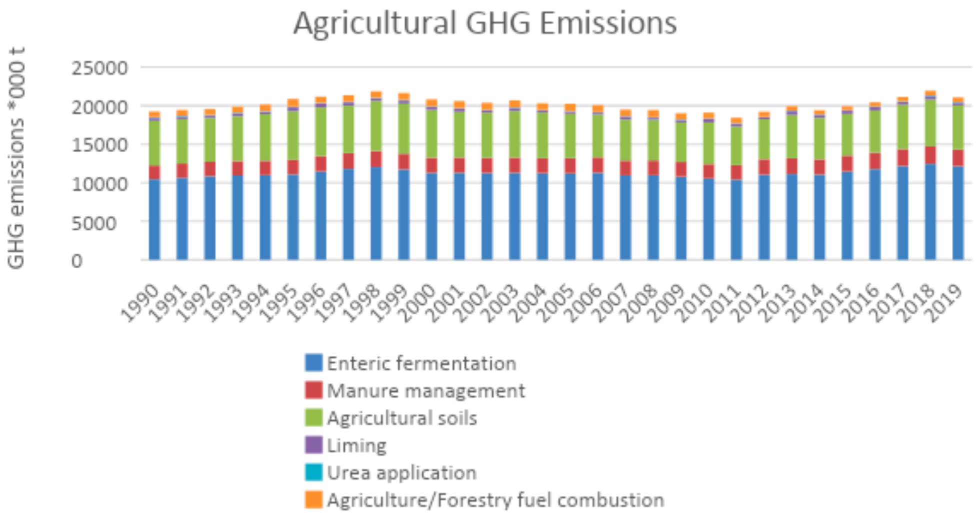

Figure 2. *Agricultural GHG emissions between 1990 and 2019 using GWP100*

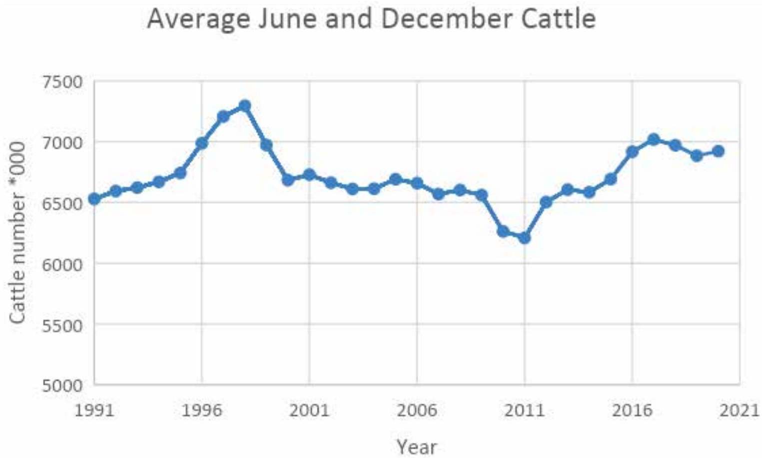

Figure 3. *Livestock numbers average June and December over the period 1991–2020 (CSO, 2021)*

Carbon footprint

The carbon footprint of Irish milk is one of the lowest in the world. Recent analysis shows that the average dairy carbon footprint is 0.99 kg CO_2e/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/kg FPCM (Herron *et al.*, 2021). While all published studies use different approaches and some are more robust than others, there are very few studies that show a footprint anywhere near these figures. The New Zealand C footprint using a similar approach to Ireland is 0.88 kg CO_2e/kg FPCM, while similar approaches in the US generate C footprints of just over 1.01 kg CO_2e/kg FPCM. While Irelands C footprint is in a strong position at present, the published strategy for the dairy industry will bring that footprint from 0.99 kg CO_2e/kg FPCM today to 0.73 kg CO_2e/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/kg FPCM. The current position and the plan to reduce emissions includes the reduction in fertiliser N use, substitution of CAN based fertilisers with urea based fertilisers, increased productivity from grazed grass with better dairy cow fertility and lower levels of supplementary feeds (less Land Use Change). The current global average C footprint is 2.4 kg CO_2e/kg FPCM (FAO, 2010). Expansion of dairy production in Ireland (0.99 kg CO_2e/kg FPCM) if displacing milk with an average C footprint (2.4 kg CO_2e/kg FPCM) has had a dramatic effect on reducing global emissions.

*GWP**

The unique properties of biogenic methane and its lifespan in the atmosphere have been discussed extensively over the past number of years. It is now universally accepted that methane is a potent GHG that is short-lived (~10 years) with a high global warming potential (GWP). It is also now generally accepted that if biogenic methane is stable/reducing slightly over a 20 year cycle then there is little additional warming effect as the overall biogenic methane levels decline. While Ireland's agricultural biogenic methane production declined between 1998 and 2011, there has been a steady increase between 2011 and 2017 since the removal of the milk quota regime (Figure 4). The GWP* metric reflects the lifespan of methane in the atmosphere and assumes that 94% of the methane produced today will have disappeared in 20 years' time. This suggests that where biogenic methane production is declining slightly, there is no additional warming effect and essentially means biogenic methane is not contributing to additional warming. However, in the situation where biogenic methane is increasing there is an increasing warming effect using the GWP* metric. For Irish agriculture, it is important that biogenic methane is stabilized and is reduced over time.

Agriculture's achievement of climate neutrality (which climate policy suggests Ireland must achieve by 2050) will be dependent on removing the additional warming effect associated with methane, reducing the emissions associated with nitrogen (N), and finally capturing and storing the residual emissions. Currently, soils act as a net source of emissions (according to inventory calculations), in order to achieve climate neutrality that source will have to be turned into a sink through measurement, management and land use change at farm level.

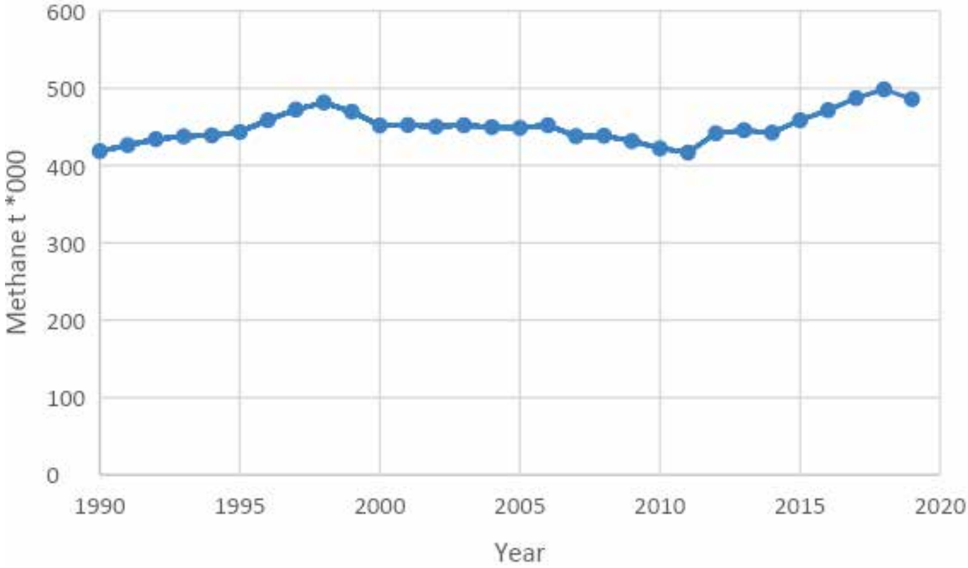

Figure 4. *Ireland's methane production over the period 1990–2020*

4. Ammonia emissions

Ammonia 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 with 47.1% of the emissions associated with manure housing and storage, 30.1% with slurry spreading, and, on average, 12.3% and 10.6% with manure deposition at pasture and N fertiliser, respectively (Figure 5). Total NH_3 emissions are above the national ceiling target since 2016, with a substantial jump in NH_3 emissions in 2018 to 135.2 thousand tonnes. Ireland's national NH_3 emissions ceiling is 116 thousand tonnes, set as part of the NEC (National Emissions Reduction Directive). Emissions in 2019 declined by 9.8 thousand tonne 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 6).

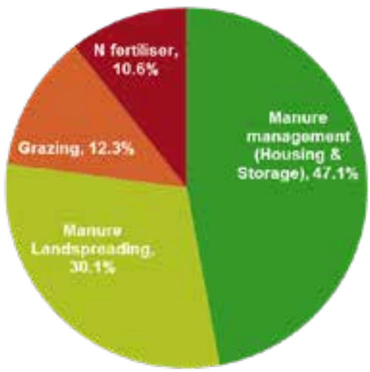

Figure 5. *Breakdown of sources of NH3 emissions in Ireland*

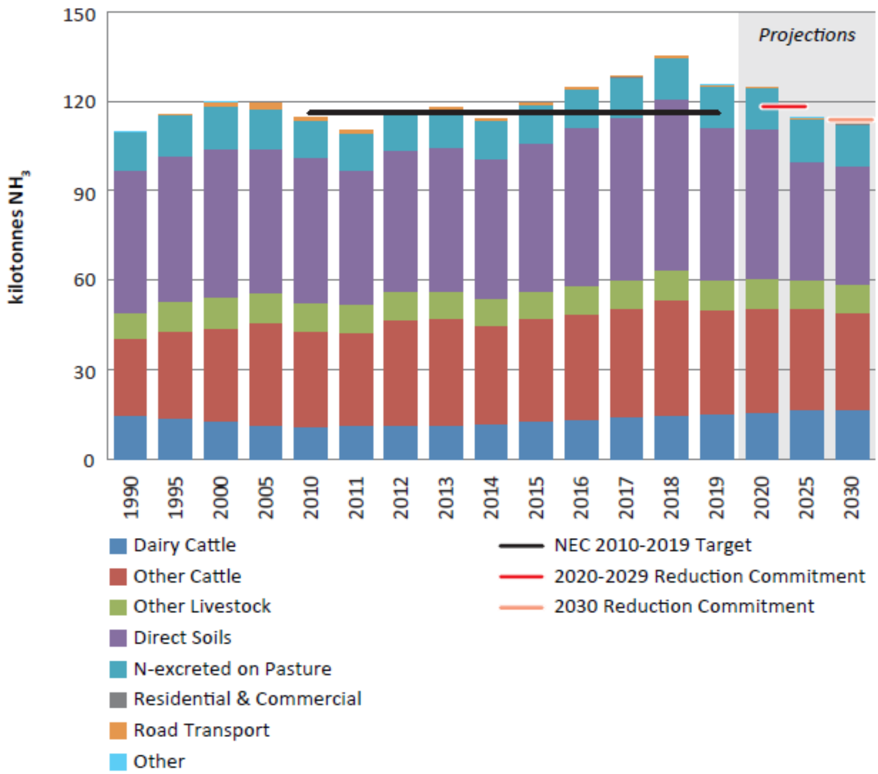

Figure 6. *Trends in NH3 emissions between 1990 and 2019 with projections to 2030*

Figure 7 shows the impact of a range of technologies on NH_3 emissions and their relative cost (Buckley *et al.*, 2020). Within this analysis, a range of different options to reduce NH_3 are proposed. These include reduced crude protein in concentrate feed, use of protected urea instead of ordinary urea, as well as the use of LESS technology for the application of animal manures. In reality, at dairy farm level, the two measures responsible for the vast majority (circa 80%) of the NH_3 emissions reductions are the use of protected urea fertiliser and LESS technology. While protected urea has a lower cost (when compared to CAN fertiliser), the use of low emissions slurry spreading technologies have a higher cost. However, with greater N constraints in the future, the value of the N retained within the system will become ever more valuable and the cost implications will be less apparent.

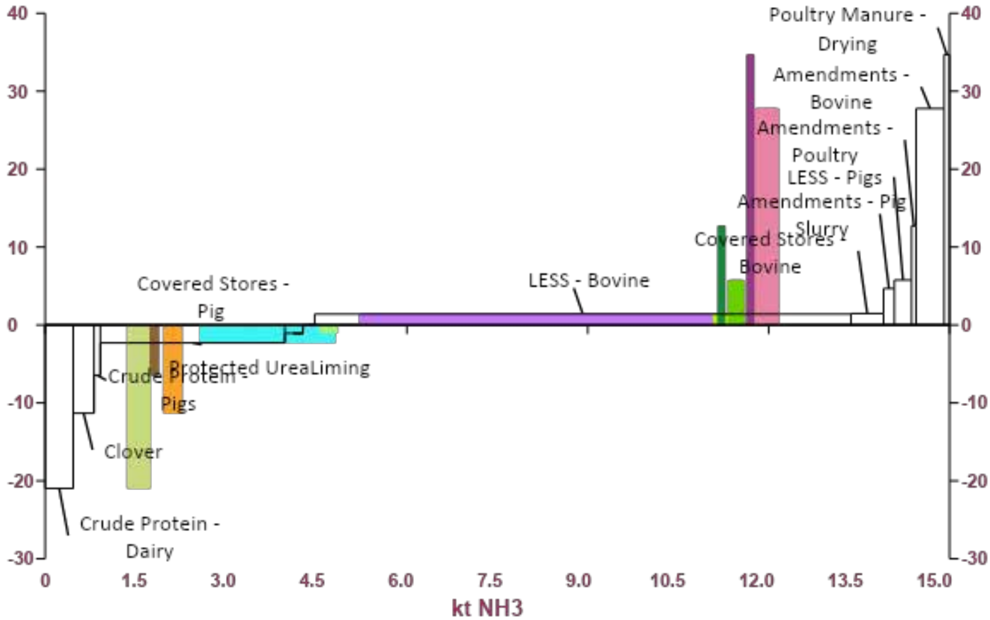

Figure 7. *Marginal abatement of NH3 emissions and its related costs*

5. Water quality

There are a number of metrics when evaluating water quality that allow the status of the water to be determined. These include the biological status, and the nitrate (NO3) as well as the phosphorous in the water. The biological quality is assessed based on macroinvertebrates and other biological elements and is a subset of overall ecological status. Within rivers, there is currently no environmental quality standards for nitrate. The nitrate standards for drinking water is 50 mg NO3/l. The thresholds for estuarine water quality is 2.6 mg N/l in freshwater at the estuary.

The EPA publish detailed reports describing the change in biological quality and nutrient concentrations on an ongoing basis. The most recent report on water quality was published in July 2021 (Trodd and O'Boyle, 2021). This report, entitled 'Water quality in 2020', covers the periods from 1987–1990 period right up to 2017–2020 period. The report shows that there is a consistent and steady reduction in river water bodies that are described as bad (3.92% in 1987–1990 period and 0.08% in the 2017–2020 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 2017–2020 period being 57%. Of the 1,836 (out of 2,355) river water bodies assessed in 2019 and 2020, 345 showed improvements in quality and 230 declined in quality, resulting in a net improvement in quality in 115 river water bodies (Figure 8).

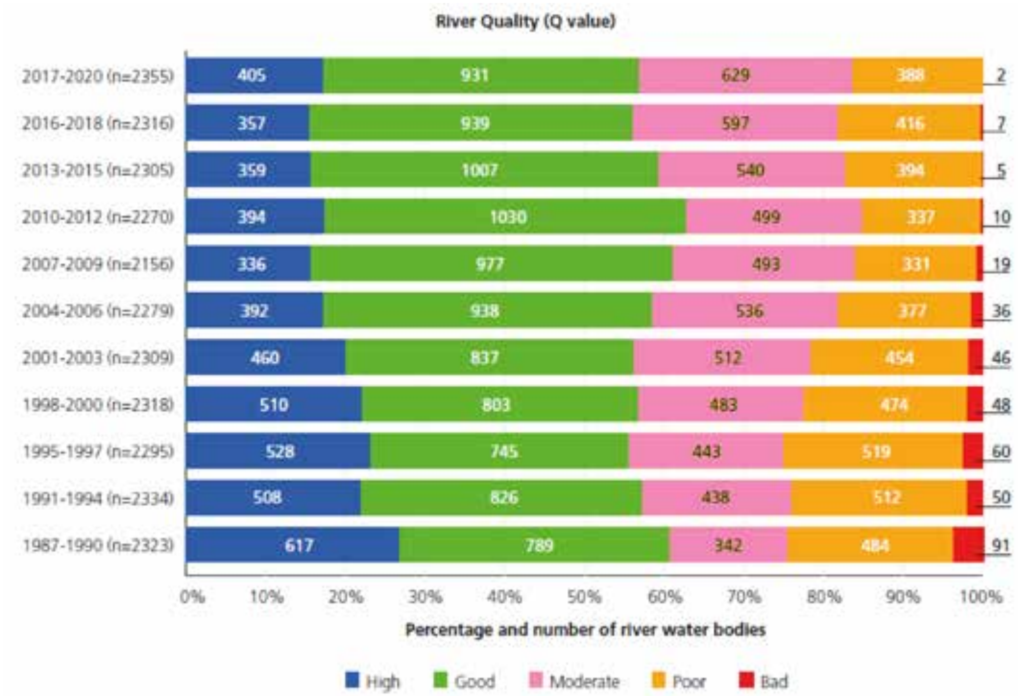

Figure 8. *Biological river water quality in Ireland over the period 1987–1990 to 2017–2020*

Recent modelling research completed by Teagasc (Dillon *et al.*, 2021) on NO3 leaching between 2004 and 2020, reported a 23% increase in N loss in 2018 when compared to the average year due to weather patterns observed. The relationships between N surplus and N lost to groundwater across different soil types is shown in Figure 9. It is evident that the risk of NO3 loss is much higher on free draining soils than heavy soils with moderate soils in between.

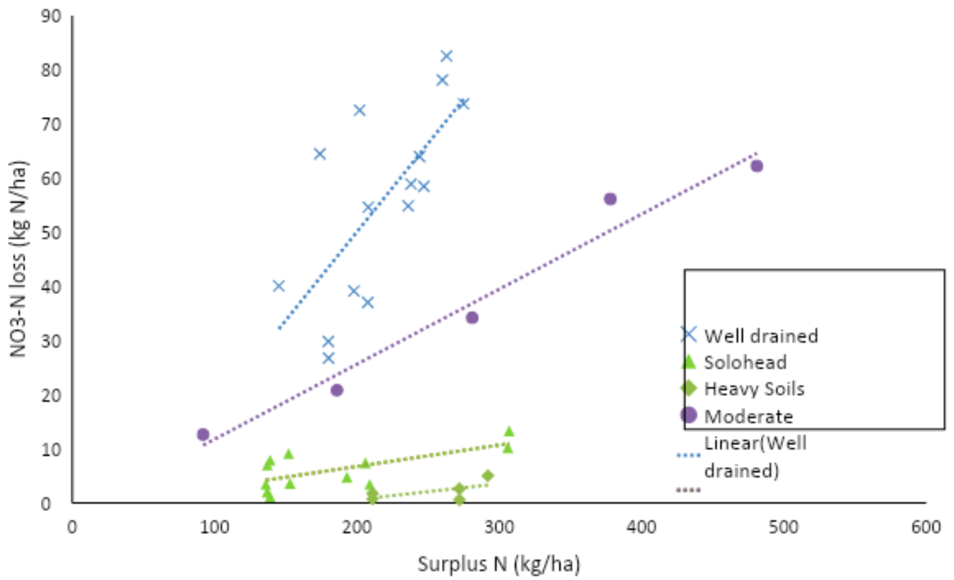

Figure 9. *Relationships between surplus N and groundwater NO3-N loss from reviewed studies on the range of different soil types used for pasture-based farming in Ireland*

A recent EPA report (WFD River Basin Management Plan — 3rd Cycle) has identified N reduction loads required to achieve the water quality standard of 2.6 mg N/l in the downstream estuary (Table 1). It is clear that there is significant year-to-year variability in N reduction loads to achieve the standard. There are a range of reasons for differences from year-to-year including dilution (effective drainage influenced by rainfall), surplus N, grass growth and NO3 leaching levels to 1 m and below. This means that a catchment with the same N load across years will have different outcomes in the water and will have different water quality at the estuary. Table 1 identifies the retrospective reductions in total N required across the catchments. Some catchments required virtually no load reductions over the period (e.g. Avoca, Corrib, Dodder, Erne, Fergus, Lee, Maigue, Moy and Tolka), while other catchments showed significant year-to-year variability (e.g. Barrow, Blackwater, Liffey, Nore, Slaney and Suir).

Table 1. Annual N load reductions (tonnes) required to achieve the environmental water quality standard of 2.6 mg N/l in the downstream estuary. Source: EPA

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average
Avoca	0	0	0	0	0	0	0	0	0	0	0	0
Bandon	168	0	158	329	231	124	531	124	424	579	616	299
Barrow	3,968	4,856	1,732	2,455	1,579	2,848	1,839	1,868	2,928	8,114	3,835	3,275
Blackwater	0	751	0	0	0	759	170	2,438	862	1,638	1,629	750
Boyne	56	1,284	594	917	89	1,544	1,124	142	351	1,847	2,310	933
Corrib	0	0	0	0	0	0	0	0	0	0	0	0
Deel	0	0	33	0	0	0	150	0	136	537	361	111
Dodder	0	0	0	0	0	0	0	0	50	0	0	5
Erne	0	0	0	0	0	0	0	0	0	0	0	0
Fergus	0	0	0	0	0	0	0	0	0	0	0	0
Lee	0	0	0	0	0	0	0	0	5	0	183	17
Liffey	0	0	0	0	23	48	165	0	0	1,123	135	136
Maigue	0	0	0	0	0	0	0	0	0	160	437	54
Moy	0	0	0	0	0	0	0	0	0	0	0	0
Nore	623	277	755	419	385	1,286	743	470	690	2,054	2,168	897
Slaney	6,561	2,593	2,040	2,824	2,877	3,371	2,288	2,088	2,366	5,995	3,290	3,299
Suir	2,778	2,633	1,255	0	0	0	0	216	445	742	545	783
Tolka	0	0	0	0	0	12	0	0	0	22	43	7
Total	**14,154**	**12,394**	**6,567**	**6,944**	**5,184**	**9,991**	**7,010**	**7,346**	**8,257**	**22,811**	**15,552**	

The total N load reductions entering the water required in individual catchments, expressed as N loss reductions per hectare across all hectares of land, is shown in Table 2. Five catchments require zero reductions (Avoca, Corrib, Erne, Fergus, Moy), eight require reductions of under 3 kg N/ha (Blackwater, Deel, Dodder, Lee, Liffey, Maigue, Suir and Tolka) while four require reductions of over 3 kg N/ha (Bandon, Boyne, Nore, Slaney). The range of reductions of N entering the water required was 0–18.7 kg N/ha. The analysis shows that the Slaney requires considerable attention and investigation as the load reductions required are a multiple of other catchments with the nearest (Bandon) requiring three and half times less of a reduction. In reality not all of the area in a catchment is farmed and therefore to achieve the levels of load reduction entering the water stipulated by the report, significantly higher reductions would be required on a per hectare farmed basis. If this analysis was completed assuming that all of the reductions would be made in the critical source areas for loss identified by the EPA in each catchment, the reductions needed would be much higher again. For example, in the Blackwater catchment the load reductions would correspond to 7.61 kg N/ha, while in the Slaney the reductions required would be 53.5 kg N/ha if all of the reductions are to be achieved within the critical source areas. In reality the load reductions required will be somewhere between the critical source area and total area calculations for each of the catchments.

A recent Teagasc report on potential N loss reduction strategies has identified a range of strategies that will reduce N loss to 1 m soil depth. These include reducing chemical N fertiliser application by 10% (reduced N loss to 1 m is 1.5 kg N/ha), adhering to the Nitrates Directive (50 kg N reduction in fertiliser N reduced N loss to 1 m by 2.9 kg N/ha), and avoiding slurry spreading during the prohibited period (reduced N loss to water by 3.2 kg N/ha) in the paddocks affected. This analysis also indicated that highly stocked land areas are of a particular risk for increased N loss. Increasing the organic N figures per cow would result in a reduction in stocking rate and that reduction would reduce N loss by 1.3 kg N/ha.

When the Teagasc analysis is joined with the EPA N load reductions, it is clear that there is a requirement for a range of actions at farm level to achieve the load reductions stipulated by the EPA.

Table 2. Annual nitrogen load reductions (kg N/ha) reaching water courses in individual catchments across all hectares required to achieve the environmental water quality standard of 2.6 mg N/l in the downstream estuary

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average
Avoca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bandon	2.76	0.00	2.60	5.41	3.80	2.04	8.73	2.04	6.97	9.52	10.13	4.91
Barrow	12.94	15.83	5.65	8.00	5.15	9.29	6.00	6.09	9.55	26.46	12.50	10.68
Blackwater	0.00	2.26	0.00	0.00	0.00	2.28	0.51	7.33	2.59	4.93	4.90	2.26
Boyne	0.21	4.76	2.20	3.40	0.33	5.73	4.17	0.53	1.30	6.85	8.57	3.46
Corrib	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deel	0.00	0.00	0.68	0.00	0.00	0.00	3.09	0.00	2.80	11.05	7.43	2.28
Dodder	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.42	0.00	0.00	0.40
Erne	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fergus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lee	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	1.46	0.14
Liffey	0.00	0.00	0.00	0.00	0.18	0.38	1.31	0.00	0.00	8.94	1.07	1.08
Maigue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.52	4.15	0.52
Moy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nore	2.46	1.09	2.98	1.66	1.52	5.08	2.94	1.86	2.73	8.12	8.57	3.55
Slaney	37.24	14.72	11.58	16.03	16.33	19.13	12.99	11.85	13.43	34.02	18.67	18.73
Suir	7.70	7.29	3.48	0.00	0.00	0.00	0.00	0.60	1.23	2.06	1.51	2.17
Tolka	0.00	0.00	0.00	0.00	0.00	0.82	0.00	0.00	0.00	1.51	2.95	0.48
Total	**3.52**	**2.55**	**1.62**	**1.92**	**1.52**	**2.49**	**2.21**	**1.68**	**2.50**	**6.39**	**4.55**	**2.81**

6. Water use

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, 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 farms has shown that blue water consumption was 6 l water/kg FPCM in Ireland (Murphy *et al.*, 2018). This compares to 108 l/kg milk in Australia and 125 L/kg FPCM in the US. The differences in blue water use are mainly driven by differences in irrigation. Even though Ireland's blue water use is extremely low it can still be reduced through prompt repair of leaks, recycling plate cooler water and integration of high pressure washers in the washing process. While not directly affecting blue water use, there is scope to introduce rainwater-harvesting systems on farm.

7. Biodiversity

There is increasing interest in biodiversity at farm level. Biodiversity (the variety of plant and animal life in a habitat) is declining globally (IPBES 2019). There are many causes for this decline, some related to farming. Actions can be put in place to reverse the decline. Key to this process is recognising that there is a problem and identifying actions that could help to reduce the loss. On the average dairy farm in Ireland, approximately 7.5% of the farm area can be described as natural or semi natural; these areas include hedgerows, streams, field margins, etc. On beef farms, the level of enriched space is even higher, however research is required to determine the total proportion allocated to natural or semi natural purposes. These levels contrast well with European farms. Typically, dairy/beef farmers are not high users of insecticides, pesticides or herbicides, which can be damaging from a biodiversity perspective. Figure 10 shows the current status and trends for species protected under the Habitats Directive in Ireland. Presently, the status of 57% of species is defined as favourable, while, positively, the trend for 72% of species is defined as stable or improving.

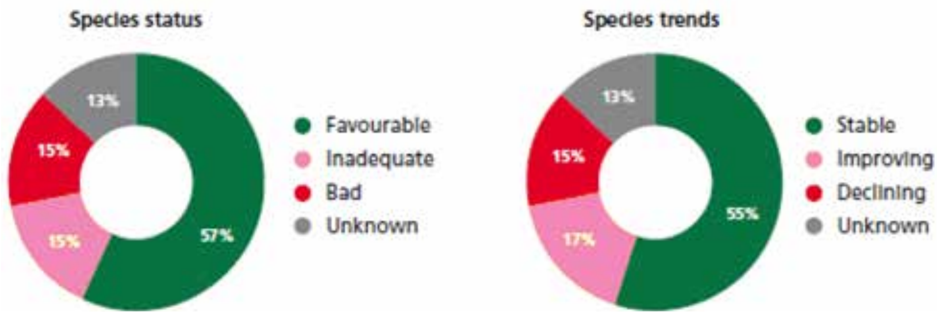

Figure 10. *Overall assessment results for the status and trends in species protected under the EU habitats directive in Ireland (Source: NPWS article 17 Data 2019)*

Farming and agriculture have been labelled as the problem when it comes to biodiversity loss. In reality, dairy farmers can help be the solution and are looking for the advice and actions to help protect biodiversity on their farms. The development of effective action plans that can be implemented are key to increasing biodiversity on dairy farms, allowing farms achieve the 10% target area with a higher quality area, while not affecting productivity and profitability. Key strategies should involve protecting existing habitats and not identifying these areas for new C related measures, advancing hedgerows and field margin management (average length is 6 km on dairy farms), protect water courses and buffer zones, and finally there should be a focus on the establishment of new habitats on the farm.

8. Land use planning

Several metrics have been developed to measure the net contribution of livestock to the supply of human digestible protein (HDP), such as the edible protein conversion ratio (EPCR) and the land-use ratio (LUR). The EPCR compares the amount of HDP in animal feed over the amount of HDP in the animal product. The LUR compares the potential

HDP from a crop grown on the land used to produce the livestock feed against the HDP in that livestock produce. In reality, internationally, there is little of this type of analysis done. While food production must increase to satisfy the increasing demand for animal based proteins, at the same time as there is a focus on reducing associated environmental burdens. Thus there is need to move the question on from not only what people should eat but to also where should that food be produced to ensure there is balance in the overall debate.

The analysis in Table 3 shows that there is significant system differences in terms of EPCR and the LUR. For both metrics dairy has the lowest (best) values. In essence, Table 3 shows that 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). Globally, when this type of analysis is completed the LURs tend to be higher. When higher LUR values are taken into account, in conjunction with some of the negative externalities associated with ruminant based agriculture, there is a question of whether it makes sense that animals are fed feed that humans could eat or should land be used to grow crops for food for humans. There is also a question of whether more of the ruminant products globally should originate from regions and countries where ruminants do not compete with land use (poorer land quality) for human edible crop production, such as Ireland. This would require a complete rethink of the global food system and how emissions are counted at a national and international level.

Table 3. Edible Protein Conversion and Land Use Ratio values of Ireland's ruminant livestock sector (Hennessy, Accepted)

	Dairy	Dairy beef	Suckler beef	Sheep meat
EPCR	0.18	0.42	0.29	0.21
LUR	0.47	1.08	1.25	0.95

Conclusion

Irish dairy has gone through a transformation over the past 10 years. Up until 2015, there had been 31 years of the EU milk quota systems, which stifled innovation. Since then there has been significant expansion due to the pent up capacity in the industry. This growth is now slowing down and in reality if this level of growth continued into the future, it would not be sustainable. Any future expansion will be based on the principle of decoupling. That is decoupling of GHG and NO3 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 be occurring at a time where there is increasing investment in research for new solutions and will provide the platform for even greater ambition around sustainability at farm level. However, it is also clear that grass-based systems of milk production have a huge role in sustainable ruminant production globally and in reality should play an even greater role in the provision of ruminant products in the future.

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Profitable milk production systems

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Summary

- The Irish dairy sector has just gone through a very successful period of expansion, with increasing milk output (68%) and family farm income (85%) from the pre-expansion period (2007–2009) to 2020
- The resilience of Irish dairy farms is underpinned by maintaining a low cost of production and minimal increase in debt
- Substantial additional gains in both farm profitability and environmental efficiency can be achieved using fertile and efficient cows fed on highly productive perennial ryegrass and white clover pastures
- There is a significant risk that Irish dairy farms will drift away from efficient grass based systems towards higher input systems that will undermine our economic and environmental sustainability, and potentially undermine the licence to farm
- Any further increases in dairy farm output cannot result in increased nitrogen and phosphorous loss, or GHG and NH3 emissions
- Ireland is uniquely positioned to exploit the growing demand for grass fed dairy products provided we continue to focus on our key competitive advantage of efficiently converting grazed grass into high quality milk products while at the same time continuing to focus on overall farm sustainability.

Introduction

The Irish dairy sector has gone through a transformational change over the past 12 years with a 68% increase in milk output and 43% increase in cow numbers in the period 2007–2009–2020 (CSO, 2021). The performance has been unparalleled, both in terms of other indigenous sectors of the Irish economy or other international dairy industries. At the core of this success story are 18,000 family-owned dairy farms, producing 8.3 billion litres of milk in 2020 and supporting over 60,000 jobs across the rural economy.

The unique nutritional quality and character of pasture-fed dairy products has been a cornerstone of the growing demand for Irish dairy products in 140 premium markets worldwide. The value of Irish dairy exports was €5.17 billion in 2020, and accounted for 40% of total food and drink exports while the corresponding values for 2010 were €2.29 billion and 29% (CSO, 2021).

During the expansion period, since 2015, dairy farm debt has not increased dramatically and has actually reduced per unit of output while farm profitability has increased by 85% (comparing 2007–09 with 2020). The average farm debt before expansion (2008–2010) was €59,622 and increased by just 21% to €71,985 in 2020. It is clear that the vast majority of the investment required for expansion has come from surplus cash generated during the expansion period. Debt has reduced from €3.08 to €1.93 per kg milk solids sold, a 37% reduction over the same period (Figure 1).

Figure 1. *Farm debt and debt per kg milk solids sold.* **Source:** *Teagasc National Farm Survey and CSO*

Teagasc Roadmap for a profitable and sustainable dairy industry

There are many challenges facing the Irish dairy industry not least the environmental issues outlined in paper "Delivering on Sustainability" (page 16) in this book. Over the last decade, Irish dairy farmers have demonstrated their ability to exploit opportunities and overcome obstacles. Dairy farming is the only major agricultural enterprise that has consistently delivered viable incomes to the majority of producers over the last decade. As environmental constraints begin to restrict production globally over the next decade, the economic outlook is quite positive for Irish dairy producers that focus on sustainable pasture based systems. The Teagasc Roadmap has set a target of achieving €2,450 net profit per hectare of owned land including full labour costs (€15/hr) at a base milk price of 29 c/l plus vat. This future sustainable farm system is based on maximising the performance from the existing platform, while at the same time ensuring that the number of unproductive livestock on the farm is minimized. Achieving a net profit of €2,450/ha necessitates attention to detail across all of the components of the farm business. The rewards are huge and place the business in a very positive position to cope with milk price volatility and to realise returns from the business comparable with some of the best possible investments (on or off farm). Whether you are achieving the future target, are close to the future target or are a long way from the target, the direction of travel should be the same for the business. The physical performance required to achieve the target system include >13.0 t DM/ha of grass utilised, milk solids output of 1,344 kg/ha and feeding <500 kg concentrate per cow. In order to achieve these targets, excellent herd fertility performance is required, with a low replacement rate (≤18%), high six week calving rate (≥90%), and a herd mean calving date of mid-February. High levels of labour efficiency are essential, where the focus is on cows and grass, thus facilitating these achievements with total labour input of <16 hours per cow per year. Within the target system, there is an increase in stocking rate based on increased grass growth, but there is also a change in enterprise as all replacement stock are moved off the milking platform to a contract rearing enterprise. All of this is achieved with less nitrogen coming onto the farm in the form of chemical nitrogen fertiliser and concentrate, and increased levels of nitrogen leaving the farm in milk sold and calves and cull cows, resulting in lower levels of surplus nitrogen overall and increased nitrogen use efficiency.

Table 1. Teagasc roadmap for the sustainable intensification of the Irish dairy industry

	Current*	Sustainable performance target
Milk delivered (kg/cow)	5,484	5,800
Milk solids (kg fat plus protein)	417	480
Protein (%)	3.47	3.70
Fat (%)	4.11	4.60
SCC (cells/ml)	170	<150
Herd EBI (€)	90	150
Six-week calving rate (%)	62	90
Labour input (hours/cow/year)	40	<16
Stocking rate (LU/ha)	2.1	2.7
Herbage utilised (tonnes DM/ha)	7.8	12.9
Concentrate per cow (kg)	1,176	<500
Fertiliser N usage (kg/ha)	184	150
Nitrogen use efficiency (%)	28	49
Net margin at 29 c/l base price (€/kg MS)	0.58	1.84
Net margin at 29 c/l base price (€/ha)	519	2,452

**Average of 2017, 2018 and 2019 (from NFS and ICBF)*

Stocking rate

Identifying the appropriate stocking rate is a key strategic decision for pasture-based dairy farms. Previous studies have indicated that increased stocking rate was associated with increased chemical nitrogen fertiliser use and supplementary feed importation, greater nutrient surpluses and reduced nutrient use efficiency, resulting in increased nutrient losses to water and to the general environment. Currently, the average Irish dairy farm has a stocking rate of 2.1 livestock units (LU)/ha. Any increase in farm stocking rate needs to occur without greater use of chemical nitrogen fertiliser, and without an increase in concentrate supplementation per cow. Based on improved grazing management, sward composition and soil fertility, increasing overall farm stocking rate will result in increased pasture utilisation and improved farm profitability and nutrient use efficiency in the future. Increasing pasture growth while simultaneously maintaining/reducing chemical nitrogen fertiliser input can only be achieved by incorporating nitrogen-fixing legumes, such as white clover, into perennial ryegrass swards. White clover is the only plant species that has consistently been shown in research to be of additional value in intensively grazed perennial ryegrass pastures.

As a component of the sustainable intensification of dairy production, improved management practices are required to maintain low levels of nutrient loss within more intensive pasture-based systems. These include greater use and more strategic use of organic manures to replace chemical nitrogen fertiliser, more strategic use of chemical nitrogen fertiliser, reduced cultivation for reseeding, improved nutrient budgeting, and the preferential management of higher risk farm areas. As described in this paper the target system will operate at 2.7 LU/ha. This will result in significant increases in profitability at farm level and should be the focus for farmers considering further expansion. Nationally, grass utilisation is just over 8 t DM/ha, but there is potential for this to be increased to 13 t DM/ha, highlighting that further expansion is realistic and achievable. The focus for farmers operating at average level of grass utilisation should be on improving efficiency of grass growth and utilisation. For farms that are currently operating at high levels of grass utilisation and efficiency, however, this is no longer possible and their strategies should be different. Expansion beyond the farms carrying capacity by including >10% of the diet originating from bought in feed has been consistently shown to reduce profitable. It might look marginally profitable, when owned labour is not included in the calculations, but when full costs are included, expansion based on additional imported feed is generally not profitable, increases risk and environmental footprint, and ultimately results in the dairy farmer working a lot harder for little gain. Internationally, many industries have fallen into the trap of importing additional feed into pasture-based systems to produce marginal extra milk and the Irish dairy industry must be careful to ensure that it does not follow suit. Ensuring capital costs are minimised and that the metrics affecting profitability rather than production are the focal points will ensure that the Irish dairy industry does not follow many industries worldwide.

Seasonality

Calving cows compactly at the start of the grass-growing season creates some significant challenges for the Irish dairy industry around labour demand and availability of adequate milk processing capacity during peak supply months that is under-utilised for the remainder of the year. However, the advantages of compact seasonal calving far outweighs the disadvantages. Seasonal compact calving facilitates the synchrony of herd demand with grass growth, which reduces cost of production (Figure 2) due to lower feed and fixed costs. It also underpins the marketing strategy of Irish grass-fed dairy production, which, by its nature, has a lower environmental footprint as less nutrients are brought onto the farm in the form of purchased feed.

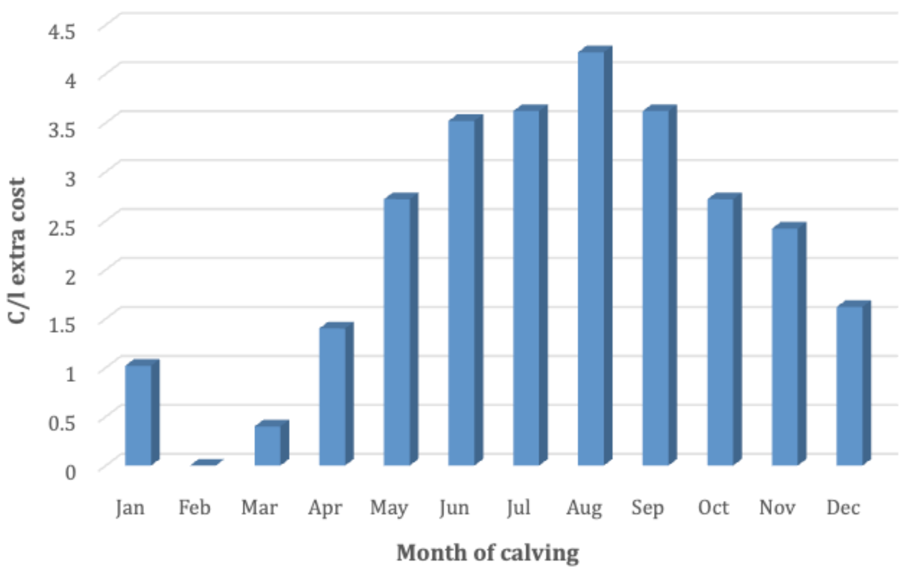

Figure 2. *The effect of month of calving on extra cost of production (c/l) relative to February calving*

System drift

During periods of moderate to high milk prices there is always a temptation to chase marginal milk by feeding higher levels of bought in feed to increase milk output. However, when the full costs associated with this extra milk are included, the extra output reduces the overall resilience of the farm to external shocks and reduces the environmental sustainability of our grass-fed dairy system. The sustainability of the Irish dairy industry will be grossly undermined by importing feeds that are produced unsustainably. There are numerous international examples of pasture-based dairy industries that have increased output using bought-in feed, which resulted in a significant decline in competitiveness and an increase in environmental footprint. Research shows that the carbon footprint of milk production is reduced by maximising the use of grazed pasture at an appropriate overall stocking rate.

Future direction

After the initial period of growth post-quota following 31 years of stagnation, where should the industry go from here? When asking this question, one must be cognisant of the potential for further growth, environmental policy constraints, international demand for Irish grass-fed dairy products and the economic considerations around enterprise shift into dairying. Nevertheless, and most importantly, we must be cognisant of the farmer's ambition for growth, the sustainability of the system, the risks associated with further growth and the physical potential for growth.

Consumer interest in the food they consume, including milk and milk products, is ever increasing. This has led to the development of milk brands that require farmers to mainly feed their cows grass and these dairy products are in high demand in many countries, and are sold at a market premium price. The sustained market interest in grass-based dairy products means that more and more consumers want to know the typical quantities of grazed pasture and forage in a dairy cow's diet. Ireland has developed a methodology to quantify the proportion of grass in the diet, which is being implemented within the Sustainable Dairy Assurance Scheme (SDAS) system. There is scope to build on this development and further develop brands and credentials to satisfy the growing market demand through producing dairy products from grass in a sustainable and efficient manner. Ireland can grow this potential further, ultimately adding value to dairy products, increasing the returns to the primary producers and satisfying the demand of consumers by producing grass-fed high value product. Ireland is uniquely positioned to capitalise on the grass-fed narrative by continuing to focus on grass-based systems.

Priorities for capital investment in 2021

This year looks like it will be a relatively profitable year for Irish dairy farmers and the priority should be to invest surplus cash in areas of the farm business that are likely to increase the resilience of the business in the future. Priority areas include:

- *Soil fertility:* ensuring adequate soil fertility will optimise grass growth and improve nitrogen utilisation. It is likely that Irish dairy farms will have to achieve higher nitrogen use efficiency in the future and this may coincide with a lower milk price. Investing now in achieving optimum soil pH and P and K status will improve the resilience of the farm to future milk price down turns and to future limits on nitrogen fertiliser use
- *Slurry storage:* investing in extra slurry storage will allow slurry to be stored and spread at a time when the response to slurry nitrogen is optimum, i.e. in spring. When slurry is applied during the winter months very little of the nitrogen is recovered by the sward, however, when slurry is applied in spring using low emission slurry spreading (LESS) equipment about 40% of the nitrogen is taken up by the sward equivalent to 2.4 kg/m^3 or 11 kg N/1,000 gallons
- *Reseeding and white clover:* incorporating white clover into perennial ryegrass pastures has been comprehensively shown to increase milk production, reduce fertiliser nitrogen requirement and improved profitability of grazing systems. Converting old swards to new perennial ryegrass-white clover pastures will build resilience of the farm business to future milk price shocks or nitrogen restrictions while also increasing farm profitability
- *Calf housing:* increasing cow numbers over the last 10 years combined with improved fertility resulting in more compact calving has put more pressure on calf housing in spring. Many farms depend on the sale of 2–3 week old calves to provide adequate space for the remaining calves. This may not always be possible due to reduced demand for young calves from beef farms or from reduced or delayed live exports. By providing extra space to facilitate holding calves on the farm through the spring peak of supply will reduce stress on the farm facilities and labour during the busiest time of the year.

Conclusion

The outlook for a profitable Irish dairy industry is still very positive if we do not drift away from efficient pasture-based systems that use high genetic merit cows to convert grazed grass to high quality milk. The key focus should remain on improving pasture growth and utilisation and matching stocking rate to the amount of grass grown. Investing in technologies that reduce environmental footprint such as incorporating white clover in grass swards, slurry storage, soil fertility, etc. will result in profitable and sustainable dairy farms.

Grazing management to increase N use efficiency

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Summary

- Nitrogen use efficiency can be improved on all dairy farms
- More targeted use of nitrogen can help farmers make better grassland management decisions
- Spring slurry applications should be used to reduce the input of chemical nitrogen fertiliser
- Research has clearly shown the advantages of incorporating white clover in grassland swards to reduce nitrogen fertiliser requirement and to increase animal production and nitrogen use efficiency
- In swards with 20–25% white clover, nitrogen fertiliser can be reduced by 50–100 kg N/ha
- Avoid spreading excess nitrogen fertiliser on silage ground. Apply slurry, where available, using LESS and reduce chemical fertiliser N application according.

Introduction

Enhanced grazing management has the potential to yield further improvements in milk production efficiency and nitrogen (N) use efficiency (NUE). National statistics reveal clear evidence of increasing production efficiencies on dairy farms in recent years through a combination of farm management practices allied with accelerated genetic improvement within the national herd.

Ireland faces significant challenges in meeting national and international environmental targets with regard to greenhouse gas (GHG) emissions, air quality, biodiversity and water quality. The Teagasc Marginal Abatement Cost Curve (MACC) has set 26 actions that farmers can use to cut GHG emission levels by 10–15% by 2030 relative to 2017 levels. The European Green Deal, Farm to Fork Strategy identifies an urgent requirement to reduce dependency on pesticides and antimicrobials, reduce chemical fertiliser use, improve animal welfare and reverse biodiversity decline in food production systems. Over the next 10 years, the Ag Climatise roadmap has set a target of an absolute reduction in the overall level of N fertiliser used on Irish farms from a high of 408,000 tonnes in 2018 to 325,000 tonnes in 2030, with an interim target of 350,000 tonnes in 2025 (14% reduction from 2018–2025).

Grassland productivity is highly dependent on the supply of plant available N from the soil. The sources of this N includes chemical fertiliser, organic fertiliser (slurry, farmyard manure, dung and faeces deposition by grazing livestock), mineralisation of N in the soil organic matter and biological N fixation by legumes, including white clover.

The N loss pathways of primary concern to the dairy industry are nitrate leaching and emissions of nitrous oxide and ammonia (NH_3). The concentration of nitrate in water bodies in recent decades has been a cause of concern because of the perceived potential threat to human health, as well as the ecological and aesthetic consequences of eutrophication. The paper focuses on increasing the NUE of pasture-based dairy production systems to minimise the environmental impact without negatively affecting the economic viability.

What is nitrogen use efficiency?

There are a number of sources of N at farm level including:

- Organic N or slurry N produced by the cow (approximately 5,000 litres of slurry per cow per year), as well as dung and urine patches deposited directly on to the paddock by grazing livestock
- Chemical N fertiliser purchased on to the farm
- Concentrate or other feed purchased on to the farm
- Background soil N — this is the N mineralised from the organic matter in the soil. The rate supplied by the soil depends on soil type and weather conditions, and there is strong year-to-year variation in the quantities released from the soil
- Nitrogen fixed from the atmosphere by white clover and available for plant growth.

Farm gate NUE is the efficiency with which the N entering the farm (feed, fertiliser and replacement livestock) is utilised on the farm and converted into product sold from the farm (milk, cull cows, calves). National Farm Survey data shows that farm gate NUE is approximately 24% in Ireland. This can be improved considerably and the more efficient farms have an NUE of >35%. Recent research clearly shows significant increases in NUE under improved grazing management (up to 40%) and the inclusion of white clover in swards NUE can increase NUE to 55–60%.

Increasing N use efficiency on farm

Grazing management

Nitrogen use efficiency on grassland farms can be improved with greater use of grass measurement and better grassland management decisions. Informed decision making based on knowledge of current average farm cover and predicted grass growth rates can result in a more efficient use of N fertiliser. The average grass DM production on dairy farms using PastureBase Ireland over the past seven years (2013–2019) is 13 t DM/ha, with an average of 263 grazing days per year. National farm survey data indicates that the national average DM production on dairy farms is just over 10 t DM/ha. There are further gains to be made in increasing DM production on farms through better spring management, use of PastureBase Ireland to help with grassland management decision making, earlier turnout in spring and the incorporation of white clover into grassland swards. Over the last year, a Nitrogen Planner has been incorporated into PastureBase Ireland, to improve N use efficiency on grassland farms. At the beginning of the grazing season, a grassland farmer can plan his/her N application strategy over the coming grazing season. The Nirogen Planner can then be populated over the grazing season with actual N application. Therefore, an up-to-date comparison between actual N applied to that planned at the start of the season can be viewed during the grazing season.

Low emissions slurry spreading (LESS)

Slurry is an important source of nutrients (N, P and K) on grassland farms and application to grassland must be appropriately timed to maximise the efficiency of nutrient capture and utilisation, as well as replenishing soil fertility levels. The targeted application of slurry in spring, based on soil test results, will ensure the most efficient use of slurry nutrients for grass production and minimize potential ammonia losses. Slurry N losses in the form of ammonia emissions are potentially the largest loss of reactive N on Irish farms. There is a 50% increase in the availability of N for grass growth when it is applied by trailing shoe compared to splash plate (Table 1). Slurry N is also more available in spring compared to summer (Table 1). To achieve the best use of the slurry N available on farm, it should be spread in spring using LESS techniques (e.g. trailing shoe or dribble bar).

Table 1. Availability of N in 1,000 gallons of slurry applied using splash plate or trailing shoe in spring and summer

	Splash plate		Trailing shoe	
	Spring	Summer	Spring	Summer
Available N (kg/ha)	6	3	9	6

Protected urea fertiliser

Recent studies have shown that protecting urea with a urease inhibitor reduces ammonia loss to the environment by 80%. Moorepark research has shown that there is no difference in herbage production between protected urea and CAN under repeated cow grazing studies. See elsewhere in this publication for more information on the effect of protected urea compared to CAN on herbage production. Protected urea can also help reduce N losses to water by holding N in the ammonium form, which is more stable in soil particularly during wet conditions.

Reducing concentrate crude protein content

The crude protein (CP) content of a feed depends on the N in that feed. On average, Irish dairy cows have a requirement for a diet with a CP content of 15–17%. High quality grazed pasture has a CP content of approximately 18% during the grazing season. Several studies have been completed during the last 10 years and have shown no benefit from feeding rations with high CP content (>16%) at pasture, as grazed grass alone can meet animal requirements for CP. Feeding high CP content concentrates during the grazing season results in excess N in the dairy cow diet. The cow has to expend energy to excrete this excess N, usually in urine resulting in high N content urine patches in grazed grassland. Reducing concentrate CP content will reduce both N surplus in the dairy cow diet and N loss to the environment. Using concentrates with a CP content of 12–14% is recommended when cows are grazing fulltime.

Increasing soil fertility

Increasing soil fertility (pH, P and K) increases NUE as it increases the availability of plant available N in the soil and increases the persistency and density of productive species (e.g. perennial ryegrass) in the sward. This will result in the production of greater quantities of grass at the same N application rate. More frequent soil fertility testing and greater use of nutrient management planning will increase NUE on grassland farms.

The role of white clover

White clover is included in perennial ryegrass mixtures to improve sward nutritive value for animal production and reduce N fertiliser use. Managing grassland with less chemical N fertiliser inputs and with greater reliance on biological N fixation by white clover can reduce costs (less chemical N fertiliser), reduce GHG emissions, and increase herbage quality and digestibility.

Results from recent research investigating the incorporation of white clover into perennial ryegrass swards at Teagasc, Moorepark and Teagasc, Clonakilty Agricultural College have shown the potential of perennial ryegrass-white clover swards to increase the productivity and profitability of Irish grazing systems. Pasture production was increased by 8% at Clonakilty when white clover was included in the sward (at a similar N fertiliser rate of 250 kg N/ha). At Moorepark the perennial ryegrass-white clover swards receiving 150 kg N/ha grew similar levels of herbage to the perennial ryegrass-only swards receiving 250 kg N/ha. Perennial ryegrass-white clover swards tend to be higher quality in mid-season compared to grass-only swards as sward white clover content increases from May onwards. Moorepark and Clonakilty research both show up to a 10% increase in milk and milk solids (kg fat + protein) production from perennial ryegrass-white clover swards compared to perennial ryegrass-only swards (Table 2).

Table 2. Effect of white clover inclusion on pasture production, milk and milk solids yield in Teagasc Moorepark (2013–2016) and Teagasc Clonakilty (2014–2017) grazing experiments

Teagasc Moorepark experiment	Grass-only 250 kg N/ha	Grass-clover 250 kg N/ha	Grass-clover 150 kg N/ha
Pasture production (t DM/ha)	13.7	14.0	13.7
White clover content (%)	-	23	27
Milk yield (kg/cow)	6,108	6,498	6,466
Milk solid yield (kg/cow)	460	496	493
Teagasc Clonakilty experiment	**Grass-only 250 kg N/ha**	**Grass-clover 250 kg N/ha**	
Pasture production (t DM/ha)	15.6	16.8	
White clover content (%)	-	23	
Milk yield (kg/cow)	5,222	5,818	
Milk solid yield (kg/cow)	437	485	

The existence of white clover is not widespread on grassland farms in Ireland, and its persistence may be problematic on heavier soils. Establishing white clover, in sufficient quantities, i.e. an annual sward white clover content of 20–25%, on dairy farms remains a big challenge. Improved methods of sowing and management at and after sowing are required for establishment. Excellent grazing management is required to maintain high levels of white clover in pastures. While this is taken for granted, grazing management is generally one of the main reasons for poor persistence of white clover on farms. Further work is required to increase the persistency of white clover at farm level and encourage greater adoption.

What can farmers do to increase nitrogen use efficiency on their farms?

The following are the key strategies all farms can use to increase NUE on their dairy farm:

- Apply slurry in spring using LESS
- Limit and control concentrate use by increasing grass quality and supply through improved grassland management. Use a lower CP concentrate
- Measure grass weekly and plan N fertiliser applications based on current farm cover and predicted grass growth
- Plan N applications on a paddock by paddock basis (use the Nitrogen Planner in PastureBase Ireland)
- Incorporate white clover into the swards. Target 20–25% annual white clover content across the farm
- Optimise the use of soiled water on paddocks and reduce chemical N fertiliser accordingly
- Manage N better on silage ground to avoid over use. Apply slurry, where available, using LESS and reduce chemical fertiliser N application accordingly
- Quantify the nutrient composition of the slurry on your farm annually.

Grazing management to improve nitrogen use efficiency

Spring management

There is always an element of debate around the right approach for spring N fertiliser application. This usually hinges around the knowledge that N applied in early spring is normally utilised less efficiently in terms of kg of grass DM grown per kg of N applied (average response of 10–12 kg DM/kg N applied in spring compared to 21 kg DM/hg N applied in summer). The high value associated with grass availability in early spring means that even relatively small additional quantities of grass can make a big contribution to the overall feed budget.

Applying N in spring in a way that maximises the response is important both to ensure a good return on investment, and to minimise potential losses of N to water or as gaseous emissions. Improving the efficiency of N use during this period provides a major opportunity to improve the environmental credentials associated with N use.

Early spring growth is influenced by the genetic capacity within the sward to respond the N fertiliser applied. Newer swards with high perennial ryegrass content are more likely to respond to N fertiliser application than older swards. Soil factors driven by soil texture in combination with weather also influence the response to N fertiliser application. Colder soils are slower to respond to fertiliser N application. The general guidance is to apply the first N fertiliser when soil temperatures are 5–6°C and rising. Avoid applying N fertiliser immediately before heavy rainfall. Likewise, soil drainage plays a big role as land that is more prone to waterlogging and poor trafficability for extended periods in spring is less likely to respond to early N fertiliser. Drier soils are more likely to respond to N, but are also more at risk of N leaching.

The response to N fertiliser in spring and the risk of N leaching are highly variable depending on year due to different weather patterns. Modelling work conducted at Moorepark shows that, depending on the year, the N response to early N fertiliser application varies from 7.4 kg DM per kg N applied in a year like 2014 to 17.4 kg DM per kg N applied in a year like 2012. The corresponding N leached (at 1 m depth) due to an early N application of 30 kg of N/ha was 12 kg N/ha and 4.5 kg N/ha, in 2014 and 2012, respectively. This highlights the need to move to more informed and precise N fertiliser application based on current weather conditions, weather forecast and predicted grass growth.

Key guidelines for spring N fertiliser usage

- Target fields/paddocks that are most likely to respond to early N application — high perennial ryegrass content/recently reseeded, drier, free draining paddocks
- Paddocks with a grass cover of >400 kg DM/ha
- Paddocks with optimum soil fertility, i.e. Index 3 for P and K, pH > 6.3
- Replace chemical N fertiliser on approximately 60% of the farm with slurry. Target slurry applications to fields with low P and K levels and low grass covers. 25 m³/ha (2,500 gals/ac) applied using LESS will supply ~25 kg/ha (20 units/ac) of available N
- Use protected urea
- Apply up to 29 kg N/ha (23 units N/ac) in the first split in late January or early February to area that has not received slurry
- Link early N application strategy with spring feed budget for the farm
- Only apply N if soil temperature are higher than 5°C and rising and no/low rainfall is forecasted for the coming days
- On wetter/heavier soils, the application dates should be delayed 3–4 weeks.

Mid-season management

The primary objective during the main grazing season is to maintain high animal performance from a high quality all-grass diet. In general, from late April onwards, grass supply exceeds demand, and pre-grazing herbage mass should be maintained at 1,300–1,600 kg DM/ha, with a grazing residual of 50 kg DM/ha (4 cm post-grazing height). Excellent pasture quality is required to maximize the potential animal performance from pasture in summer. From mid-April to mid-August, farm cover should be maintained between 150–180 kg DM/cow with a rotation length of 18–21 days. The aim in that period is to achieve six grazing rotations and utilise 8,000 kg DM/ha. Paddocks with surplus grass should be removed as baled silage as soon as possible to maintain grass quality.

In mid-season, when grass growth exceeds herd demand, careful consideration of N fertiliser application strategies is important. In planning N fertiliser in mid-season it is important to know what grass you have on the farm and how much grass you need. Key to this is utilising all available information including:

- How much grass do you need (herd demand)?
- How much grass is currently on the farm (average farm cover)?
- What grass growth is predicted (MoSt Grass Growth Model)?
- Is there slurry available? If there is apply using LESS
- What is/are the weather forecast/growing conditions — consider soil N mineralisation. Mineralisation increases with increasing soil temperature once there is adequate soil moisture (rainfall)
- Is N available from N fixation (is white clover present on the farm)?
- Are you making bales in every rotation, particularly in July and August? If you are there is too much grass on the farm and there is a great opportunity to reduce N fertiliser application.

Mid-season N fertiliser applications generally result in a high grass growth response (≈ 20–35 kg DM/kg N applied on average), provided conditions are optimum. In periods of high soil moisture deficits (low/no rainfall or drought) the response to N fertiliser is much reduced; there is little point to applying N when grass growth is <30 kg DM/ha/day. Applying N fertiliser could lead to excessive N loss when rainfall occurs. Post drought (high soil temperatures and increasing soil moisture content), there is a large release of soil N which negates the requirement to restart N fertiliser application until grass supply returns to excess on the farm.

Autumn management

Autumn closing date is the main management factor influencing grass supply in early spring. To ensure that adequate quantities of grass are available at the start of calving on highly stocked farms, an average farm cover of 650–750 kg DM/ha is required on 1st December (at closing). Farmers must calculate their own spring grass demand, and implement an autumn closing strategy to facilitate the required opening spring farm cover. The final decisions regarding closing strategy also require some consideration of the expected grass growth over the winter period (i.e. average of previous five years). Typically, the grazing rotation length is extended from mid-August (+2 days/week) to allow for large quantities of herbage to be accumulated prior to the decline in grass growth to facilitate the extension of the grazing season for the final rotation. Any surplus paddocks should be removed in early August. Removing paddocks from the rotation for bales after the first week of September should be avoided, if possible, as harvesting this late in the year results in slow regrowth's. By achieving the right average farm cover at the right time, grazing decisions are easier to make. Average farm cover must be increased from mid-August with peak cover achieved in late September (≈1,100 kg DM/ha). Achieving this will reduce supplementation requirement for the remainder of the grazing season and ensure that average farm cover is not reduced below 650–700 kg DM/ha at closing. Disappointingly, many farms do not build up enough grass in the autumn, resulting in high levels of supplementation in September and October and a shorter grazing season period, both of which have a negative impact on NUE.

As grass growth reduces from September onwards, the capacity of the sward to utilise N reduces steadily. Any N not used by grass in autumn is susceptible to leaching over autumn, winter and even spring, particularly in free draining soils. Ensuring that good N fertiliser management is practiced in late summer/early autumn is of critical importance to ensure adequate grass available on farm for the extension of the grazing season while minimising N losses.

Conclusion

Significant changes to how grass is managed inside the farm gate are required to maintain the current levels of DM production in a scenario where N fertiliser allowances are reduced. Developing N fertiliser management plans, more grassland measurement and better grassland management, making better use of slurry, and incorporating white clover on farm can all contribute to reduce N fertiliser use, maintenance of herbage production, improved herbage quality and an increase in farm NUE.

Sustainable breeding — what are the options?

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Summary

- The Irish national dairy cow breeding index, the EBI, is 20 years old and it continues to deliver profitable, low environmental hoofprint cows for the Irish dairy sector
- A benefit from crossbreeding Holstein-Friesian with Jersey is still anticipated even in high EBI Holstein-Friesian herds, albeit the benefit is expected to be greater in lower EBI herds
- Recent advances in reproductive technologies including sexed semen and in vitro embryo production offer further potential to accelerate genetic gain in both dairy and beef-for-dairy populations
- The dairy-beef index is a tool, akin to the EBI for dairying, to help identify beef bulls for use on dairy females and, in doing so, increase the beef value of the surplus calves from the dairy herd
- Using sexed semen to generate replacement heifers can reduce the proportion of male dairy calves in the calf crop from 30% to 3%, facilitating greater use of high dairy-beef index semen, and thereby increasing the proportion of beef-cross calves from 40% to almost 70%.

Introduction

The Irish Economic Breeding Index (EBI) celebrates 20 years of existence in 2021. Over the past two decades, the EBI has evolved both in the array of traits considered, but also in their respective relative emphasis. Three criteria dictate whether or not a trait is considered within a breeding index like the EBI:

- Trait must be (economically, socially or environmentally) important
- Trait must demonstrate genetic differences among animals
- Individual animal information must exist on the trait itself or a correlated trait (for example, live-weight as an indicator of feed intake).

The evolution of the EBI since its introduction 20 years ago is illustrated in Figure 1. New traits were included as data became available. The (economic) weight on each trait changed as the relative value and costs of output and inputs varied over time. The composition of the EBI has, nonetheless, remained relatively consistent over the past decade reflecting the maturity of the index.

The mean EBI, milk sub-index and fertility sub-index of Irish dairy cows by year of calving is illustrated in Figure 2. The mean EBI of cows calving in 2020 is €141 greater than cows that calved in 2000. Assuming a yield per cow of 5,300 litres, this equates to 5.3 c/l additional profit. The annual rate of gain in EBI (for cows calving) has been €11.37 over the past 10 years with no sign of deceleration. While the genetic trends in the traits explicitly included in the EBI is evident, other key traits such as those pertinent to environmental sustainability are also reaping the benefits of the genetic gain in EBI. The modern high EBI cow is 14% more carbon efficient per kg milk solids produced compared with cows that existed before the EBI was introduced; she is also more efficient at utilising nitrogen. Both environmental benefits were achieved through a combination of improved milk solids yield and reproductive performance accompanied by cows producing for longer. The advantage of breeding over other strategies for improving efficiency is that the gains achieved accumulate over time but also do not return to baseline should technology adoption cease.

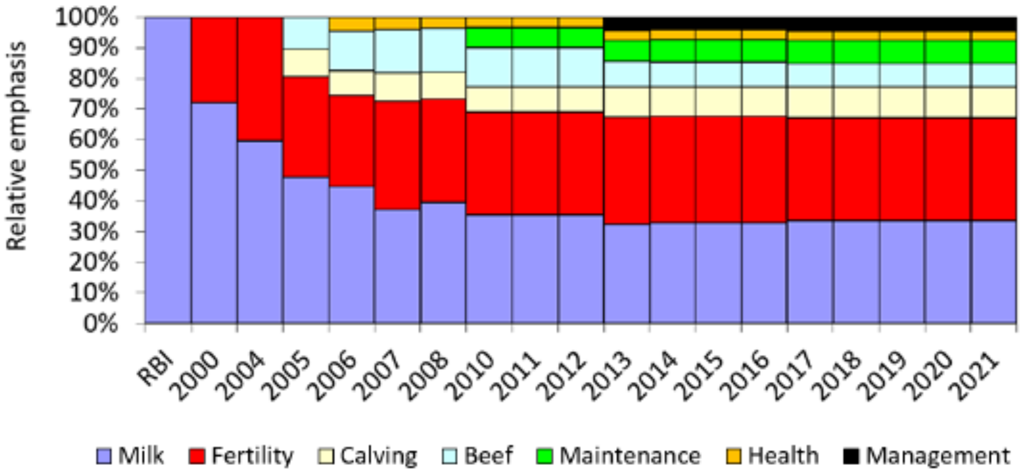

Figure 1. *Relative emphasis on different subindexes within the EBI as it evolved over the last 20 years since replacing the Relative Breeding Index (RBI)*

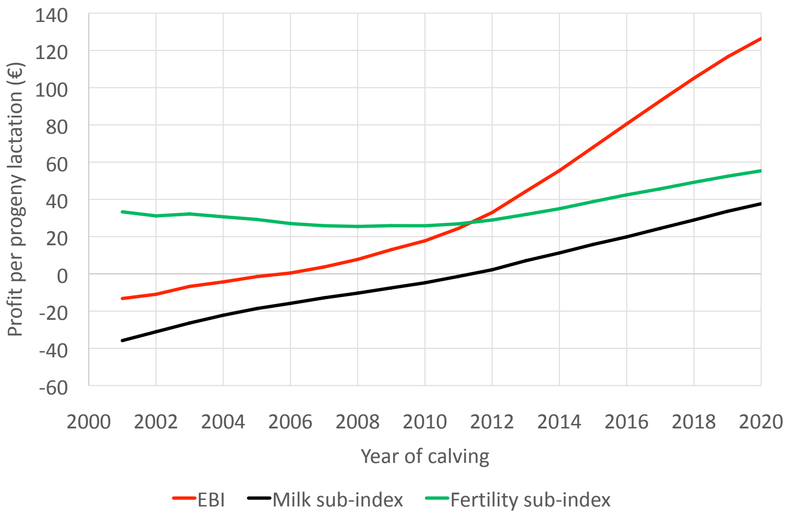

Figure 2. *Mean genetic merit of the Irish dairy cow population by year of calving for EBI and both the milk and fertility sub-indexes*

Selection for increased milk solids

It has sometimes been suggested that, in pursuing high milk solids output, only bulls above a certain threshold for fat and protein genetic merit (i.e. PTA) should be used. Such a target genetic merit for milk solids for any given herd can only be established with knowledge of the average genetic merit of the milking herd; this is best determined through the herd summary report in Herdplus. A simple target to be used across all herds is not practical since the actual milk solids yield of genetically identical cows can differ considerably between herds; in other words, management plays a large role in how genetic merit is expressed and thus widely different yields can be achieved from genetically similar cows. Figure 3 illustrates the mean mature equivalent milk solids yield of spring-calving Irish Holstein-Friesian dairy cows with a genetic merit for fat plus protein PTA of ~20 kg. Of the 160,000 cows included in the analysis, their 305-day milk solids yield was, on average, 562 kg but 10% of the cows yielded less than 462 kg while 10% of the cows yielded more than 672 kg. Therefore, using a single target genetic merit common to all herds is simply just wrong.

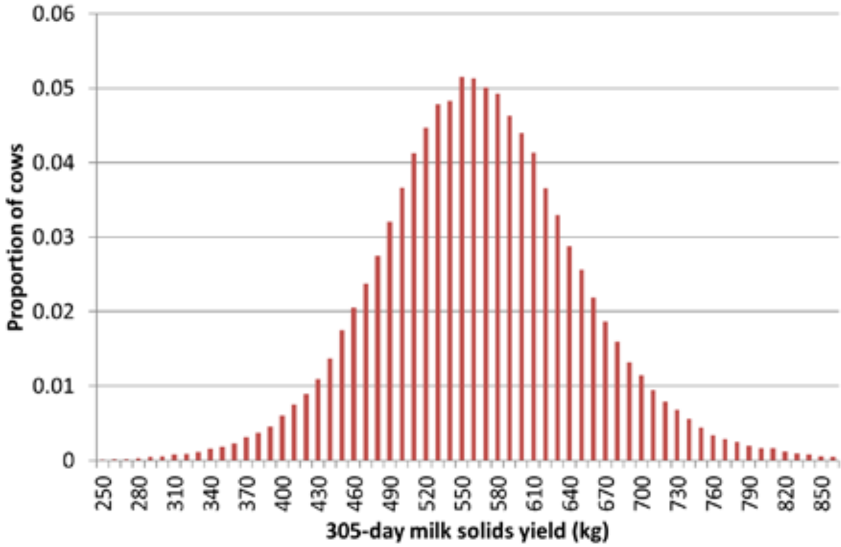

Figure 3. *Distribution of mature equivalent 305-day milk solids yield for cows with a genetic merit for milk solids yield of between 18 and 22 kg*

Of more importance, from both economic and environmental perspectives, is lifetime productivity. Figure 4 demonstrates the lifetime 305-day milk solids yield for cows born in 2015. While the majority of the cows lived to produce for three parities, 20% were culled before reaching second parity. Three "humps" are evident representing, from left to right, the cows that only lived for one lactation, for two lactations, or for at least three lactations. The greater the fertility index of the cows, the more lactations those cows produced. Hence, selection for improved longevity, in combination with greater milk solids yield (per lactation), is a good strategy to dilute the (economic and carbon) costs of heifer rearing over a longer productive life.

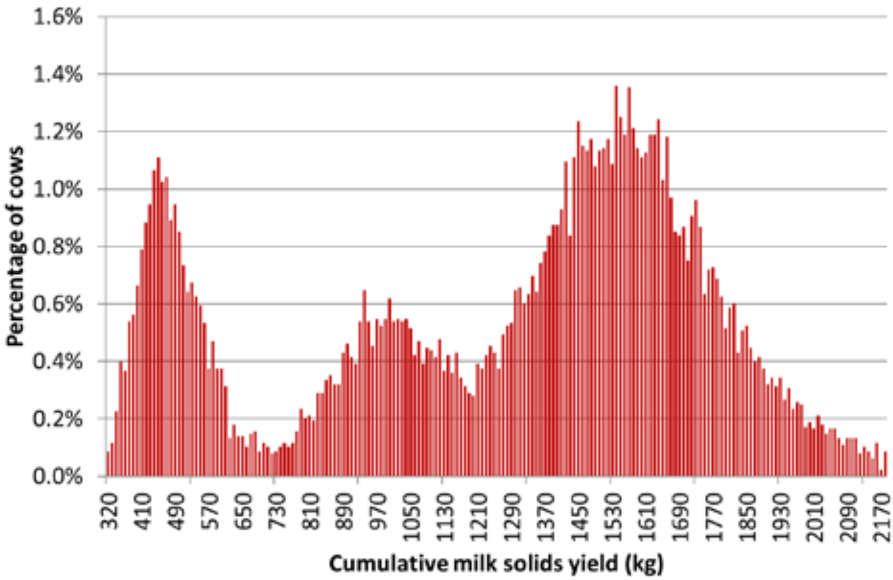

Figure 4. *Lifetime milk solids yield for cows with a genetic merit (i.e., PTA) for milk solids yield of ~20 kg all given the opportunity to produce for three lactations*

Crossbreeding with Jersey — is it still worthwhile?

Crossbreeding exploits favourable characteristics among contrasting breeds, removes inbreeding depression, and capitalises on heterosis or hybrid vigour. Heterosis occurs in crossbred animals resulting in synergies that mean crossbred animals perform better for certain traits than expected based on the average of their parents. It results in 'non-additive' genetic improvement, the magnitude of which depends on the genetic distance between the parents. The heterosis effect also varies depending on the trait of interest; for example, the heterosis effect is greater for fertility than milk yield, and is greater for milk yield than milk composition. Heterosis is not directly passed from generation to generation, and reflects the contribution of genetics from different breeds within an individual animal (degree to which the animal is crossbred). For this reason, heterosis is not and cannot be included directly in the EBI although it is included in the COW index.

The Jersey breed has many favourable dairy characteristics for crossbreeding in Ireland: small size, moderate yield coupled with high milk fat and protein content, high intake capacity, superior feed efficiency and compatibility with a pasture-based system. These characteristics complement the higher yielding Holstein-Friesian. Research has been conducted at Teagasc Moorepark to evaluate the merits of crossbreeding with Jersey since 2006. Five independent studies have been completed, ranging from controlled systems studies in research herds to analyses of commercial farm data. The findings from each study have been entirely consistent with each other and with international research findings. Each has demonstrated that Jersey×Holstein-Friesian cows outperform Holstein-Friesian cows due to a combination of improved fertility and herd productivity. The economic advantage estimated varied between studies, but generally approximated €150 per cow per lactation.

High EBI purebred Jersey cows were introduced into Teagasc's *Next Generation Herd* in 2018 to provide a direct comparison with high EBI Holstein-Friesian cows. Results to date are based on three years (see "Teagasc's *Next Generation Herd* — an update " on page 218 in this booklet). The relative breed differences are in line with previous research. Milk constituent (and yield) values for both breeds are high, representing the favourable genetic progress for milk fat and protein content in both our high EBI Holstein-Friesian and the Jersey, especially the Jersey of New Zealand origin. There are no Jersey×Holstein-Friesian cows in the *Next Generation Herd* currently. However, the relative purebred performances that have been obtained indicate a very likely benefit due to the expression of complementary breed differences and the expression of the phenomenon that is heterosis, even at high EBI, due to improved production characteristics and efficiency, but particularly at low EBI due to the expected marked improvement in fertility in addition to the productivity and efficiency gains. Recent analysis by ICBF using national data confirmed the benefits of crossbreeding. On average, herds considered mainly crossbred had higher EBI (+€47), higher annual milk receipts per cow (+€63) and a higher six week calving rate (+13.7 percentage units) compared with the average of straight Holstein-Friesian herds.

While crossbreeding strategies incorporating Jersey can improve herd productivity and profitability metrics, we cannot ignore that non-replacement (surplus) calves typically have very low financial value, and are a potential welfare concern for the dairy industry. For these reasons, crossbreeding with Jersey (and Jersey crossbred) bulls should be practiced responsibly. Their use should only be undertaken with sexed semen. Equally, to further minimise the number of low-value male calves generated annually, the practice of running dairy 'sweeper' bulls, often Jersey crossbred, should be avoided. Easy calving, short gestation bulls of a suitable beef breed or the use of vasectomised teaser bulls in conjunction with beef AI should be implemented.

Dairy-beef index

The recently developed dairy-beef index (DBI) ranks beef bulls for use on dairy females. The DBI of a bull is based on his estimated genetic potential to produce profitable, high quality cattle, born with minimal repercussions on subsequent performance of the dairy dam. The makeup of the DBI is in Figure 5. Half of the emphasis in the DBI is on traits for the dairy producer (i.e. calving difficulty, gestation length and calf mortality) with the other half representing important traits for the beef producer (i.e. carcass, docility and feed intake).

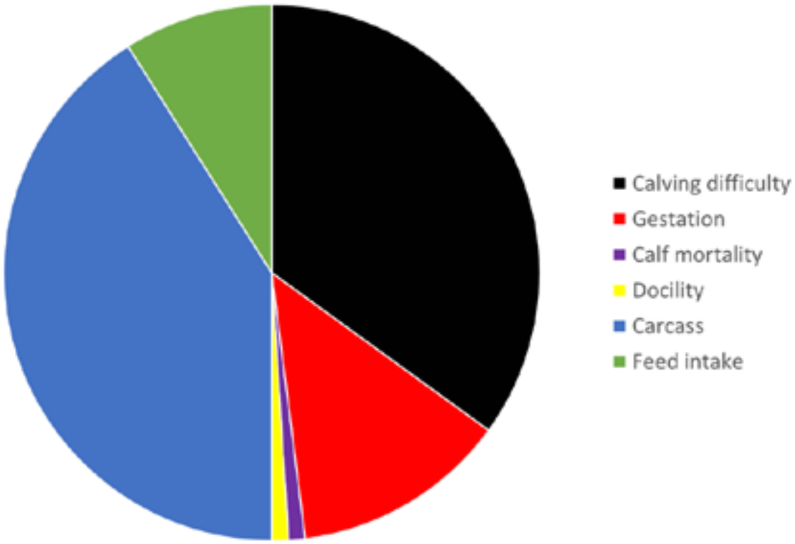

Figure 5. *Relative emphasis on the component traits of the dairy beef index*

Prudent selection on DBI has been proven to deliver cattle with a more conformed carcass, grown at a faster daily rate. Selection solely on DBI will, on average, however, lengthen gestation and contribute to slightly more calvings requiring assistance. Nonetheless, the direction of the DBI is clearly in the right direction; as with the EBI, it is simply a matter of the breeding program delivering higher (and balanced) DBI bulls (and bull dams). The end result will be cattle boasting superior beef characteristics without any compromise in gestation length or calving difficulty. Genetic gain in the DBI has the potential to far exceed that achieved for the EBI. This is because traits in the DBI are expressed by both sexes (unlike in the EBI where only the female express many of the traits), the traits are expressed early in life (data on the traits representing half the emphasis in the DBI are expressed at birth), almost all traits are highly heritable and thus relatively few progeny records are required to achieve a high accuracy of selection unlike for fertility in dairy cows where many progeny records are required. Matings using the DBI also benefits from the lack of a requirement to monitor inbreeding as is the case for the EBI. Hence, the DBI is expected to deliver a calf more in-line with the expectations of beef producers with minimal to no repercussions for the dairy female.

Reproductive technologies to solve problems in the dairy industry

Dairy and beef production are inextricably linked. A dairy cow must have a calf to initiate lactation, but in all dairy herds the total number of calves born is greater than the required number of replacement females. Hence, in most herds, ≥70% of the calves born are destined for beef production, but their genetics have been selected for dairy traits rather than beef traits, resulting in low economic value, as well as welfare and environmental concerns. Can reproductive technologies help to resolve this problem?

Sexed semen

Sexed semen involves the sorting of X ("female") and Y ("male") sperm cells by flow cytometry and reliably produces a 9:1 female to male sex ratio, reducing the number of male dairy calves. At present, the pregnancy rates achieved with conventional semen continues to be better than sexed semen, with a reduction of ~10% observed in recent large scale field trials in lactating dairy cows. It is likely that the gap in pregnancy rates between conventional and sexed semen will continue to close as the technologies for creating sex-biased semen improve in the years to come, fostering greater uptake and usage of sex-sorted semen.

Increasing the dam-side selection pressure by breeding replacement females from only genetically superior heifers and cows in the herd could accelerate herd genetic gain by up to 15%. This is only feasible, however, with widespread uptake of sexed semen from the best bulls. For the 2022 breeding season, Sexing Technologies will operate a semen sorting lab located at Teagasc, Moorepark, with the service available to all Irish AI companies. This will increase the number of high genetic merit bulls with sexed semen available.

As farmers move towards greater usage of sexed semen on genetically superior females to generate replacements, there is scope to have a corresponding increase in beef semen usage (to produce crossbred beef calf offspring). For example, a typical herd using conventional dairy semen for the first half of the breeding season followed by beef semen or natural service beef bulls for the remainder of the breeding season could expect a calf crop with 30% female dairy calves, 30% male dairy calves and 40% beef cross calves. By using sexed semen instead of conventional dairy semen, the calf crop could be readily changed to 30% female dairy calves, 3% male dairy calves and 67% beef cross calves. In the long term, this altered calf crop is a more sustainable option for the dairy industry, markedly reducing the number of male dairy calves.

In vitro produced embryos

If sexed semen becomes widely used, the reduced number of male dairy calves could have unfavourable implications for the national breeding programme. One solution would involve a targeted mating between elite bulls and dams of interest, but the number of male calves born is likely to be small. A better solution would involve multiple matings between these elite bulls and dams within a single breeding season. This can be achieved using a combination of Assisted Reproductive Technologies called oocyte pick-up (harvesting of oocytes from live donor dams), in vitro embryo production (fertilisation and embryo development for seven days in a lab) and embryo transfer to recipients that are synchronised to be on day seven of the cycle on the same day that the embryos are on day seven of development. As an additional option, sexed semen can be used to fertilise the oocytes. These technologies can be used to intensively select for genetic improvement in dairy breeds (Economic Breeding Index (EBI)) and beef breeds suitable for use in the dairy herd (Dairy Beef Index (DBI)).

Harvesting oocytes from live donors requires specific veterinary expertise and expensive equipment, and hence the cost of these embryos will be at least 10 times the cost of AI. This will limit the application of this technology to the elite breeding herds that have the potential to produce high value offspring. It is also possible to generate in vitro produced embryos that rely on ovaries that have been recovered post-slaughter as the source of oocytes, which would reduce the cost of producing the embryos. This method could be used to produce embryos with ≥75% beef breed genetics by harvesting ovaries from beef heifers, fertilising the oocytes using semen from bulls that are suitable for use on the dairy herd (high DBI), and transferring the embryos to lactating dairy cows that are not suitable for generating replacement heifers. These offspring will be terminal beef, and could offer another avenue for increasing the beef value of non-replacement stock on dairy farms. The expected benefits include accelerated genetic gain for milk and beef production, and transformation of the dairy herd calf crop to a combination of high genetic merit dairy female calves and premium quality beef calves. This structural change takes advantage of new tools that are now available for animal breeding (sexed semen, IVP embryos), and will help to increase the efficiency of dairy and beef production.

A large field trial was undertaken in 2021 to generate elite dairy, elite beef and commercial beef offspring using live donors (elite dairy and elite beef) and slaughterhouse ovaries (commercial beef) as the source of oocytes. In total, 1,200 cows were enrolled in the study, with 20% assigned to receive AI and 80% to receive different categories of embryos. The results are described in detail on page 224 (Results from dairy and beef IVF-ET trial), but it is clear that the in vitro produced embryos that are transferred fresh can achieve pregnancy rates that are comparable with AI.

Conclusion

The EBI continues to evolve and contribute towards improved performance and profitability on Irish dairy farms, as well as favourably impact some environmental credentials of milk production. Crossbreeding, particularly with Jersey bulls, can also improve herd productivity and profitability metrics, but non-replacement calves typically have low financial value, and are a potential welfare concern for the dairy industry. For these reasons, crossbreeding with Jersey bulls should only be undertaken with sexed semen. It is anticipated that the uptake and usage of sexed semen will increase markedly in the coming years, which will facilitate a simultaneous increase in the usage of high DBI beef bulls on all dams that are not required to generate replacements. This will have the welcome effect of markedly reducing the number of male dairy calves and increasing the number of beef-cross calves born. In vitro embryo production is a viable technology for seasonal calving systems, and will become an important tool to accelerate genetic gain in both dairy breeds and beef breeds suitable to crossing with dairy dams.

GRASS10

Perennial ryegrass variety grazing efficiency

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Summary

- Plot grazing studies have been conducted over the past six years investigating grazing efficiency differences between perennial ryegrass varieties
- 'Residual Grazed Height' has been developed as a measure of grazing efficiency accounting for pre-grazing differences between varieties
- Variety grazing efficiency is now included in the Pasture Profit Index to assist grass variety selection.

Introduction

Grazing to post-grazing sward heights of approximately 4 cm is optimum to maintain/increase sward quality as the grazing season progresses. High grass quality maximises grass utilisation, which has a positive impact on sustainability. Farmers involved in the 'Teagasc on-farm variety evaluation' study reported that some perennial ryegrass varieties were easier to graze to lower post-grazing sward heights compared to others but no indication of a varieties grazing efficiency was available within the Pasture Profit Index (PPI). Plot studies at Moorepark also found differences in variety grazing efficiency, and these results were used to generate a new grazing trait within the PPI.

Variety plot grazing evaluation

Variety plot studies were undertaken at Teagasc Moorepark. Plots were grazed by dairy cows when average pre-grazing herbage mass was 1,400 kg DM/ha. At each grazing event pre-grazing sward height was recorded on each plot using a rising plate meter. Dairy cows then grazed all plots simultaneously to an average post-grazing sward height of 4 cm. Once grazed, individual plot post-grazing sward height was recorded.

Residual grazed height

Despite having the same regrowth interval, differences in pre-grazing DM yield/sward height occurred between varieties as a result of their growth potential and previous post-grazing sward height. Comparing grazing efficiency based on post-grazing sward height alone was biased towards varieties with lower pre-grazing sward height (i.e. low pre-grazing sward height = low post-grazing sward height). Differences in varietal pre-grazing sward height had to be accounted for to accurately measure grazing efficiency differences. The post-grazing sward height of each variety was predicted based on pre-grazing sward height, grazing event and year. The predicted post-grazing sward height of a variety was then subtracted from the achieved post-grazing sward height of that variety, giving the 'Residual Grazed Height' (RGH) of that variety. Residual Grazed Height is the measure of grazing efficiency between varieties. Figure 1 displays the RGH of the varieties currently on the Irish Recommended List. Negative values of RGH are desirable as this indicates that grazing performance of a variety was better than expected, thereby showing high grazing efficiency. Varieties with positive RGH values performed poorly under grazing and therefore should not be selected when reseeding for swards intended for intensive rotational grazing.

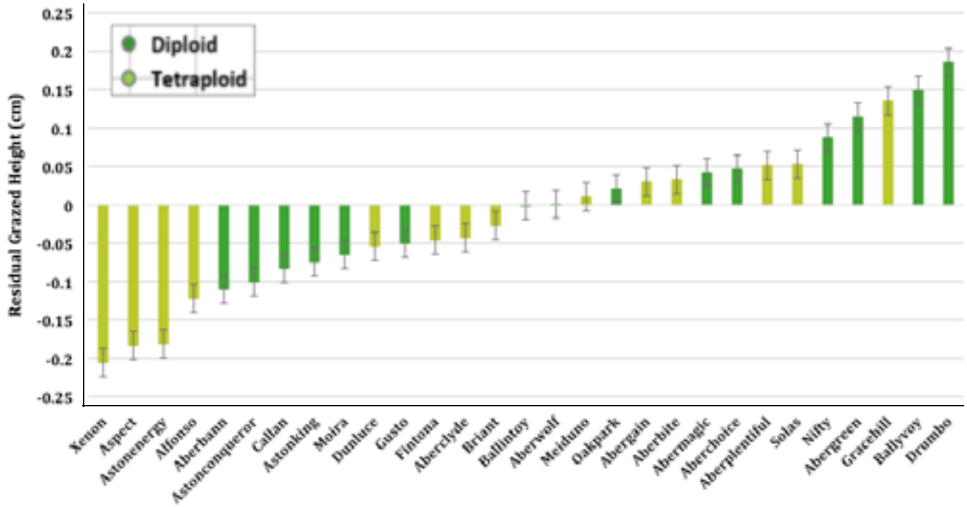

Figure 1. *Residual grazed height of PPI varieties*

Tetraploid varieties dominate the left (negative) side of Figure 1, indicating that they are more grazing efficient than diploid varieties. A number of plant traits were measured as predictors of grazing efficiency. The single greatest predictor of high grazing efficiency was high digestibility (Figure 2). The remaining variation was partly explained by plant morphology such as leaf size, stem proportion and tiller density. Further research is on-going to determine if there are other plant traits highly related to increased grazing efficiency.

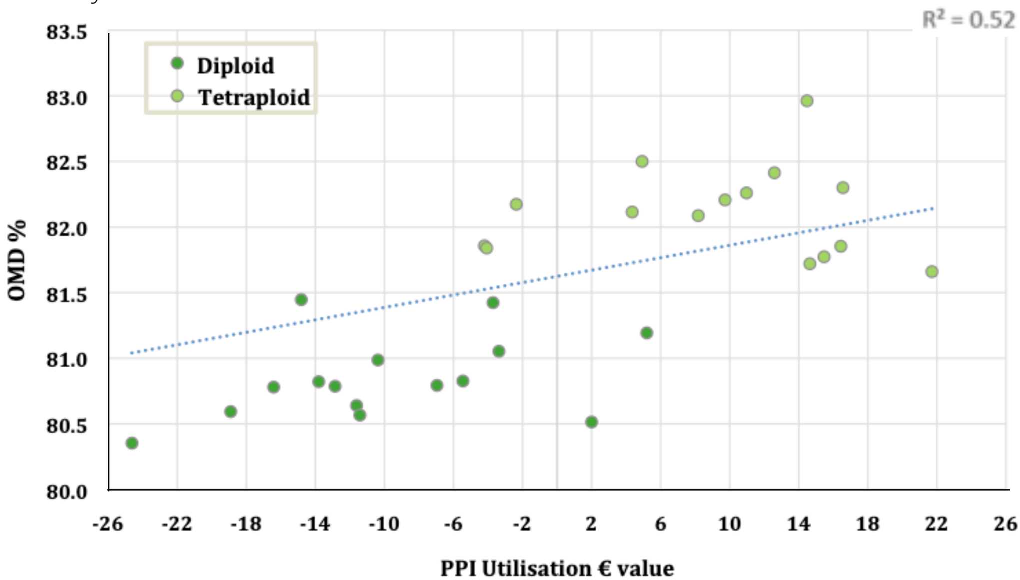

Figure 2. *Relationship between organic matter digestibility (OMD%) and Residual Grazed Height (PPI Utilisation value) of perennial ryegrass varieties on the 2021 Pasture Profit Index*

Conclusion

Grazing efficiency differences, as measured by RGH, were found between varieties. The Grazing Utilisation sub-index in the PPI allows farmers make informed decisions when choosing varieties for reseeding.

Updates to the Pasture Profit Index for 2021

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Summary

- The Pasture Profit Index (PPI) identifies the best perennial ryegrass varieties available. Key traits in the PPI are Spring, Summer and Autumn DM production, Grass Quality, Silage DM yield, Persistence and Grazing Utilisation
- Grazing utilisation is a new trait included in the 2021 list with variety performance expressed using the 'Star rating system'.

Introduction

Regular reseeding of pasture allows farmers to grow increased yields of higher quality grass, increasing the feed self-sufficiency and sustainability of their farms. The Pasture Profit Index (PPI) is used when selecting varieties to sow when reseeding. 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 2021 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. Varieties are ranked based on their overall PPI value which is calculated by adding a variety's 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%) 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 2021 with a PPI value of €225. This value indicates that by sowing Aberclyde on your farm, net profit will increase by €225/ha per year relative to the national average sward performance in Ireland. New to the 2021 PPI is the addition of the 'Grazing Utilisation' sub-index expressed using the 'Star rating system'. This trait uses grazing data from the Teagasc Moorepark variety grazing studies. The index provides an indication of how suited a variety is to intensive grazing. Varieties with five stars are highly suited while one star varieties are poorly grazed by cattle.

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. 2021 Pasture Profit Index

Variety	Ploidy	Heading date	PPI values €/ha/year							
			Tot.	Sub-indices						
			PPI	Spring	Summer	Autumn	Quality	Silage	Persistency	Utilisation
Aberclyde	T	25th May	225	42	62	48	41	31	0	****
Gracehill	T	4th Jun	222	35	57	61	12	56	0	*
Abergain	T	4th Jun	212	18	56	54	52	32	0	***
Nashota	T	3rd Jun	200	37	51	45	32	36	0	-
Abermagic	D	28th May	199	24	63	81	17	14	0	**
Astonconqueror	D	27th May	195	70	50	52	-7	30	0	****
Glenfield	T	3rd Jun	188	48	50	44	5	31	0	-
Moira	D	26th May	187	97	36	61	-33	25	0	****
Aberplentiful	T	8th Jun	186	42	60	54	13	16	0	**
Aberchoice	D	11th Jun	182	9	62	60	43	8	0	**
Meiduno	T	3rd Jun	180	34	53	50	30	13	0	***
Aberwolf	D	30th May	179	44	49	50	10	26	0	***
Abergreen	D	31st May	169	23	68	74	0	4	0	*
Fintona	T	24th May	168	38	50	53	-9	36	0	****
Ballyvoy	D	3rd Jun	167	54	42	50	21	-1	0	*
Dunluce	T	29th May	161	10	54	54	20	22	0	****
Ballintoy	T	4th Jun	159	19	55	47	19	19	0	***
Elysium	T	27th May	157	38	46	36	13	24	0	-
Aberbite	T	1st Jun	156	-13	52	56	35	26	0	**
Bowie	D	16th Jun	152	9	50	57	31	5	0	-
Gusto	D	31st May	149	31	46	64	11	-4	0	****
Astonenergy	T	1st Jun	138	-7	45	48	51	0	0	*****
Briant	T	3rd Jun	137	-1	55	49	15	19	0	***
Oakpark	D	2nd Jun	132	21	49	55	-10	16	0	***
Drumbo	D	5th Jun	129	12	40	45	27	4	0	*
Solas	T	10th Jun	129	-2	46	61	6	19	0	**
Xenon	T	7th Jun	128	2	46	40	31	9	0	*****
Nifty	D	28th May	127	28	57	61	-34	15	0	**
Callan	D	3rd Jun	123	59	38	41	-25	11	0	****
Aspect	T	3rd Jun	122	1	47	34	29	12	0	*****
Triwarwic	T	2nd Jun	122	9	50	33	9	21	0	-
Astonking	D	5th Jun	115	52	42	36	-19	4	0	****
Smile	D	4th Jun	68	-8	35	48	-9	0	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 for reseeding.

The importance of on-farm grass variety evaluation

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Summary

- PastureBase Ireland provides a platform where grass varieties can be assessed on commercial grassland farms
- On-farm variety evaluation can provide new insights in to how grass varieties perform on grassland farms, particularly in relation to grazing measurements and long term performance.

Introduction

Perennial ryegrass is considered the most important temperate forage species used in pasture production. This is due to its high yield potential, high nutritive value when managed correctly, and its relatively low cost compared to other feed sources for dairy cows. A limitation that currently exists is the lack of information regarding the long term dry matter (DM) production of varieties and their overall productivity persistence. Conducting perennial ryegrass variety evaluations using commercial on-farm data is now considered the most accurate means to assess the true value of varieties at farm level. The evolution of technology in the form of PastureBase Ireland (PBI) has provided Teagasc researchers with access to real (in situ) data previously unavailable. Data availed of in the current study included DM yield across a seven-year period from ten perennial ryegrass varieties grown as monocultures in 559 paddocks on 98 Irish commercial farms. The results illustrate how perennial ryegrass variety can impact a range of agronomic performance traits including total and seasonal DM production, individual grazing DM yield, number of grazings annually etc.

Results

All of the varieties evaluated had official heading dates within ten days of each other, meaning that the influence of heading date on seasonal production between PRG varieties was minimal.

AberGain produced the highest level of total and individual grazing DM yields over the course of the seven-year study (Table 1); the difference between AberGain and Glenveagh over a six-year period was large; almost 10 t DM/ha. The varieties that had the highest total DM production tended to be more productive throughout the growing season, including the shoulders; spring and autumn. Similarly, varieties which performed well continued to do so, relative to other varieties, across all years and sward ages measured.

The results also highlighted how some varieties may be more suitable to grazing than others; Astonenergy and AberGain achieved an average of 0.75 grazing events per year more than Dunluce and Glenveagh (Table 1).

Table 1. Varietal total, grazing and silage production (kg DM/ha) and number of defoliation events achieved

Variety	Total	Grazing	Grazing events	Silage	Silage events
AberChoice	14,390	12,820	7.7	1,687	0.60
AberGain (T)	15,434	13,281	8.0	2,243	0.77
Astonenergy (T)	14,224	12,899	8.0	1,569	0.56
Drumbo	14,438	12,863	7.9	1,745	0.45
Dunluce (T)	13,947	11,741	7.2	2,382	0.66
Glenveagh	13,568	11,541	7.3	2,263	0.65
Kintyre (T)	13,936	12,408	7.9	1,594	0.55
Majestic	14,245	12,365	7.8	2,009	0.63
Twymax (T)	14,326	12,360	7.6	2,100	0.63
Tyrella	13,752	11,946	7.5	1,785	0.64

(T) denotes tetraploid varieties, all other varieties are diploid

Conclusion

Improved seasonal DM production is cited as one of the major reasons why grassland farmers reseed pastures. It is important that farmers choose the most appropriate variety for their systems; on-farm variety assessment can provide more information to help farmers make such decisions.

The number of varieties being assessed on farms has now increased to include more than 20 varieties from the recommended list. The current work provides a basis for the consideration of on-farm variety assessment in the composition of future variety evaluation protocols.

Principles of reseeding

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Summary

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

Introduction

Reseeding levels in Ireland are low with less than 2% of our national grassland area 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 to maximise herbage production on farms. Swards with low perennial ryegrass content can cost farmers up to €300/ha per year due to reduced herbage production and reduced nitrogen (N) use efficiency. Reseeding costs approximately €750/ha; however, the increased profitability resulting from the new sward will on average recoup the cost in just two years, making reseeding one of the most cost effective on-farm investments.

Cultivation techniques

How paddocks are best 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 or either of the Irish (Republic or Northern) Recommended Lists
- Sow at a rate of 28–30 kg/ha of grass plus 3.5–5.0 kg medium leaved clover
- Include no more than three or four perennial ryegrass cultivars per seed 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/early summer reseed is as much as, if not more than, old permanent pasture in the establishment year. Establishing white clover in spring/early summer is more reliable than autumn due to the stability of soil temperatures. Conditions for post-emergence weed control are also more favourable following spring/early summer 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. 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 white 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 600–1,000 kg 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 white clover establishment resulting in an open sward which is liable to weed ingress.

Conclusion

Reseeding in spring/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.

Establishment of white clover on commercial grassland farms

Michael Egan

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

Summary

- The development of a national white clover pilot farm study establishing clover on farm commenced in April 2021
- Reseeding (3–5 kg/ha) & over-sowing (4–6 kg/ha) of white clover should commence as early in the year as possible (April-June)
- The first grazing of a new reseed and over-sown swards should be completed at a pre-grazing yield of 600–1,000 kg DM/ha.

Introduction

White clover has an important role to play in reducing chemical fertiliser usage on grassland farms in Ireland. Recent research in Teagasc Moorepark has shown increases in milk (+30 to +60 kg milk solids/cow/year) and herbage production (+1,100 kg DM/ha/year) and reductions in N fertiliser by up to 100 kg N/ha from incorporating white clover into grass-swards in high stocking rate systems. To-date the uptake of meaningful inclusion of white clover in swards on commercial farms has been low. Data from DAFM 2020 shows no increase in white clover seed imported over the last five years. Reseeding an entire farm to introduce white clover into pastures is impractical, coupled with the removal of legume safe herbicides in 2020 will further the challenge of establishing white clover into swards. Introducing white clover into existing grass swards (over-sowing) is an option to introduce white clover into pastures.

New on farm study in 2021

White clover is being established on thirty grassland farms by two methods: 1) reseeding and 2) oversowing. White clover is anticipated to be established on these farms within a three year period (approx. 10% reseeding/year and 30% over-sowing/year), with a aim of establishing an average annual sward white clover content of 20%, with an objective of reducing chemical N fertiliser across the pilot farms.

Establishing a white clover sward on your farm

Incorporating white clover in a full reseed is the most reliable method of establishing white clover and provides the best opportunity for weed control. Over-sowing is a simple and low cost method of introducing white clover into swards; however, success is very much dependent on; soil fertility, soil moisture, post-sowing grazing management and competition from the existing sward. Suitable paddocks for over-sowing are those with good soil fertility, high perennial ryegrass content and low weed content.

Reseeding — See 'Principles of Reseeding' paper

Over-sowing

- Do not over-sow old 'butty' swards with a low content of perennial ryegrass — white clover will not establish well under these conditions
- Control weeds before over-sowing white clover as weed control options afterwards are limited. Some herbicides have a residue of up to four months — always check the residual time on the label of the product or seek advice on a suitable weed control product

- Take a representative soil sample for analysis of P, K and pH:
    - » Optimal soil fertility when over-sowing aids in clover establishment and persistence
- White clover seed can be broadcast onto the sward or stitched in using a suitable machine
- If broadcasting with a fertiliser spreader:
    - » Mix white clover seed with 0:7:30 fertiliser and only add white clover to the spreader when you are in the field to avoid white clover settling at the base of the spreader
    - » Do a maximum of 1 ha at a time (to avoid seed settling) and spread in two directions across the field
- Stitching in white clover seed with a drill/harrow ensures better seed to soil contact
- Over-sow directly after grazing (≤ 4 cm post-grazing sward height) or after cutting the paddock for surplus bales — ideally only over-sow 3–4 paddocks at a time to allow for more targeted grazing management post-sowing
- Sow at a rate of 4.0–6.0 kg of white clover seed/ha
- Soil contact post over-sowing is one of the most crucial factors effecting germination:
    - » Roll paddocks post sowing to ensure soil contact
    - » Apply watery slurry (if available) — ideally around 2,000 gallons/acre
- Reduce N fertiliser post over-sowing for one to two rotations to reduce grass growth.

Post-sowing management — (full reseed or over-sowing)

- Graze as soon as the new plants are strong enough to withstand grazing
    - » Early grazing is important to allow light to the base of the plant to encourage stolon development
- The first grazing of a new reseed can be completed at a pre-grazing yield of 600–1,000 kg DM/ha. Frequent grazing of the reseeds at light pre-grazing yields (<1,400 kg DM/ha) during the first year post-establishment will have a beneficial effect on the sward
- Freshly reseeded or over-sown swards should not be closed for silage in their first year of production as the shading effect of heavy covers results in poor white clover establishment and an open sward which is liable to weed ingress
- Reseeded or over-sown swards should, if possible, be closed later in the autumn to avoid carrying heavy covers over the winter period.

Weed control in new grassland swards

John Maher and Ciaran Collins
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Summary

- Some of the benefits of reseeding are lost if proper weed control is not practised
- The incorporation of clover into new pastures has placed greater focus on achieving proper weed control
- Timely assessment of the weed population, spectrum of weeds to be controlled and making the appropriate herbicide choice is critical.

Introduction

The benefits of reseeding are well recognised. However some of those benefits are lost if proper weed control is not practised. Previous surveys by Teagasc have demonstrated that many farmers fail to apply a herbicide to new reseeds even though herbicide application is warranted. This is particularly true where reseeding takes place in the latter half of the grazing season.

More recently the incorporation of clover into new pastures has placed greater focus on achieving proper weed control. 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 improving animal performance and pasture quality.

Outlined below is some key points in achieving proper herbicide application to reseeds.

Weed control in New Leys

- Assess the weed population, spectrum of weeds to be controlled and make the appropriate herbicide choice (see Table 1)
- Apply the herbicide after grass has three leaves and the clover has one trifoliate leaf
- Generally apply the herbicide 4–6 weeks after grass emergence
- Good growing conditions are necessary at application
- Do not apply if grass stressed due to drought, pest attack, etc.
- Care must be taken when applying herbicides. It is necessary to avoid drift and follow buffer zone recommendations. Grassland herbicides are a major source of pesticide contamination of surface water
- Cutting/grazing restrictions may need to be extended to allow for control of poisonous weeds e.g. ragwort
- Costs in Table 1 are guide prices only and exclude VAT.

Table 1. Weed control in New Leys			
Trade Name	**Clover safe**	**Rate/ Ha**	**Comment**
LegumexDB Underclear CloveX *Clover max *DB Plus	Yes	7L/ha	Contains 2,4DB plus MCPA. Controls moderate levels of docks, thistles, etc. and most annual weeds. Needs small actively growing weeds for best effect. Apply after two leaf stage of grass and from one leaf clover stage. ~€45/ha+. Use up October 31 2021. *Clover max / DB Plus purchased under emergency approval in 2021 must be used by September 11 2021.
Farmco Undersown Embutone Headland Spruce	Yes	4.5L	Contains straight 2,4DB. Modest weed control on its own. Use up October 31 2021.
Binder Hurler Reaper Hyflux Echo Pro Tomahawk2 Tandus	No	0.75L	Contains Fluroxypyr. Best option for high numbers of docks, chickweed, dandelion, nettles. Limited use on thistles and buttercups. Apply from three leaf grass stage. ~€14/ha+.
Envy Grass Care Pro	No	1.5L	Contains Fluroxypyr and Florasulam. Additional control of many weeds compared to straight Fluroxypyr, esp. buttercups. Also useful where temperatures fluctuate. ~€38/ha.
Pastor Trio Esteem	No	1.0L	Contains Fluroxypyr, Clopyralid & Florasulam. Controls docks, thistles, chickweed, shepherds purse, charlock. Good all-around option. Not allowed after August 31st. ~€28/ha.

Ensuring proper grazing management after herbicide application is both beneficial to proper establishment of the sward and the control of weed populations. This is greatly a facilitated by timely application of the herbicide as many of the herbicides listed above in Table 1 have a long restriction time before grazing can commence after application (check individual product label).

New developments in the Teagasc grass + clover breeding programme

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Summary

- Strong pipeline of new perennial ryegrass, white clover and red clover varieties coming through
- First breeding programme to select for grazing utilisation
- Adopting a multispecies breeding strategy to improve animal production potential and farm sustainability.

History

The Teagasc breeding programme was established at Oakpark, Carlow in the early 1960's. Initially, the breeding of commercial varieties was a secondary focus. Over the first 25 years only two varieties were commercialised: Greenisle, an early tetraploid perennial ryegrass in 1980, and Aran a large leaf white clover in 1983. In the mid-1980's, the programme was restructured and breeding to generate varieties of commercial value was prioritised. Since then 40 new varieties of perennial ryegrass, white clover and red clover have been commercialised or on average 1.1 new varieties per year.

In the past, the primary objective of the programme was to increase forage yield and quality with the aim to increase animal production per ha. Today, the programme is challenged by the difficulty of addressing contrasting demands by farmers (higher animal production potential) and society (reduced environmental and climatic footprint). The programme has adopted a multispecies (perennial ryegrass + white clover + red clover) breeding approach to meet these demands.

Perennial ryegrass

The majority of resources in the breeding programme are committed to the improvement of perennial ryegrass, as it is the main forage species sown in Ireland. The traditional traits for improvement (e.g. yield, quality, persistency and disease resistance) that were important 20 years ago are still important today. However, the programme continues to evolve and introduce new traits. Starting in 2019, the programme became 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. Improvements in grazing utilisation may translate into genetic gain for multiple traits on the Recommended List.

Characterising/measuring plant phenotypes is a major bottleneck in the breeding process. The programme takes up to 20,000 plot harvests per year. To this end, the programme has invested in high throughput phenotyping using advances in machinery, optical sensors (e.g. near infrared spectroscopy) and machine learning. Genomic selection has revolutionised animal breeding and has the potential to do likewise for grass and clover breeding increasing genetic gain by an estimated two- to three-fold. Genomic selection is selection based on plant DNA. The Teagasc breeding programme conducted its first cycle of genomic selection in a perennial ryegrass population in 2017. Genomic selection is being developed as a selection tool for all species in the programme.

White clover

Teagasc has a long, successful history of breeding white clover starting with Aran in 1983. The white clover 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.

The breeding process consists of a multistep and cyclic process where the best plants (genotypes) are evaluated, selected and intercrossed to produce a new variety. The development of the next generation of Teagasc white clover varieties began in 2008 with 250 crosses conducted among elite populations. There followed a rigorous evaluation of these new crosses across 1,140 plots using mechanical cutting and sheep grazing over a 3-year period to identify the best plants. These elite plants were intercrossed to produce eight new varieties. These new varieties are presently under evaluation in the Ireland Recommended List trials. Results to date are promising with the new varieties offering an average 5% higher annual yield of grass and clover than the present Recommended List varieties.

Seed of the next generation of Teagasc white clover varieties are currently being multiplied by Goldcrop with release to start in 2023.

Red clover

Red clover has traditionally been a minor crop species in Ireland but its merits for animal production and sustainability are currently coming to the fore and its importance is growing. Recognising its potential, a new red clover breeding programme was initiated by Teagasc in 2007.

The first variety from this new programme is Fearga. Fearga is the first Irish bred red clover variety. It was bred from the variety Merviot for high yield, persistency and longevity. While there are no official red clover trials in Ireland, Fearga has completed the UK Recommended List trials. Fearga was found to be the highest yielding variety in the UK; yielding 22% and 31% more than the control variety Merviot in the second and third harvest year, respectively. Fearga also offered significant improvements in persistency with 54% higher autumn ground cover than Merviot in the third harvest year. Fearga is currently being commercialised by Goldcrop for release in 2023.

Conclusion

The Teagasc forage breeding programme continues to adapt and incorporate the latest technology and breeding methodology to develop new varieties of grass and clover. The next generation of Teagasc white clover and red clover varieties will be available to farmers from 2023.

Acknowledgements

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Genomic selection as a tool to support forage grass breeding

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Summary

- Genomic selection can help forage breeding by increasing selection intensity, increasing selection accuracy, and reducing the generation interval
- At Teagasc, we are now developing genomic selection as a tool to support development of cultivars with improved forage yield and digestibility.

Introduction

The goal of forage grass breeding is to select the best plants and use these as parents to produce a new improved population. If we keep repeating this in a process known as recurrent selection, then we continuously improve the population over time by increasing the frequency of favourable genes. A typical cycle of recurrent selection can take up to seven years and includes seed multiplication for establishing sward plots, multiyear field evaluation, and data analysis and selection. There is scope to increase the rate of genetic gain in forage grass breeding using genomic selection.

Genomic selection in forage grass breeding

Genomic selection is a breeding tool that uses information from a plant's (or animal's) DNA to predict its breeding value (Figure 1). In recent years, there has been increased interest in its application to forage grass breeding, mainly driven by a reduction in the cost of DNA sequencing, but also from the demonstrable success of genomic selection in animal breeding. In genomic selection, DNA evaluations are associated to field measurements in a reference population and data used to develop statistical models. Using these statistical models, we can generate Genomic Estimated Breeding Values (GEBVs) for progeny of the reference population, based solely on its DNA information. The major advantages of genomic selection to forage grass breeding are:

- Improve the selection accuracy and select the best plants within the best families
- Reduce the length of the breeding cycle to a single year
- Increase the intensity of selection by evaluating the DNA of thousands of plants in the glasshouse.

Therefore, implementing genomic selection in forage grass breeding has the potential to more than double the rate of genetic gain.

Teagasc research into genomic selection

In Teagasc, genomic prediction models for many traits have been developed, with a large focus on developing tools to support improvements in forage digestibility. A large reference population consisting of 1,800 individual plants was clonally propagated and established in a replicated field trial, where samples for forage quality analysis were taken at multiple cuts and over multiple years. At the same time, the DNA were evaluated, and DNA profiles established for each individual in the reference population. Initial genomic prediction models developed for forage quality parameters are promising, and can now be validated on descendants of this reference population.

Figure 1. *An example of selection of forage yield with field evaluations versus selection with genomics. In genomic selection, plants can be grown in the glasshouse, DNA analysed, and the best plants selected from DNA information alone. These can then be used as parents in the next round of selection or to develop a candidate cultivar.*

Conclusions and future directions

Forage grass breeders will take advantage of all available tools and technologies at their disposal to increase genetic gain and produce improved cultivars in response to sectoral demands. Genomic selection is just one such tool that is being fully integrated into routine breeding activities. In such a scenario, field-evaluations will be used to continually update and improve statistical models, and to add new traits as breeding goals evolve. Selection of plants to produce new candidate cultivars and as parents to initiate a new cycle of selection will be based on genomic estimated breeding values.

Acknowedgements

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Getting familiar with the new tools on PastureBase Ireland

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Summary

- Grass for 25% of the national dairy herd is now managed through PastureBase Ireland (PBI)
- Over 800 dairy farms completed 30 farm covers or more in 2020
- Dairy farmers recording farm cover regularly on PBI have grown between 11.1 and 14.4 t DM/ha per year over the last eight years
- Farmers are encouraged to download the 'PBI Grass' app
- An array of new tools are available to PBI users.

Introduction

PastureBase Ireland (PBI) is the first choice grassland management platform for thousands of dairy 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 dairy farmers. Each year the number of farmers using the application and the measuring intensity continues to increase. In 2020, dairy farmers using PBI recorded a farm cover on average 18.8 times, up from 13.8 in 2019, which suggests an increasing engagement by dairy farmers with grassland measurement/management.

Linking with soil laboratories

Correcting soil fertility is key to increasing grass production on Irish dairy farms. Farmers who use FBA Laboratories, Cappaquinn, Co. Waterford for soil testing can now have their latest soil fertility results automatically uploaded to their PBI profile. It is hoped that other laboratories will join this facility later in 2021. There are two informative soil fertility reports available on the PBI Grass app: (1) the soil fertility data for each paddock, and (2) if recorded, the total kg per hectare of N, P, K and S applied. This information is expected to greatly aid farmers in selecting the appropriate fertiliser type for individual paddocks.

Nitrogen management planning

More dairy farmers are now recording their fertiliser and slurry applications on PBI. However, up to now no fertiliser advice based on paddock use (grazing, grazing/one cut of silage, grazing/two cuts of silage and grazing high white clover content paddocks) was provided in PBI. The new N planner is now available to help farmers plan chemical and organic N applications providing monthly recommendations from the Teagasc Green Book. As the year progresses actual fertiliser applied can be recorded and compared with the monthly recommendations.

Milk data

Milk data can be easily uploaded by the milk processor each day to your PBI profile. Currently, 13 milk processors are linked to PBI. A new milk report was developed to allow farmers to compared their herd fat percentage, protein percentage, litres per cow, milk solids per cow and per hectare across different years. When linking to other farmers in PBI, milk data can the shared to compare and benchmark results.

Farm weather data

The weather has a major influence on grass growth and grass utilisation. In early 2021 a new 'farm weather' module was deployed onto the PBI application. A PBI farmer can now:

- Link to a Met Eireann or Teagasc weather station located near their farm to download the latest actual weather recorded
- Manually enter weather data recorded for their own farm
- Enter the location of their farm to download the forecast and actual weather data.

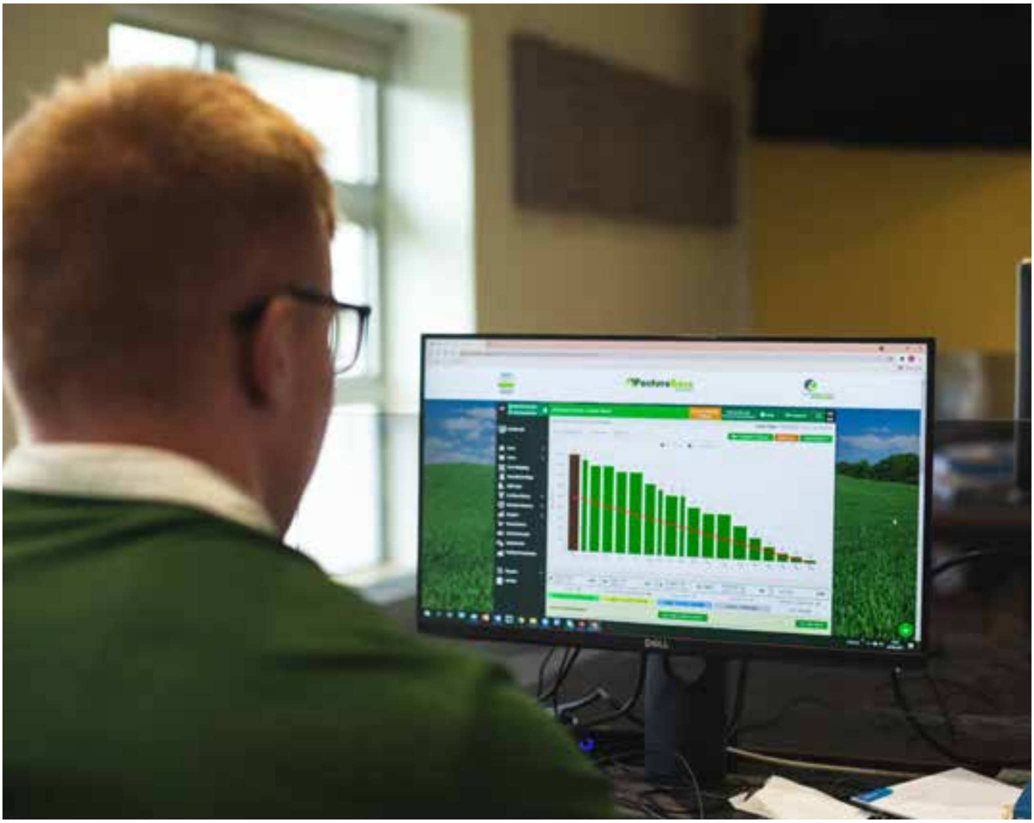
This tool should aid farmers in making informed decisions such as whether or not to apply fertiliser or slurry, and to predict grass growth rate for next week.

Farm map

The most recent tool added to PBI is the farm mapping option. Now a farmer can map their own farm on the application and a range of parameters can be displayed on the map (paddock covers, soil fertility, annual tonnage, days last grazed/fertilised, etc.). This is a move away from tables to a more visual approach. Again this should help farmers to manage their farm better and improve communication when employing labour and contractors.

Conclusion

PastureBase Ireland offers the medium for farms to improve grazing management through grassland measurement and better decision making. The application continues to increase and improve the range of tools available to farmers. PastureBase Ireland is available to all 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.



The MoSt GG model — predicting grass growth live on farm

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Summary

- The MoSt Grass Growth model has been developed to predict grass growth, grass nitrogen (N) content and N leaching at the individual paddock and farm level
- The MoSt Grass Growth model is currently used bi-weekly on 57 pilot commercial farms to predict grass growth for the following seven days
- When looking at the grass growth prediction, the trend of the growth (is it increasing or decreasing) is more important than the absolute value
- The MoSt Grass Growth model will soon be incorporated into PastureBase Ireland (PBI) and so grass growth prediction will be available to all PBI farms.

Introduction

PastureBase Ireland (PBI) is a grassland management tool used by farmers. It helps farmers to manage grass on their farm; identify grass supply surpluses or deficits and to take appropriate action. However, 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 can be variable, depending heavily on climatic conditions and soil type. Using the MoSt Grass Growth (MoSt GG) prediction model can help farmers make better grassland management decisions based on the future and not on the past.

Model description

The MoSt GG model was developed at Teagasc Moorepark in conjuction with INRAE St Gilles, France for Irish grazing systems and Irish meteorological conditions. The model predicts daily grass growth (kg DM/ha) depending on weather conditions and farm management. Farmer decisions which can impact on grass growth within the model are nitrogen fertiliser application, 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 animal grazing (through urine and dung patches) on growth. The MoSt GG model has also been developed with the aim of recreating the nitrogen (N) flow in the soil and the plant to predict N leaching and the N content of the grass.

On farm grass growth prediction

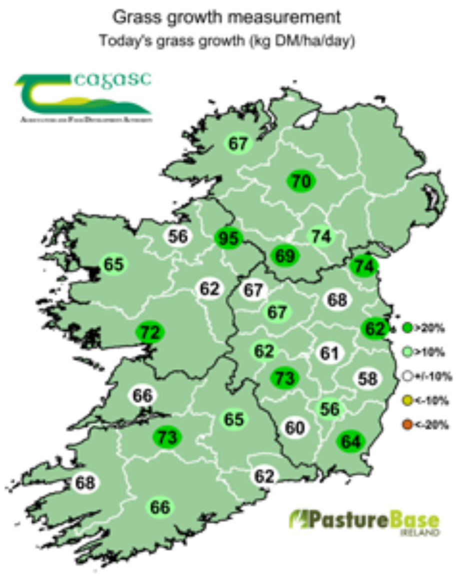
The number of pilot farms where the grass growth is predicted started with 30 in 2019 and is currently at 57 farms. These are mostly commercial dairy farms. Most of the data required to make the prediction is currently available in PBI: the paddocks and their respective areas, the grazing and cutting dates, the number of livestock grazing, the level of supplementation offered, and the N fertilisation (chemical and organic). Other data necessary are the type of soil for each paddock which is determined using the Irish Soil Information System and the weather data, historical and forecasted, provided by Met Eireann. The 57 farms chosen in this programme are farmers who are recording farm cover weekly and are recording N fertiliser application. The farms are also spread across the country allowing the representation of variability in terms of location and soil type. The number of farms included in the programme will soon be increased.

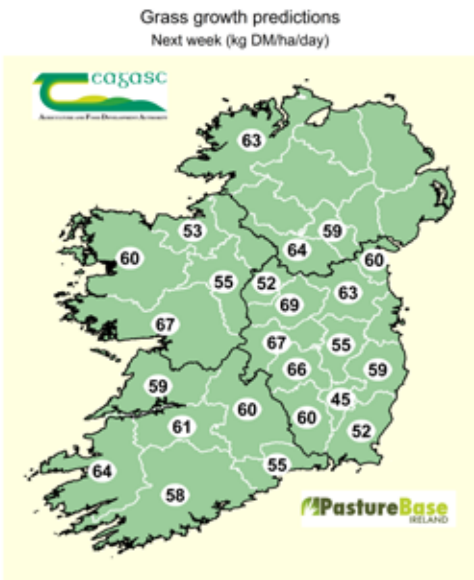
Where can I access the grass growth prediction?

The data is sent weekly to all the farmers involved in the pilot programme, but also by email to all Teagasc advisors with other information such as predicted rainfall and predicted soil temperature for the coming week. The weekly grass growth predictions are also available to the public through the Grass10 newsletter which can be viewed through the PBI website. Since August 2020 the grass growth prediction is also presented each Sunday on RTE1 during the Farming Forecast.

How to use grass growth predictions and famer feedback

The feedback from participating farmers is very positive; a survey of the farmers in 2019 found they rated the accuracy of the model 3.7/5 and its usefulness 4.0/5. More importantly, 70% of the farmers have said they adapted their management depending on the prediction (feeding more or less concentrate/silage, closing a paddock for silage and so on). While the grass growth predictions are currently farm specific, and a precise value is generated, i.e. it is different for each farm. This is why the trend of the grass growth prediction (whether it is increasing or decreasing compared to the previous week) is more important than the absolute prediction. A farm may be consistently growing less than the prediction but the overall trend should be valid.





Grass measurement techniques — understanding the platemeter

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Summary

- Average variation in herbage mass on grazed paddocks was 36% across the growing season, which represents a challenge for the rising platemeter
- Improving the accuracy of the rising platemeter may be achieved by integrating the rising platemeter data with grassland management data, such as nitrogen fertilisation and grazing rotation; integration with meteorological data resulted in a minimal increase in accuracy
- A prototype decision support tool (Grass Measurement Optimisation Tool) to use with the rising platemeter has been developed. It can generate different grass measurement routes (with different measurement frequencies) and can select a route optimized for time and accuracy.

Introduction

Accurate estimation of herbage mass is essential for optimising grass allocation and utilisation, and ultimately, for increasing profit margins for pasture-based dairy and beef production. There are a number of conventional grass measurement techniques in use, including 'cutting and weighing' and 'visual assessment'. The rising platemeter is also a well-established tool for measuring pasture in Ireland.

The rising platemeter

The rising platemeter records a combined measure of pasture height and density, referred to as compressed sward height, and from this, estimates grass quantity in a paddock. The rising platemeter is an upright staff with a horizontal disc that moves up the staff, depending on the height and density of the grass underneath it. Usually the farmer walks across the paddock and takes 30–50 measures to achieve an average grass height. Recorded compressed sward height is then used to model herbage mass. Once the herbage mass is known, the farmer calculates the area of the field that will supply the cow herd with the correct amount of grass, and sets up the fences.

While use of the rising platemeter requires minimal training and measurements can be recorded throughout a paddock relatively quickly, limitations in accuracy are evident. A considerable source of rising platemeter error is diversity within the sward. Large variations can be recorded between compressed sward height measurements within pastures, resulting from the interaction between the rising plate and the variation in density at different heights of the sward. A study was conducted to investigate variation of herbage mass within pastures, determine the number of rising platemeter measurements required to accurately predict mean herbage mass, and assess the precision of the rising platemeter by measuring its repeatability. Intensive compressed sward height measurements and herbage mass reference cuts were carried out on controlled trial plots and grazed paddocks over two grazing seasons. Results indicated that herbage mass varied by 36% across the growing season and was affected by grazing, fertilisation, sward composition and seasonality. Mean compressed sward height could be estimated to within 5% error by recording 24 measurements per ha. The standard deviation around repeated measures of the rising platemeter was calculated to be 4.34 mm. The equation for predicting herbage mass was the largest source of error associated with the rising platemeter when a robust methodology for measurement was used.

Modifying the model to increase accuracy

There is scope to improve the accuracy of the rising platemeter. A recent Moorepark study investigated the integration of grassland management and climate data with rising platemeter data to achieve a more accurate prediction of herbage mass. It showed that the most important variables to include in the model were compressed sward height, nitrogen fertilisation and grazing rotation. Further addition of meteorological factors resulted in a minimal increase in accuracy. The new models indicated a marked improvement compared with conventional models currently used on Irish farms. The optimum model developed is now ready for integration with conventional rising platemeters and with PastureBase Ireland for use on Irish grasslands.

Grass measurement optimisation tool

Sward variation may be accounted for by increasing measurement intensity, however, this leads to increases in measurement labour and time. A prototype decision support tool (Grass Measurement Optimisation Tool; https://messo.cit.ie/gmot) was designed to generate a measurement methodology to optimise for time and accuracy. This tool was developed to generate interactive paddock maps so it could simulate different potential measurement routes within the paddock (with different measurement frequencies), examine the associated errors and select the option optimized for time and accuracy. Rising platemeter measurements and reference herbage cuts were performed on trial plots and grazed paddocks over three years. Actual error for the rising platemeter decreased from 37%–26% as measurement rates increased from 1–8/ha and reductions in error were negligible (<1%) as measurements increased from 8–32/ha. The benefits of this tool include the removal of operator subjectivity along with increasing the precision and efficiency of grassland measurement. It also means that the time required to measure grass to a desired level of accuracy during a farm walk can be accurately predicted and scheduled for.

Conclusion

Variation in herbage mass within optimally managed grass swards has been benchmarked at 36%. More accurate grass measurement technologies and robust sampling protocols are required to account for this variation. The research outlined here has developed optimised models and protocols for the rising platemeter.

Grass10 campaign — summary of Phase 1 (2017–2020)

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Summary

- The Grass10 campaign promotes sustainable grassland excellence
- The objective of the campaign is to achieve 10 grazings per paddock per year, utilising 10 tonnes of grass dry matter (DM) /hectare
- The number of farmers recording grass measurements and using PastureBase Ireland to manage grass on their farms has increased significantly over the campaign.

Introduction

There is a strong relationship between the amount of grazed pasture in the diet and the costs of milk with operating costs of production declining with increased reliance on grazed pasture. Recent Teagasc analysis has indicated that net profit per hectare is increased by €173/ha for each additional tonne of grass DM utilised on dairy farms.

Grass10 campaign

Teagasc launched a multi-year Grass10 campaign (four years, 2017–2020) 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. As well as working closely with all partners and Teagasc advisory programme, the Grass10 programme worked closely with the Grassland Science Department in Teagasc. The primary objective of the Grass10 Campaign was to utilise 10 tonnes of grass DM/ha/year using 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
- PastureBase Ireland (PBI) usage
- Improving grassland management skills

Grass measurement

The number of farmers recording 20 or more grass measurements and using PBI to manage grass on their farms has increased by over 100% since the Grass10 Campaign begun. About 2,000 users now record grass measurements on a regular basis using PBI. Increasing the level of PBI usage has been one of the key objectives of the Grass10 campaign. The level of regular pasture measurement needs to increase to gain greater improvements in grassland management. There has been a strong focus on training of farmers to become PBI users particularly through the Grass10 courses.

From Teagasc National Farm Survey data, grass utilisation per ha increased by 0.3 tonnes (7.7–8.0 tonnes of DM/ha) on dairy farms over the last few years. This corresponds to a grass production of 10.7 tonnes of DM/ha annually. The estimated 10.7 tonnes grass grown on dairy farms is much lower than the 13.6 tonnes of DM/ha recorded by dairy farms measuring on PBI, indicating that there is still significant potential to grow more grass on the average dairy farm. There was a significant improvement in soil fertility over the period with about 20% of soils now at optimal soil fertility compared to 10% at the start.

Grass10 courses

About 45 farmer training courses were delivered over the last two years and the venue for these courses was on farm using the concept of a 'Grazing Coach'. The aim of these training courses was to up-skill farmers in grassland management and to enable more farmers to improve their grassland management decision making. The courses took the Grazing Coach format, where grass course members attend the same farm every month and monitor grazing decisions and performance throughout the year. The Grazing Coach selected is a farmer who wants to learn, but has the potential to improve grass production and grazing efficiency on the farm.

Weekly Grass10 newsletter

The Grass10 newsletter is dispersed to over 1,500 industry stakeholders and 4,000 PBI users weekly. It is a very successful communication tool for the Grass10 programme. It is produced every Tuesday using the grass measurements taken by farmers obtained from PBI. Also included in the newsletter is the predicted grass growth for the upcoming week. Farmers daily grass management decisions is of huge importance to ensure good quality feed availability for the cows during the grazing season. Being able to predict grass growth for the following week at farm level would help farmers to better anticipate variations in grass growth. The Moorepark St Gilles Grass Growth (MoSt GG) model is a dynamic model working at the paddock and farm level. The model takes into account soil type, weather and the grazing management practice to predict farm grass growth.

Grassland farmer of the year competition

Grass10 launched a grassland competition to recognise those farmers who are achieving high levels of grass utilisation in a sustainable manner. The Grassland Farmer of the Year was launched in 2017 to coincide with the Year of Sustainable Grassland supported by the Department of Agriculture, Food & the Marine, in collaboration with the other stakeholders as part of the Grass10 campaign.

Grass10 wishes to acknowledge the support of our industry stakeholders in the Grass10 Campaign.

Increasing nitrogen use efficiency through soil fertility and nutrient management

David Wall and Mark Plunkett

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Summary

- Optimising soil fertility (pH, P and K) leads to increased grass production, better persistency of perennial ryegrass and white clover in the sward and enables an extended grazing season
- Balanced soil fertility can increase nitrogen (N) fertiliser use efficiency (+30%) and reduce chemical N fertiliser requirement
- Managing slurry effectively by having sufficient slurry storage, applying slurry in spring and using low emission slurry spreading methods can help to offset chemical N fertiliser.

Introduction

We rely on agricultural land to produce our food. In Ireland, grass-based animal production is the dominant land-use, which suits our soils and climatic conditions. Agricultural land also provides a host of other benefits such as recycling nutrients from organic manures and storing nutrients and carbon in soil organic matter. The soil hosts an enormous population of living organisms, which are central to nutrient recycling processes and to maintaining the productivity of agricultural soils for future food production. The management of nutrients and fertiliser inputs to agricultural soils is critical and plays a key role in meeting the demand for food production.

Balanced soil fertility leading to productivity gains

Grass yields typically respond positively to balanced soil fertility. Balanced inputs of nutrients from organic and chemical fertiliser sources replenish nutrients removed from soil in harvested grass silage, meat and milk, and are critical for maintaining the grassland production potential of soils and the livestock carrying capacity and profitability of farms. Fertiliser application combined with other productivity factors such as improved grass varieties, animal genetics, grassland and animal management have led to a significant increase in grass yields and milk and meat production on Irish farms. However, this growth in agricultural output has resulted in important ecological and environmental pressures. The EU Farm-to-Fork Strategy calls for reductions in N fertiliser use by up to 20%. While further improvement in nutrient management may be necessary to reduce nutrient emissions to the environment, it must also be considered that, in a global context, agriculture without any synthetic inputs can often have a greater environmental impact as more land is required to produce similar quantities of food.

Enhancing nitrogen fertiliser use efficiency through optimising soil fertility

Optimised soil fertility, especially soil pH, P and K levels, leads to increased N use efficiency and opportunities to save fertilizer N 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%, on average (Table 1). Correcting soil pH alone increased N fertiliser use efficiency to 53%, with further gains from optimising soil P and K. Overall, highest levels of N fertiliser use efficiency were achieved in fields with balanced soil fertility (optimum soil pH, P and K). Therefore, more frequent soil fertility testing and greater use of nutrient management planning will help to increase N use efficiency on grassland farms.

Table 1. Percentage nitrogen (N) use efficiency (NUE) across grassland fields according to the status of soil pH, phosphorus (P) and potassium (K) fertility			
Mean grassland N use efficiency	Soil pH with optimum range	Soil P within optimum range	Soil K within optimum range
63%	✔	✔	✔
54%	✔	✕	✔
57%	✔	✔	✕
53%	✔	✕	✕
35%	✕	✕	✕

Grassland nitrogen use efficiency was calculated at the percentage of the applied fertiliser and manure N recovered by the grass sward across the 446 fields on which measurements were taken over two years on commercial Irish dairy farms

Saving nitrogen fertiliser with low emissions slurry spreading (LESS)

Slurry is an important source of nutrients (N, P & K) and application to grassland must be properly timed to maximise the efficiency of slurry nutrient capture and utilisation by the grass, as well as replenishing soil fertility levels. The targeted application of slurry in spring will ensure the most efficient use of slurry nutrients for grass production and minimise potential ammonia-N losses. Slurry N losses in the form of ammonia emissions are potentially the largest loss of reactive N on Irish farms. Using LESS methods, such as trailing shoe or band spreaders reduces slurry N losses as ammonia gas and increases slurry N value, thereby increasing pasture productivity and reducing chemical fertiliser N requirements (Table 2). Adequate slurry storage at farm level is required to capitalize on this during the growing season.

Table 2. Nitrogen (N) availability and value (€) using low emission slurry spreading (LESS) methods						
Nitrogen Use Efficiency	Cattle slurry N value when applied at 33 m³/ha					
	Splash plate		Trailing-shoe/ bandspreader (LESS)		Direct injection (LESS)	
	Spring	Summer	Spring	Summer	Spring	Summer
N recovery (%)	25	15	40	30	50	45
Available N (kg/ha)	20	12	33	23	40	36
N value (€/ha)	20	12	33	23	40	36

Conclusion

Maintaining soil fertility through balanced nutrient management creates a solid basis for productive and high yielding grassland, and is also critical for increasing N fertiliser use efficiency and enhancing the environmental sustainability and profitability of grass based dairy farms in Ireland.

An evaluation of the efficacy of nitrogen fertiliser type and rate at different sites on herbage production

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Summary

- There was no effect of fertiliser type on herbage dry matter (DM) production: average herbage production was 13,326 kg DM/ha across all four sites
- There was a 1,284 kg DM/ha difference in herbage production between the 150 and 250 kg nitrogen/ha treatments.

Introduction

Inorganic nitrogen (N) fertiliser is a major contributor to greenhouse gas (GHG) emissions through ammonia (NH_3) and nitrous oxide (N_2O) losses. The EU has set a target to reduce GHG emissions by 55% by 2030 compared to 1990 levels. Ammonia emissions from agriculture account for 98% of Irelands total ammonia emissions. In Ireland calcium ammonium nitrate (CAN) accounts for 84% of the straight N market. This in contrast to other temperate regions where urea accounts for the larger proportion of the N market. This is due to N loss from urea due to ammonia volatilisation. There has been a growing interest in the use of N stabilisers such as urease inhibitors to reduce ammonia emissions. Nitrogen stabilisers are compounds that prolong the period of time the N component of the fertiliser remains in the urea form. Urease inhibitors, e.g., N-(n-butyl) thiophosphoric triamide (NBPT), reduce ammonia volatilisation from urea by inhibiting the enzyme urease which catalyses urea hydrolysis. A study was conducted to investigate the effect of N fertiliser type (CAN, urea, urea + NBPT) and rate (150 and 250 kg N/ha per year) on perennial ryegrass (*Lolium perenne* L.) production under grazing at various locations across the country.

Plot experiment

The experiment was a plot trial carried out at four locations; Teagasc Moorepark, Cork and Clonakilty Agricultural College, Cork in 2019 and 2020, Ballyhaise Agricultural College, Cavan, and Teagasc Athenry, Galway in 2020. The study compared CAN, urea and urea + NBPT at two rates (150 kg N/ha and 250 kg N/ha). At all sites the plots were maintained under the same management and grazed with lactating dairy cows or sheep in Athenry, at the beginning of March, mid-April and then on a three week cycle thereafter. The aim was to mimic ten rounds of grazing during the grazing season, where the CAN-250 treatment was the control. Fertiliser application for the year commenced six weeks prior to first grazing, where the fertiliser was spread by hand. Fertiliser was applied after each grazing event. The next graze date decision was dictated by the pre-grazing herbage mass of the control plot. When the control treatment plot (CAN-250) was at a pre-grazing herbage mass of 1,500 kg DM/ha, all plots at each site were grazed simultaneously with the aim of having a desired post-grazing sward height of 4 cm.

Results 2019 and 2020

There were no significant treatment differences in pre-grazing herbage mass or total herbage production between the three fertiliser types, over the growing season (Table 1). As expected, the 250 kg N/ha fertiliser rates had significantly higher pre-grazing herbage mass (+160 kg DM) and total herbage DM production compared to the 150 kg N/ha treatments, delivering an additional 1.3 t DM/ha for the year (P <0.001). Herbage production increased by 13 kg DM/ha for each additional 1 kg N/ha applied.

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)	1,490	1,470	1,464	1,555	1,394
Grass grown (kg DM/ha)	13,485	13,282	13,213	13,970	12,686

All data are averages of four sites, nine cuts in Clonakilty, Moorepark (2 years), 10 cuts in Ballyhaise, eight cuts in Athenry (1 year); N type data are means of two N rates, N rates data are means of three N types.

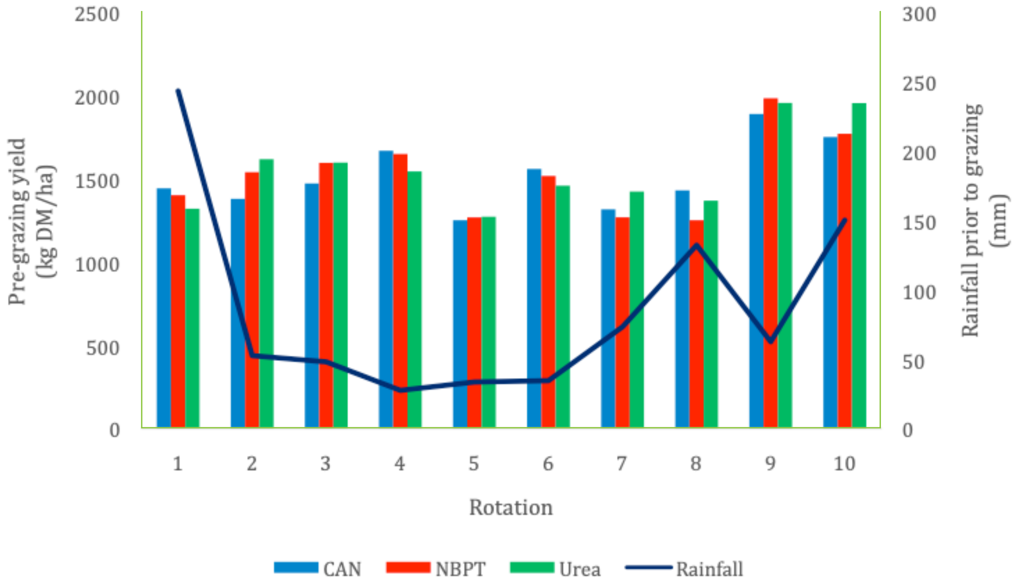

Figure 1. *Average pre-grazing herbage yield rotation for each nitrogen fertiliser type for all sites*

Conclusion

There was no evidence of differences in efficacy between the three fertiliser types, as all supported similar herbage production and pre-grazing yields. The consistency between CAN and both urea formulations was maintained even at the higher application rates.

Improving autumn grazing management - for a longer grazing season

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Summary

- Every day at grass is worth €1.80/cow/day in autumn
- PastureBase Ireland provides useful tools to help autumn grazing management
- Autumn management of grazed grass is the primary factor influencing the supply of grass available in spring.

Introduction

There are two objectives in autumn grazing management of dairy cows. Firstly, the cows must be adequately fed using the cheapest feed available which is grazed grass. Every day at grass is worth about €1.80 per cow per day in this period. However, data from PastureBase Ireland (PBI) indicates most farmers do not reach the autumn grazing targets set out in Table 1. This limits the potential financial gain that can be achieved by having grass in the diet of the grazing animal.

The second objective is to set the farm up for spring grass. Many farmers do not realise that the grazing season begins in the autumn and that autumn management of grazed grass is the primary factor influencing the supply of grass available in spring on any farm. The timing of the last rotation in autumn, the cover of grass grazed and level of grass cover on the farm in late November/early December will have a large influence on the supply of grass available in early spring. The aim of autumn grazing management is maximise the length of the grazing season. A shorter grazing season results in an increase in Greenhouse Gas Emissions by the cow.

The last two grazing rotations need to be planned to have an adequate supply of autumn grass and to provide early spring grass. The average farm cover (AFC) is an excellent guide for setting up the farm for autumn grazing. During the autumn/early winter period, it is important to measure grass supply weekly so that you know how much grass you have and how much you need to have. Using the autumn grass budget tool on PBI is a very useful guide to achieving the farm grazing targets.

Targets for the end of September

- 2.5 cows/ha — 1,000 kg DM/ha
- 2.7 cows/ha — 1,100 kg DM/ha
- 3.0 cows/ha — 1,200 kg DM/ha

Where the stocking rate is more than 3.0 cows/ha, it is not advisable to allow the peak AFC to build higher than 1,200 kg DM/ha. Otherwise cows will be grazing covers of grass consistently in excess of 2,000 kg/ha which will have a negative effect on graze out of paddocks with a lot of dead material remaining in the sward. Paddocks should be cleaned off as well as possible at closing.

Table 1. Autumn grazing management targets

Date	Cover/cow (Kg DM)	Average farm cover (Kg DM/Ha)	Rotation length
Stocking rate of 2.5 LU/HA			
1st August	180	450	20 Days
Mid-August	200	500	25 Days
1st September	300	750	30 Days
Mid-September	400–450	1,000–1,100	35 Days
1st October	400	1,000	40 Days
1st November	60% of the grazing platform should be closed for Spring at this stage		
Fully housed	600		
Stocking rate of 3.0 LU/HA			
1st August	180	540	20 Days
Mid-August	250	750	25 Days
1st September	330	990	30 Days
Mid-September	370	1,100	35 Days
1st October	380	1,150	40 Days
1st November	65% of the grazing platform should be closed for Spring at this stage		
Fully housed	650–700		
Stocking rate of 3.5 LU/HA			
1st August	190–200	650–700	20 Days
Mid-August	220	770	25 Days
1st September	280	980	30 Days
Mid-September	340	1,200	35 Days
1st October	335	1,175	40 Days
1st November	75% of the grazing platform should be closed for Spring at this stage		
Fully housed	700–750		

The last rotation should begin in early October. This date will vary according to grass growth, weather conditions, soil type and to a lesser extent with stocking rate. For farms with a difficult soil type closing up should even begin in late September. Cows can be housed by night and graze by day to extend the length of the grazing season and this should be considered if weather conditions allow. The date when 60% is closed is a very critical date. For most farms this is early November. This is because most of the grass available in early spring has been grown in October/early November. Very little growth occurs over the winter months so most of the grass available in spring is carried over from the previous autumn/early winter. The target is to have about 60% of the farm closed up by November 1st. Higher stocking rates on the milking platform will require over 70% closed.

Building herbage masses in autumn — the effect on sward quality and production

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Summary

- Farm cover needs to be accumulated from August prior to the anticipated reduction in grass growth rate
- Paddocks with high (>2,000 kg DM/ha) covers on the 15th October should be targeted for grazing before the 7th of November
- Paddocks with medium (≈1,500 kg DM/ha) covers on the 15th October can be grazed at any stage in the final rotation
- Paddocks with low (500 kg DM/ha) covers on the 15th October should be defoliated in November and have the potential to be carried forward to spring.

Introduction

Achieving a grazing season length of 300 days has been shown to increase on farm profitability. Extending the grazing season in autumn while maintaining adequate spring herbage at turnout is a key objective of lengthening the grazing season. To facilitate extension in autumn, rotation length is extended, allowing large quantities of herbage to accumulate, prior to the decline of grass growth in August. Current recommendations state that the final rotation should begin in early October and end around the 21st of November. However, accumulating large amounts of herbage during this period has the potential to negatively impact herbage production and sward quality.

New autumn management research at Teagasc Moorepark

In August 2018, a plot trial was established at Teagasc Moorepark and conducted over two years. The objective of the experiment was to examine the effect of accumulating four different Target Herbage Masses (THM; Low — 500 kg DM/ha, Medium — 1,500 kg DM/ha, High — 2,000 kg DM/ha and Very High 3,000 kg DM/ha) by the 15th of October, and defoliating at three different time points in autumn (DD; DD1 — 15th October, DD2 — 7th November, DD3 — 21st November) and its impact on over winter herbage production. All plots were mechanically harvested, which is a useful indicator for animal grazing, to a height of 3.5 cm and received the same application of fertiliser.

Results

In autumn, the low THM continued to increase herbage mass (+12 kg DM/ha/day) over the final rotation and maintained the greatest sward quality (Figure 1). The medium THM maintained sward quality, however herbage mass was reduced when defoliated after November 7th (DD2 -25 kg DM/ha; Figure 1). The high THM reduced sward quality and herbage mass from DD1 to DD3, by -18 kg DM/ha/day (Figure 1). The very high herbage mass had the lowest sward quality and reduce in herbage from DD2 (-11 kg DM/ha; Figure 1). The THM in autumn did not affect available herbage mass in spring, however DD in autumn had a large impact on spring herbage mass; with earlier defoliation (DD1) resulting in the greatest herbage mass the following spring (932 kg DM/ha).

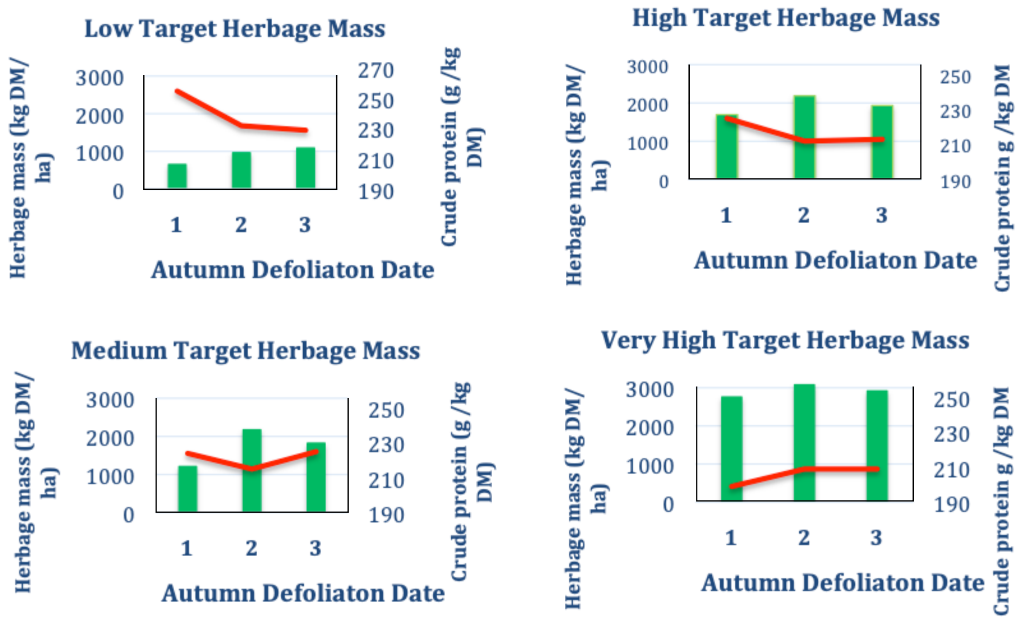

Figure 1. *The effect autumn DD (DD1 — 15th Oct, DD2 — 7th Nov, and DD3 — 21 Nov) on herbage mass (kg DM/ha) and crude protein (g/kg DM) presented for the four target herbage masses (Low, Medium, High and Very High) over two years (18/19 and 19/20)*

Consequences for autumn management

Accumulating herbage on swards to facilitate the extension of the grazing season in autumn needs to begin in August. To increase utilisation particular attention should be paid to defoliation date of swards in autumn. The high and very high THM (> 2,000 kg DM/ ha), need to be prioritised for defoliation early in the final rotation and should be defoliated prior to the 7th of November, as herbage mass and sward quality decline thereafter. Swards with a low THM (500 kg DM/ha) should be targeted for grazing later in the final rotation, as these swards continue to accumulate herbage to the end of November, while maintaining a high sward quality. Swards with a low THM are also optimum to carry over winter if, average farm cover is below farm targets. Implementing a grazing strategy will improve autumn grazing management to optimise the utilisation of herbage masses accumulated for the extension of the grazing season.

Effect of autumn grazing management in late lactation

Sarah Walsh and Michael Egan

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Summary

- Autumn closing date did not impact milk production in late lactation
- Autumn closing date has a significant impact on grass availability in spring
- Increased herbage available in spring is more beneficial than extending the grazing season in autumn.

Introduction

Autumn closing date is one of the most important factors influencing grass supply the following spring. There is little grass growth over winter, and, as such, there is a requirement for careful planning in autumn to ensure adequate grass will be available to meet the herds demand the following spring.

One of the most important factors to consider during the final rotation in autumn is maintaining an adequate closing farm cover of 650–750 Kg DM/ha on December 1st. This will allow for sufficient herbage accumulation during the winter months, which will allow for early turnout in spring. It has been reported that earlier closing of swards, can be more beneficial than extending the grazing season in autumn, as there is increased quantities of grass available in spring. However, Pasturebase Ireland data in recent years, reports that many farms are not achieving sufficient levels of grass on farm in autumn or at closing and therefore will require increased levels of supplementation to support the demand of the herd in early lactation.

Autumn grazing research at Teagasc Moorepark

A study was carried at Teagasc Moorepark over a two-year period, investigating the impact of autumn closing dates. The objectives of the experiment were to evaluate the potential of alternative autumn closing date on late lactation milk production and spring grass availability. Three autumn closing dates were investigated; (1) Early — September 25th to November 9th, (2) Normal — October 10th to November 24th and (3) Late — October 25th to December 9th. Cows were randomly assigned to one of the three autumn closing dates. As each closing date treatment finished grazing, cows were housed and offered grass silage until all groups were housed (December 9th). All cows were offered the same level of concentrate (3 kg DM/cow) for the experimental period. Milk production was recorded daily and milk composition weekly.

Results

There was no impact of autumn closing date on late lactation milk production (Table 1), however, as cows were housed milk protein concentration tended to decline with the inclusion of grass silage in the diet. There was a significant impact of closing date on the amount of silage offered; cows housed earlier were offered 314 Kg DM/cow more silage than cows housed later in autumn. The Late closing date did result in a considerably lower closing farm cover (December 9th) compared to the earlier closing treatments (315, 554 and 945 kg DM/ha for the Late, Normal and Early closing treatments, respectively). These differences in closing farm cover resulted in reduced over winter growth rates, with each day delay in closing from late September reducing spring grass availability by 16.0 kg DM/ha. As a result opening farm cover was greater on the early closed treatments, (1,230, 880 and 615 kg DM/ha, for the Early, Normal and Late, respectively).

Table 1. The effect of autumn closing treatment on milk production during early lactation in the subsequent spring			
	Early	Normal	Late
Milk yield (kg/cow/day)	25.7	25.2	24.5
Fat content %	4.69	5.00	4.88
Protein content %	3.26	3.31	3.28
Milk solids yield (kg/cow/day)	2.11	2.07	2.00
Cumulative silage fed (DM/cow) Autumn & Spring	628	528	419

Conclusion

Autumn grazing management did not have a significant impact on late lactation animal production, however, later closing of swards in autumn resulted in a large reduction in spring grass availability (-16 kg DM/ha/day). The increased level of supplementation in autumn can result in increased feed costs. However, the positive effects of increased spring grass availability can outweigh the higher input costs in the autumn, by reducing feed costs and increasing animal performance. On farms where there is a high demand for spring grass, it is recommended that the final grazing rotation begins by the end of September and continues until early November, this will allow for sufficient herbage accumulation over winter.

Effect of grass allocations and silage supplementation on methane emissions in early lactation

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Summary

- Increasing grass allocations in early lactation improved milk production while reducing methane emission intensity
- Less silage in the early lactation diet improved milk solids production and reduced methane emission intensity.

Introduction

Spring grazing management is crucial with regards to maximising grass utilisation, increasing animal performance and minimising feed costs in Irish dairy herds. Increasing spring grass availability on farm reduces the level of supplementation required and can increase animal performance. Enteric methane is a natural gas emitted by ruminant livestock due to ruminal fermentation of feed. The diet consumed by animals plays a significant role in the level of methane emitted. Understanding methane emissions in early lactation and how the proportions of grazed grass and grass silage in the diet can impact methane production, and animal performance, is essential to maximising performance while at the same time maintaining low methane levels. Factors that drive early lactation methane emissions in dairy cows are not yet fully understood. Understanding these factors can contribute beneficially to the dairy industry by providing dairy farmers the necessary management tools to reduce methane emissions while maintaining production.

New Methane research in early lactation at Teagasc, Moorepark

A research trial at Teagasc Moorepark was established in February 2021 to examine the effect of different grass allocations and silage supplementation on methane emissions in early lactation. As cows calved they were allocated to one of two grazing treatments; High grass allowance (HG) and Low grass allowance (LG) treatment. The HG treatment were offered a high daily herbage allowance (DHA) of 12.4 kg DM/cow, whereas the LG treatment were offered a low DHA of 9.3 kg DM/cow with 3 kg DM/cow of silage supplemented daily over the course of the 12-week experiment. Both treatments were offered the same level of concentrate supplementation. Milk yield was recorded daily with milk composition measured weekly. Methane emissions were recorded daily using the C-Lock greenfeed emissions monitoring unit. The trial was conducted from the 1st February–25th April in early lactation (average DIM 71). Period 1 corresponded to weeks 1–6 of lactation and Period 2 from week 7–12 of the experiment. During Period 1, due to adverse weather, both treatments required housing by night, with the 3 kg differential in silage allocation maintained between both treatments at all times. As grazing conditions improved silage was removed from the HG treatment.

Results

The results are presented from Period 1 and Period 2 of the experimental period in Table 1. In Period 1, there was no significant difference in animal performance or methane emissions between either treatments; however, there was a numerical difference in methane, with the LG treatment, having a lower methane emissions and intensity, compared to the HG treatment. This could be as a result of the adverse weather conditions which reduced grass utilisation and potentially overall DMI on the HG treatment in Period 1. In Period 2, total DM allocation increased similarly on both treatments, the HG treatment had a greater DHA, with no silage supplementation. Milk solids (fat plus protein; MS) yield was greater with the HG treatment compared to the LG treatment (2.4 and 2.2 kg MS/cow/day, respectively). As milk production increased on the HG treatment, methane emissions reduced across Period 2. This resulted in the HG treatment having lower methane emission intensity compared to the LG treatment (123 and 141 g/Kg MS/day, respectively) over Period 2. The differences between treatments in Period 2, is likely as a result of the overall improvement in total feed quality on the HG treatment compared to the LG treatment with the inclusion of grass silage.

Table 1. Impact of grass allocations and silage supplementation on milk production and methane emissions in early lactation (Period 1: weeks 1–6, Period 2: weeks 7–12)

		Period 1		Period 2	
Item	Unit	HG	LG	HG	LG
Daily herbage allowance	kg DM/cow	10.6	8.1	14.6	10.8
Silage intake	kg DM/cow	2.0	4.5	0.0	3.4
Concentrates	kg/cow	3.1	3.1	2.2	2.2
Milk solids	kg/cow	1.9	1.9	2.4	2.2
CH_4 emissions	g/day	342	328	296	311
CH_4 emissions	g/kg milk solids	180	172	123	141

Conclusion

Early lactation animal performance and methane emissions is related to the grass and silage supplementation. When silage was included in the diet of animals in Period 1 (both treatments) and Period 2 (LG treatment), methane emissions were greater than when silage supplementation was removed from the diet (HG Period 2). The HG treatment had a 9% increase in milk production and a 13% reduction in methane emission intensity in Period 2. Increasing grazed grass and removing grass silage in the diet of cows in early lactation is a key factor when improving animal performance and reducing methane emissions.

Quantitatively describing pasture fibre digestion

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Summary

- Large intakes of digestible pasture is imperative for achieving high performance from pasture-fed cows
- A new feed chemistry method can increase our ability to accurately quantify pasture fibre digestion
- This new method combined with mathematical modelling can enhance our understanding of dry matter intake and the nutrients limiting milk production from pasture-based diets.

Introduction

Many factors can affect the digestibility of pasture, such as species, cultivar, morphological proportions, environmental conditions, nitrogen (N) fertilizer application and seasonal variation. Ideally, to assess the effect of these factors on the digestibility of pasture, all combinations would be evaluated using controlled cow experiments (i.e. in vivo methods). However, this is neither practical nor cost effective, and therefore, nutritionists rely on laboratory feed evaluation techniques (i.e. in vitro methods) and mathematical models to estimate the digestibility of a feed. This allows the nutritionist to estimate the energy and protein value of a feed as well as the intake potential. Current in vitro methods to assess the digestibility of perennial ryegrass (*Lolium perenne* L.) depend upon the use of commercial enzymes (e.g. neutral detergent cellulase organic matter digestibility). Such cellulolytic enzymes do not degrade fibre (aNDFom) as efficiently as rumen microbes which might result in biased predictions of in vivo digestibility and the need to continuously re-calibrate correction equations. Additionally, a single fermentation time point is often performed, reducing the method's ability to capture the dynamic and heterogeneous nature of aNDFom. Recently, an in vitro method to generate a comprehensive in vitro description of aNDFom digestion was developed utilizing rumen fluid, a small pore size filter paper and multiple fermentation time points. A mathematical model subsequently utilises the in vitro output and quantitatively describes aNDFom digestion. This is achieved by fractionating the total aNDFom into three 'pools' that behave distinctly different from one another [i.e fast- and slow-degrading pools, and an undigested pool (uNDFom)] while also estimating their respective rates of digestion. Numerous lactating dairy cow experiments have described the influence of these pools and rates on cow variables such as dry matter intake, rumen pool size, rumination, and milk production. Therefore, the objective of this study was to quantitatively describe the aNDFom digestion of pasture, across the grazing season, using this new in vitro method.

Experimental design and results

Fifty-five pasture samples were obtained from experiments conducted at Teagasc. Samples were analyzed to determine the in vitro aNDFom digestibility of pasture at Cornell University, Ithaca, NY, following the procedures described by Raffrenato *et al.* (2018). The effect of season and drought condition on the pool sizes and rate of digestion of PRG are shown in Table 1. The amount of uNDFom was affected by category, whereby spring and summer were lowest, autumn intermediate, and drought highest. In comparison to spring, the drought samples had a lower fast pool. The rate of digestion was highest for spring, intermediate for summer and lowest for drought samples. Additionally, the rate of digestion of autumn samples tended to be lower than that of spring, similar to summer, and higher than drought samples. Overall, the results demonstrate that the aNDFom of well-managed pasture comprises a large potentially digestible pool that degrades rapidly in the rumen, allowing for high milk production performance to be achieved from pasture-only diets.

Table 1. The pool sizes and rate of digestion of fibre for pasture categorized by season or drought condition

	Category			
Item	Spring	Summer	Autumn	Drought
Fast pool, g/kg aNDFom	717	653	695	477
Slow pool, g/kg aNDFom	185	236	150	325
uNDFom, g/kg aNDFom	98	111	155	200
Rate of digestion, %/h	9.8	7.3	7.7	5.0

In a separate investigation, the amount aNDFom digested in the rumen of lactating dairy cows offered a pasture-only diet was determined. Using this measurement to evaluate the capability of the new in vitro method, the predicted estimate was in close agreement with the observed measurement (4.3 vs. 4.2 kg of aNDFom digested in the rumen, respectively). This highlights the strong potential of the new in vitro method to accurately predict rumen aNDFom digestion.

Conclusion

The new in vitro method utilized in this investigation can provide improved knowledge about the digestibility of pasture. This knowledge can aid in the development of nutritional strategies, such as optimization of concentrate supplementation, selection of superior plant genetics, and the development of multi-species pastures, to increase the efficiency and productivity of pasture-based systems. Further work is required to confirm the relationships between the estimated in vitro aNDFom digestibility described here and the in vivo aNDFom digestibility of cows consuming pasture-based diets. Capability to perform this new in vitro feed chemistry method is currently being developed at Teagasc, Moorepark.

Amino acid supply of cows consuming pasture-based diets

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Summary

- The energy supply to pasture-fed cows is often assumed to be the primary limiting factor for milk production
- Extensive rumen degradation of pasture amino acids (AA) occurs resulting in a large dependence on microbial AA
- Further investigation is warranted to assess if AA supply can limit the milk production of pasture-fed cows.

Introduction

Although immature perennial ryegrass (PRG) swards are energy dense [2.75–2.90 Mcal of metabolizable energy per kilogram of dry matter], the ME supply to cows consuming such swards is typically cited as the primary limiting factor for milk production. This assumption is often justified by the observation that the crude protein concentration of PRG exceeds the crude protein requirements of the lactating dairy cow. However, PRG can contain high levels of non-protein nitrogen (N), soluble N, and rumen-degradable N, potentially limiting the ability of PRG to meet the AA requirement of the lactating dairy cow. In addition, lower chemical N application rates and low protein concentrate supplements could potentially reduce the AA intake of pasture-fed cows. Amino acids are the building blocks of protein and are required for several biological processes such as milk protein synthesis. Therefore, the objective of this study was to evaluate the omasal flows of microbial and non-microbial AA in cows consuming fresh PRG not supplemented or supplemented with rolled barley.

Experimental design

Ten rumen cannulated multiparous Holstein cows averaging 49 days in milk and 513 kg of body weight were randomly assigned to one of two treatment sequences in a switchback design. The study consisted of three 29-d experimental periods, where each period contained 21 d for diet adaptation and 8 d of data and sample collection. Treatment diets were (1) PRG only (G) or (2) PRG plus 3.5 kg of DM rolled barley (G+RB). The high starch concentration of the rolled barley was postulated to increase the fermentable carbohydrate supply for ruminal microbes, and thereby increase the microbial AA flow at the omasal canal compared with a PRG-only diet. The swards of PRG were mechanically harvested twice daily (0800 and 1500 h) and were refrigerated at 4°C between feedings to minimize respiration and nutrient loss. The rolled barley was offered to the respective cows at the time of milking (0730 and 1530 h) as two equal meals. The omasal sampling technique and a double-marker system was used to quantify nutrient flow entering the omasal canal along with ^{15}N-ammonium sulphate to label and measure the microbial and non-microbial omasal flow of AA. Non-microbial AA were assumed to comprise of primarily undigested feed AA and a smaller contribution of endogenous AA.

Results

The effects of rolled barley supplementation on microbial and non-microbial AA flow are presented in Table 1. Microbial AA flow increased for all AA when cows were supplemented with rolled barley. Rolled barley supplementation did not affect the non-microbial AA flow. The non-microbial AA portion of the total AA flow accounted for 16.5% and 14.7% in cows fed the G and G+RB diets, respectively. For cows consuming the G diet, this indicated that 83.5% of the PRG AA were degraded in the rumen. Overall, rolled barley supplementation to a PRG diet increased the flow of all AA compared with the G diet, resulting in a 228 g/d increase in total AA flow in cows fed the G+RB diet (1,964 vs. 2,193 g/d for G vs. G+RB, respectively). Although cows fed the G+RB diet did not increase milk yield, an increase in milk protein concentration might have been supported by increased AA supply.

Table 1. Omasal flow of microbial and non-microbial essential amino acids in lactating dairy cows fed fresh perennial ryegrass not supplemented or supplemented with rolled barley

	Microbial AA flow, g/d		Non-microbial AA flow, g/d	
	Treatment[1]		Treatment	
Item	G	G+RB	G	G+RB
Arg	80.0	92.6	5.7	5.4
His	27.6	32.3	5.3	5.2
Ile	97.0	109.6	10.1	9.6
Leu	123.2	141.1	31.9	32.5
Lys	136.3	146.9	20.7	18.8
Met	47.9	55.6	3.9	2.6
Phe	72.4	82.9	20.3	20.6
Thr	88.1	100.1	17.7	16.5
Trp	30.9	35.3	5.8	4.9
Val	90.0	102.6	19.3	18.8
Total EAA	790.1	902.5	140.8	134.9
Total AA	1,639.0	1,872.9	323.6	321.1

[1]*G = 100% (DM basis) perennial ryegrass; G+RB = 79% perennial ryegrass and 21% rolled barley.*

Conclusion

Rolled barley supplementation increased the omasal flow of microbial AA in cows consuming PRG-based diets. Further research is required to elucidate if this increased AA supply can support higher milk yield under such dietary conditions. Notably, extensive ruminal degradation of PRG AA occurred (83.5%) and cows consuming PRG-based diets exhibited a large dependence on microbial AA to support metabolizable AA supply.

Using white clover to reduce nitrogen fertiliser application

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Summary

- Grass-white clover swards with annual average clover content of 20% receiving 150 kg N/ha grew the same quantity of grass as grass-only receiving 250 kg N/ha
- Milk production was increased on grass-white clover swards compared to grass-only swards
- Nitrogen use efficiency was greater in grass-white clover compared to grass-only.

Introduction

White clover is the most commonly sown legume species in temperate grassland. It grows well in association with grass. It is tolerant of grazing and can grow over a wide range of climatic conditions. There are several benefits associated with the use of white clover in grass-based milk production systems including nitrogen (N) fixation resulting in reduced requirement for fertiliser N, herbage production and quality, increased milk production and increased N use efficiency.

Long-term research at Moorepark

Eight years (2013–2020) of research at Moorepark comparing the standard grass-only grazing system receiving 250 kg fertiliser N/ha with a grass-white clover system receiving 150 kg N/ha have been completed. Both systems were stocked at 2.74 cows/ha. The chemical N fertiliser application for each treatment is shown in Table 1. Cows were assigned to their respective system post-calving each spring and remained on that system until housing in late November each year. Measurements undertaken included herbage production, sward clover content, milk yield and milk solids yield and N use efficiency.

Table 1. Nitrogen fertiliser application strategy by rotation on grass-only swards receiving 250 kg N/ha and grass-white clover swards receiving 150 kg N/ha

Date (rotation)	Grass 250	Grass-white clover 150
Mid-late January	28	28
Mid March	28	28
April (2nd rotation)	33	28
Early-May (3rd rotation)	30	9
Late -May (4th rotation)	30	9
June (5th rotation)	17	9
Early-July (6th rotation)	17	9
Late-July (7th rotation)	17	9
August (8th rotation)	17	9
Mid-September	33	12

Results

The main results from the eight years are presented in Table 2. Herbage production was similar on the two sward types despite the 100 kg/ha reduction in N fertiliser used on the grass-clover swards. Approximately 75 kg DM/cow more silage were fed during lactation to the grass-clover cows, mostly in autumn. Neither system was self-sufficient in terms of herbage production due to the high stocking rate. Milk and milk solids yield were greater on the grass-clover system compared to grass-only. Reduced N fertiliser input and increased milk production contributed to increased net profit in the grass-white clover system compared to the grass-only system (Table 2). Average sward clover content was 22%.

N use efficiency

Pasture-based milk production systems are under increasing pressure to increase N use efficiency; that is the efficiency with which N entering the farm (fertiliser, feed and livestock) is converted into N leaving the farm (milk, calves and cull cows). Increasing N use efficiency reduces the N surplus and therefore reduces the N available to be lost to the environment. Incorporating white clover in the swards allowed a reduction in N fertiliser coming on to the farm of 100 kg N/ha and increased milk sold from the farm (+55 kg), resulting in an increase in the overall N use efficiency (Table 2).

Table 2. 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 prod. (t DM/ha)	13.5	13.4	-0.1
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
Net profit (€/ha) (2013–2016)	1,974	2,082	+108

Conclusions

Incorporating white clover in grassland swards results in a reduction in N fertiliser use and an increase in milk production, farm profitability and N use efficiency.

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Milk production from grass-white clover systems receiving 100 and 150 kg N/ha

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Summary

- Grass-clover swards receiving 100 or 150 kg N/ha/year had greater milk and milk solids yield compared to grass only swards receiving 250 kg N/ha/year
- Grass clover swards receiving 100 or 150 kg N/ha/year both had an average annual sward clover content of 19%.

Introduction

There is increased interest in the incorporation of white clover into grass swards due to its ability to fix atmospheric nitrogen (N) making it available for plant growth and therefore offering an alternative source of N to chemical fertiliser. The EU Farm to Fork Strategy is targeting a 20% reduction in chemical fertiliser N use. Additionally, there is a requirement to include white clover in new reseeds on farms in nitrates derogation, and so interest in white clover use at farm level has intensified. White clover systems have reported greater milk production due to superior nutritional quality of pasture and higher intakes. Recent Moorepark research has reported that with the inclusion of white clover in the sward, a 100 kg/ha reduction in chemical N application has no impact on herbage production compared to grass-only swards receiving 250 kg N/ha. Therefore, white clover offers the potential to increase milk production and reduce N fertiliser application in pasture-based milk production systems.

Grazing experiment

A farm systems experiment was undertaken at Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork in 2019 and 2020. The experiment compared milk and herbage production from grass-only swards receiving 250 kg N/ha (GR250) and grass-white clover swards receiving 150 kg N/ha per year (CL150) or 100 kg N/ha per year (CL100). Fertiliser N was applied in the form of protected urea following each grazing (Table 1). There were 18 cows per treatment and each treatment was stocked at 2.74 cows/ha. Target rotation length, pre-grazing herbage mass (1,200–1,500 kg DM/ha in mid-season) and post grazing sward height (4 cm) were the same for all treatments. Concentrate feeding levels were also the same for the three treatments (535 kg/cow/yr).

Results

Average annual pasture production was 13.9, 13.5 and 13.0 t DM/ha on the GR250, CL150 and CL100 treatments, respectively. During lactation, on average across the two years, the GR250 cows were fed 363 kg silage DM/cow, the CL150 cows were fed 387 kg silage DM/cow and the Cl100 cows were fed 408 kg silage DM/cow. Average sward clover content was 19% (Figure 1). Daily and cumulative milk and milk solids yield was greater on the clover treatments compared to GR250 (Table 2).

Table 1. Nitrogen fertiliser application strategy (kg N/ha)			
Rotation/Date	GR250	CL150	CL100
Mid-late January	28	28	28
Mid-March	28	28	20
April (2nd rotation)	33	28	7
May (3rd rotation)	30	9	7
May (4th rotation)	30	9	6
June (5th rotation)	17	9	6
July (6th rotation)	17	9	6
July (7th rotation)	17	9	6
August (8th rotation)	17	9	7
Mid-September	33	12	7

Table 2. Average daily milk yield, fat %, protein % and milk solids yield and cumulative milk and milk solids yield on grass-clover swards receiving 150 or 100 kg N/ha (CL150 and CL100, respectively) and grass-only swards receiving 250 kg N/ha (GR250)			
	GR250	CL150	CL100
Milk yield (kg/cow/day)	20.9	21.2	21.7
Fat content (%)	4.97	5.09	5.03
Protein content (%)	3.71	3.77	3.80
Fat + protein yield (kg/cow/d)	1.77	1.84	1.87
Milk yield (kg/cow)	5,934	5,998	6,076
Milk solid yield (kg/cow)	508	523	534

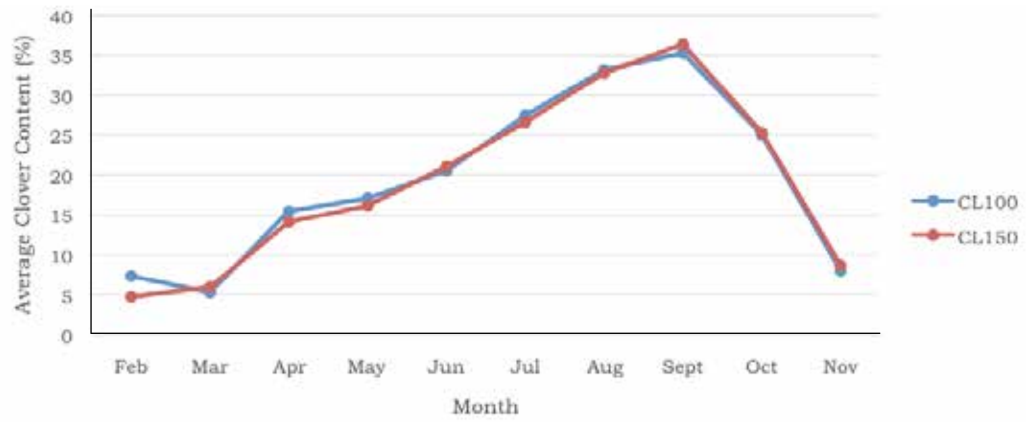

Figure 1. *Average monthly sward white clover content for grass-white clover swards receiving 150 or 100 kg N/ha (CL150 and CL100, respectively)*

Conclusions

The incorporation of white clover into grass swards resulted in greater milk yield and milk solids yield compared to grass-only swards.

Acknowledgements

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Milk production from grass, partial mixed ration and total mixed ration diets

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Summary

- Milk production was greater on a total mixed ration (TMR) and a partial mixed ration(PMR) diet compared to a Grass diet
- Milk yield was more persistent on PMR and TMR compared to Grass likely due to a more consistent feed supply.

Introduction

The removal of the EU milk quota in 2015 gave dairy farmers the opportunity to increase milk production. Where access to additional land is limited, much of the increase in production will occur on the same land area, requiring farmers to either increase herbage production, feed higher levels of supplementary feed or consider alternatives, e.g. partial mixed ration (PMR) or total mixed ration (TMR) feeding systems. However, a unique selling point of Irish milk is that it is produced from pasture. Research shows that approximately 95% of an Irish dairy cow's lactation diet is composed of pasture. Pasture-based systems have the ability to efficiently convert human inedible protein into human edible protein such as meat and milk. With this in mind, a joint project with Moorepark Food Research Centre is examining the milk production, composition and processibility of milk produced from Grass-, PMR- and TMR-based systems. Here we present the milk production results from year one of the project.

Experimental design

An experiment was established at Teagasc, Moorepark, Fermoy, Co. Cork in 2020. The objective of the study was to compare milk production from cows grazing fulltime (Grass) and those on a PMR or a TMR diet. Fifty-four cows were randomly allocated to one of three treatment groups (18 cows/treatment). Cows on Grass grazed fulltime, were allocated 17 kg DM/cow/day and received on average 1.5 kg parlour concentrate daily. Cows on TMR were housed fulltime and offered a diet consisting of 4.5 kg DM grass silage, 9 kg DM maize silage and 10.5 kg concentrate (9 kg in the TMR plus 1.5 kg in the parlour). Cows on PMR grazed by day and were offered the TMR diet at night (2.25 kg DM grass silage, 4.5 kg DM maize silage and 6 kg concentrate (4.5 kg in the TMR plus 1.5 kg in the parlour) (Table 1).

Table 1. TMR, PMR and Grass diets

	Grass	TMR	PMR
14% crude protein parlour ration (kg as fed)	1.5	1.5	1.5
24% conc. blend (kg as fed)	0.0	9.0	4.5
Grass silage (kg DM)	0.0	4.5	2.25
Maize silage (kg DM)	0.0	9.0	4.5
Grazed grass (kg DM)	17.0	0.0	9.0
Total feed offered (kg DM/cow/day)	18.3	22.6	21.0

Results

Daily and cumulative milk and milk solids yield was greater on PMR and TMR compared to Grass (Table 2). Cumulative milk solids yield on PMR was 102 kg/cow greater than Grass and on TMR it was 39 kg/cow greater than PMR and 141 kg greater than Grass. The increased feed available to the TMR and PMR treatments likely increased dry matter intake resulting in the increased milk production. In addition, the feed quality of TMR is less variable than that of grass-based systems throughout lactation. This helps to maintain a higher milk yield later into lactation (Figure 2). This experiment is continuing in 2021. Once all the data is available, an appraisal of the three systems will be completed.

Table 2. The Effect of diet (Grass, TMR, PMR) on animal performance

	Grass	TMR	PMR
Average daily milk yield (kg/cow/day)	21.5	26.9	26.2
Fat content (%)	4.94	4.96	4.78
Protein content (%)	3.67	3.73	3.61
Lactose content (%)	4.67	4.75	4.65
Milk solids yield (kg/cow/d)	1.82	2.29	2.13
Cumulative milk yield (kg/cow)	6,045	8,047	7,709
Cumulative milk solids yield (kg/cow)	515	656	617

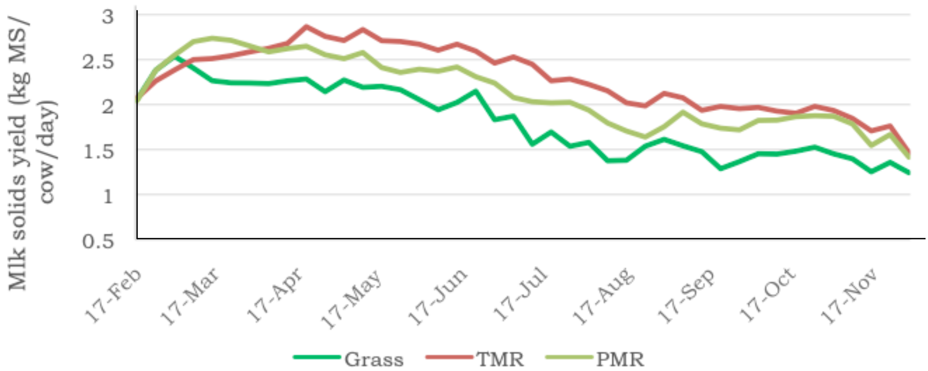

Figure 1. *Average daily milk solids yield (kg MS/cow/day) from cows fed Grass, PMR and TMR.*

Conclusions

Daily milk production and quality was highest for the TMR treatment and lowest for cows on the Grass treatment. Offering a more consistent feed quality diet such as that in the ration offered to the TMR and the PMR at night resulted in higher milk and milk solids yield.

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Evaluating the dry matter production of multispecies swards in intensive dairy grazing regimes

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Summary

- All swards evaluated increased dry matter production in response to increasing levels of nitrogen fertiliser
- Perennial ryegrass, white clover & plantain sward mixture was the most productive sward in the first year of the study
- The level of sown species present in multispecies swards changed significantly over the grazing season.

Introduction

Increasing the level of herbage available to grazing animals is of high importance in Irish dairy production systems, as grazed herbage is the cheapest feed source available. Interest is growing around the use of multispecies swards (MSS), which include legumes and forage herbs, as they have been shown to increase the production of pasture dry matter (DM) with lower nitrogen (N) input. Currently, many swards in Ireland are mixtures of perennial ryegrass (PRG) and white clover (WC) which have been shown to produce similar levels of herbage DM under reduced N application levels compared to PRG monocultures in grazing scenarios, while increasing animal performance. Decreasing the level of chemical N fertiliser used to promote pasture growth is an issue of growing concern among Irish dairy farmers as its use is coming under more regulation in recent years. In contrast to the grass clover research undertaken, which has many years work, the MSS research work is in its infancy and there is very little research completed under intensive grazing. The deficit in knowledge exists regarding persistency of the swards and the actual contribution of the individual species to overall performance. Recently, Teagasc Moorepark has initiated a number of MSS studies under grazing; the current work was set out to assess the DM production potential of MSS within a dairy grazing scenario with varied levels of N fertiliser application.

Project work

Pasture swards of varying species complexity were sown in grazing plots in June 2019 at Teagasc Moorepark. The following sward species treatments were imposed: PRG only, PRG & WC, PRG & Red Clover (RC), PRG & WC & RC, PRG & Chicory (CH), PRG & Plantain (PL), PRG & PL & CH, PRG & WC & PL, PRG & WC & PL & CH and PRG & WC & RC & PL & CH; three different N application rates of 100, 150 & 200 kg N/ha/year were applied. Perennial Ryegrass receiving 200 kg N/ha/year is the control treatment within the study.

Herbage dry matter yield was determined prior to grazing by dairy cows on eight occasions from February to October 2020. Plots were grazed when pre-grazing herbage mass reached 1,200–1,400 kg DM/ha and cows grazed all plots simultaneously until the average post-grazing sward height across the study area was 4 cm. Sward composition was measured prior to grazing at four time points (spring, early and late summer and autumn) during the year.

Results

The following results are from the first year of the study only and should be treated with a level of caution until additional years are included in the database. Increasing N application rate increased the herbage DM production in all sward treatments (Table 1); on average, swards receiving 200 kg N/ha/year produced 1,286 and 594 kg DM/ha more than those receiving 100 and 150 kg N/ha/year, respectively.

In the first year of the study, increased sward complexity was associated with increased DM production across all rates of N application. The most productive swards included a combination of grass, legume and herb species; the PRG & WC & PL was the most productive sward while the PRG monoculture sward was the least productive. Some sward combinations were negligible in their DM production response (i.e. the PRG & RC combination). Multispecies sward composition changed seasonally over the year; the legume and CH contents increased by 26% and 2%, respectively, while PL decreased by 29% on average across the year between spring and autumn grazing's.

Table 1. Annual (2020) dry matter yield (kg DM/ha) of multispecies swards across three nitrogen application rates (kg N/ha)

Species Mixture	100 N	150 N	200 N
PRG	6,976	7,899	8,304
PRG & WC	8,171	8,143	9,273
PRG & RC	7,226	7,626	8,605
PRG & WC & RC	8,230	8,480	9,192
PRG & CH	7,302	8,141	9,158
PRG & PL	8,423	9,258	9,008
PRG & CH & PL	8,374	8,890	9,270
PRG & WC & PL	8,685	10,496	10,282
PRG & WC & PL & CH	8,710	9,448	10,072
PRG & WC & RC & PL & CH	8,932	9,572	10,728

Conclusion

Increasing N fertilisation appears to increase DM production under grazing across all sward types assessed in the study. In the first full production year post sowing MSS containing both legumes and herbs produced higher levels of DM than the PRG sward at all levels of N fertilisation. Results presented are from year one of a three year trial; seasonal sward species content changes are evident in year one although sward persistency will only be fully assessed after multiple grazing seasons. Performance of MSS in a dairy farm system is currently being investigated as part of a full systems study at Curtins research farm.

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Using image analysis and machine learning to estimate sward clover content

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Summary

- Grass-white clover swards can fix atmospheric nitrogen (N) making it available for plant growth and as a result reduce the requirement for N fertiliser, and it can result in increased herbage and milk production
- Quantifying sward white clover content is laborious and time consuming
- Machine learning methods to estimate sward composition (grass and clover content) from images has huge potential.

Introduction

Many grassland measurements including sward clover content, farm cover and pre-grazing herbage mass are laborious and time consuming. Techniques like image (photo) analysis using machine learning can be used to rapidly appraise sward composition (e.g. grass and clover content) providing an automated and non-destructive approach to sward clover content and herbage mass estimation that will help farmers to less laboriously optimise grassland management decisions. An ongoing trial at Teagasc, Moorepark aims to create dataset of images and associated sward grass, white clover and weed proportions to train a machine learning model to estimate sward white clover content.

Figure 1. *Camera used to capture images*

Creation of the image dataset

An image dataset was created using grass-only and grass-white clover plots at Teagasc Moorepark during July 2020. In each plot, one image (photo) in each of five quadrates (0.5 × 0.5 m) was captured. Post-imaging the herbage within each quadrat was harvested at 2–4 cm above ground level using a Gardena hand shears. The herbage was weighed and separated into its components (grass, weeds and/or white clover). Each of the components were dried and subsequently weighed to provide a DM yield and the proportionate composition of grass, clover and weeds.

Training a machine learning model

First a model pre-trained on images from Danish farms was used to analyse the images. Then the model was then re-trained on the Irish image dataset from Moorepark. The performance of both models was compared.

Figure 2. *Sample of collected images in the dataset*

Results and discussion

There was a large error (15.2%) in the accuracy of the prediction of sward grass and white clover content when the Danish model was used. This was because swards used in the Danish dataset had a different composition to our dataset (i.e. they had more herbs, weeds and clovers and less grass). When the model was re-trained on the Irish dataset, the performance was greatly improved. The model predicted sward grass, clover and weed proportions with 95.3% accuracy.

Conclusion

These results indicate that machine learning methods can be used to predict sward composition from images. This could potentially offer an alternative to the current time consuming, expensive, destructive and laborious approaches. In the next stage of the project the potential of image analyses and machine learning to measure farm cover will be investigated.

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Feed-food competition in Ireland's pasture based systems

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Summary

- Feed-food competition occurs when land is used to feed ruminants which could be used to produce human edible food
- Some feed-food competition occurs in Ireland's ruminant sector; but overall the sector produces more edible protein than if there was no ruminant sector
- Activities including increasing pasture yield or removing ruminants from land suitable for arable production can significantly decrease the level of feed-food competition occurring.

Introduction

Feed-food competition occurs when land that is suitable for providing food for human consumption is instead used to provide feed, fodder, and forage for ruminant production. This can be problematic, as inefficient ruminant production can mean less food has been produced from the finite land-area than if the land was used to grow crops for human consumption. As a consequence, a greater area of land is needed to provide the same amount of food, with the negative environmental consequences of ruminant production occurring. Hence, calculating the degree of feed-food competition in a ruminant sector could be used to outline which agriculture sector should be prioritised in the development of our agriculture industry.

To demonstrate the occurrence of feed-food competition in Ireland's ruminant sector, we quantified the Land Use Ratio (LUR). This quantifies the total amount of edible protein from a ruminant system in the form of meat and milk, and compares it with the potential edible protein from the alternative crop rotation grown on the land used for that ruminant system. This includes the land used to grow feed both nationally and internationally, and land used for pasture that is suitable for arable crops. This demonstrates the potential alternative level of food production from the land used by the ruminant system.

In this study, we evaluated the LUR of four ruminant sectors, evaluating the feed-food competition occurring in edible protein production. We conducted LUR of each sector, accounting for their location in Ireland, and how the location affects the potential alternative crop yield. The sectors studied include the pasture-based dairy sector, the dairy-beef fattening sector, the pasture-based suckler beef sector and the lowland-pasture based sheep sector. Data from Teagasc's National Farm Survey and the CSO's Census of Agriculture were used to outline the feed structures of the sectors studied.

Results

The LUR values for the ruminant sectors are shown in Table 1. The results demonstrate the potential alternative crop sourced edible protein compared to the 1 kg of current ruminant sourced edible protein produced. A value of one implies equal value in the quantity of edible protein produced between the sector and the alternative crop. A value below one indicates that the ruminant sector studied is proportionally more efficient than the alternative crop.

Table 1. The Land Use Ratio (LUR) for four pasture-based ruminant production systems in Ireland and a national ratio of the ruminant sector	
Ruminant System	LUR of the Sector
Dairy	0.47
Dairy-beef	1.08
Suckler beef	1.25
Sheep	0.95
Total ruminants	0.69

Table 1 demonstrates that for every 1 kg of human edible protein produced by the dairy sector, only 0.47 kg of crop sourced human edible protein could be produced from the land-used. Further we can see that as a whole, the ruminant sector produces more edible protein than the potential alternative crop. However, the sectors vary between being efficient edible meat protein producers like sheep meat and inefficient like suckler beef. Despite both providing beef, the dairy-beef sector is more feed-food competition efficient than the suckler beef sectors. This is because the suckler beef system includes a dam that is not producing any edible protein and the land-area used to feed her has to be considered part of the footprint of the slaughtered suckler beef animal.

Reducing feed-food competition can ensure that a greater level of food production can occur while maintaining the same level of ruminant production. Such activities include removing the use of purchased feed by substituting it with pasture and increasing pasture yields to decrease the area of land needed for ruminant production. This increased efficiency can ensure that ruminant production becomes an even greater positive food producer, which can be considered by policymakers when deciding where best to maintain current ruminant sectors.

Conclusion

Feed-food competition is present in Ireland's ruminant sectors. By minimising feed-food competition while maintaining ruminant numbers, there can be a net increase in the level of food produced. This can be achieved by efficient pasture management resulting in minimising or removing human edible crops from feed systems.

Completing a simple winter feed budget for a dairy herd

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Summary

- Winter feed budgeting is a simple but important management task. Once animal numbers and feed stocks have been measured, calculations can be done manually or by using the PastureBase budgeting tool
- A small feed deficit in early winter can become a major issue the following spring. Act early if needed to secure extra feed or reduce demand
- Build a reserve of good quality silage in addition to standard winter feed requirements. Approximately two bales per cow is recommended.

Introduction

Silage accounts for at least 25% of the annual feed budget for the average spring calving dairy herd. This will be greater on farms operating high grazing stocking rates or on heavy soils. Weather shocks such as drought or poor spring growth can create significant short-term problems. These issues often tend to affect many farms simultaneously, increasing risk of feed shortages and price rises. It is important therefore that farms complete a winter feed budget and take steps to ensure an adequate supply of winter feed.

Herd feed demand: How much silage is needed?

To estimate total silage demand, a simple approach is to estimate the typical full days on silage for the milking herd and multiply by an average intake of 12 kg dry matter (DM). In-calf heifers and cull cows for finishing will eat 1–2 kg DM less per day but for simplicity they can be included in the cow numbers. Allow 0.5 days of silage feeding for every day where cows are usually housed by night in autumn or spring. Weanling heifers will consume approximately 5 kg DM silage per day depending on quality. The figures for each stock class can be summed to give an estimate of total silage required (Table 1).

Table 1. Estimating silage requirement for a 100 cow dairy

Stock	Days	Intake Kg DM	No. animals	Tonnes silage DM	Fresh silage @ 22% DM
Cows	140	12	100	168	763
Weanlings	120	5	25	15	68
Total				183	831
Of which dry cow feed				77	350

It is also important to consider the silage quality required by each class of stock. The target dry matter digestibility (DMD) for dry cows is 68–70%, suitable for moderate body condition gain over the dry period. All remaining silage will be fed to milking or growing stock and therefore should be of good quality (73–78% DMD approximately depending on the system). Assuming that herd average dry period length is approximately 70 days, dry cow silage requirement will be 0.77 tonnes of DM in total (11 kg DM intake per day), or 3.5 tonnes per cow fresh weight at silage dry matter of 24%. Estimate the total dry cow silage requirement and subtract this from the total to calculate the tonnage of good quality silage needed. In the example outlined in Table 1, a 100-cow herd requires 350 tonnes as fed of dry cow silage, meaning 481 tonnes of good quality silage is needed; that equates to 58% of total winter feed. It is also advised that farms build a feed reserve of approximately 400 kg DM high quality silage per cow to mitigate risk of weather shocks.

Measuring winter feed supplies

Pits should be measured (length x breadth x average height in metres) to calculate volume of silage. The estimated feed in the pit will vary due to dry matter so it is important to also have silage sampled and analysed in the lab. Drier silage will weigh have less fresh weight per cubic metre but will actually contain more feed due to reduced water content (Table 2). Drier silage is also usually better value when purchasing feed as a result.

Table 2. Estimated fresh and dry matter of forage per cubic metre of settled silage pits

Silage dry matter	Fresh tonnes per m^3	Dry matter tonnes per m^3
22	0.74	0.163
25	0.70	0.174
28	0.66	0.185

Multiplying total pit volume by the correct factor will give a good estimate of feed in the pit. For example a pit measuring 25 m long, 14 m wide, and 3 m height at 25% dry matter will have: 25*14*3 = 1,050 m^3 * 0.70 = 735 tonnes fresh silage or 1,050 m^3 * 0.174 = 183 tonnes DM. For baled silage, recent appraisals of bale weights would indicate that silage bales are 800–900 kg fresh or 200–260 kg DM with an average of 220 kg DM. A 220 kg DM bale is equivalent to one tonne of pit silage at 22% DM.

Budgeting winter feed and mitigation of shortages

Winter budgets can be completed manually or using PastureBase. In general, deficits of <10% at the onset of winter are manageable but the situation should be kept under review. An initial feed deficit of 10–15% may seem small but it can become a major problem by the end of winter depending on spring grazing conditions and local forage availability. It is thus recommended to take early steps to mitigate deficits of this scale. Teagasc advisers are available to assist with completing budgets and to assess options for winter feed.

Assessing silage quality for the dairy herd

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Summary

- Grass silage should be of moderate quality (68–70 dry matter digestibility (DMD)) and low macro mineral content for dry cows. This helps to prevent metabolic issues around calving
- Growing heifers and milking cows require higher quality (73+ DMD) silage to ensure nutrient needs are met. At least 50% of silage on dairy farms should be high quality
- Cutting date, sward quality and early season management are key factors affecting silage quality.

Introduction

The aim across all grass silage types is to have a clean, well preserved silage, with good intake potential and aerobic stability. The fermentation characteristics of the silage will determine these parameters. Feed energy value of grass silage is largely dictated by its DMD. This parameter measures the proportion of the crop that can be digested and utilised for production by the animal; DMD is also positively associated with the intake potential and protein value of the silage.

Figure 1. *Grass growth stage at cutting for dry cow and milking cow silage*

Achieving silage quality targets for dairy stock

Optimal grass silage quality very much depends on the class of stock to be fed in winter. For dairy herds, there is a requirement of approximately 0.75 tonnes dry matter (DM) per cow of 68–70 DMD silage for dry cow feeding. This will return adequate but not excessive body condition gain in the dry period. Ideally, this portion of the feed stock will also have a potassium (K) content of less than 2.2% of DM. Lower silage K can be achieved by limiting spring applications to 90 kg per ha and applying K for soil build-up in autumn, and by increasing the proportion of stem to leaf in the crop at harvesting. These factors will reduce risk of metabolic disease such as milk fever. For growing heifers and milking cows, the requirement is for silage of higher digestibility (>73% DMD), and greater intake potential. To achieve this in first cut crops, harvest must occur in mid-May before the emergence of seed heading the standing crop. Higher K content in milking cow or growing heifer silage is not problematic. Tight grazing in early spring is necessary for silage quality where there is dead material in the base of the sward. The same effect can be achieved on less accessible areas of the farm by late autumn grazing. There is ample evidence to show that delaying first cuts beyond optimal cutting date to 'bulk up' crops is counterproductive as it reduces both annual DM yield and quality. On the other hand, reseeded swards and good soil fertility management facilitate simultaneous improvement of yield and quality in grass silage crops.

Table 1. Key parameters for assessing quality of grass silage

Measure	Target	Comment
Dry Matter %	25–30	Wilting for 24 hours helps achieve this DM target
DMD %	68–70 (dry cows) 73–78 (milking cows	Targets correspond to late-May cutting for dry cow silage and mid-May for milking cows
UFL (Energy) per kg	0.72 dry cows 0.85 milking cows	Directly affected by DMD, higher UFL means more weight energy for weight gain and milk
Crude protein % (CP)	12–16	12% adequate for dry cows. Lower DMD or N application reduce CP. Applying Sulphur can improve silage CP
PDIE g/kg (protein)	75–80	Determined by UFL and CP levels in silage
Intake Value g/kg LW0.75	90–115	Higher values indicate silage with better intake potential
pH	3.8–4.2 4.5 for drier crops	Silage at <28% DM require pH of 3.8–4.2, while wilted crops can be well-preserved at pH 4.5.
Ammonia	Less than 8% of N	Ammonia results from protein breakdown in silage. High values reduce intakes.
Lactic Acid	8–10% of DM	Higher values indicate a palatable silage with good aerobic stability
Ash	<8% of DM	High ash content indicates soil contamination. Mineral profile testing is advised in such cases

SIGNPOST FARM PROGRAMME

The role of Once-a-day milking on Irish dairy farms

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Summary

- Compared to twice-a-day milking, once-a-day milking reduces annual milk yield by 28% and milk solids yield by 21%
- Early lactation once-a-day milking for up to six weeks reduces immediate milk production by up to 24% and milk solids yield by 20%
- Late lactation once-a-day milking for up to seven weeks at the end of lactation had no affect on total lactation milk or milk solids yield
- To achieve good performance with once-a-day milking excellent grassland and milking management is required.

Introduction

Be it due to labour issues, spring workload or lifestyle choice various forms of once-a-day (OAD) milking are now in operation on many Irish dairy farms. While full-time OAD may not be suitable on all farms there are many situations that short-term OAD can play a role. The success of OAD milking is dependent on excellent grassland management and milking management. Over the past number of years a programme of research has been undertaken at Teagasc Moorepark investigating the effects of full-time and short-term OAD compared to twice-a-day (TAD) milking.

Early lactation OAD milking

Growing herd sizes and more compact calving patterns, coupled with difficulty sourcing short-term labour has led to increased workload in spring. Once-a-day milking in early lactation can be a solution to reduce workload during calving. Teagasc Moorepark investigated the effect of short-term OAD for 2, 4, 6 or 8 weeks, from the start of lactation, on immediate and total lactation production. Results showed:

- Initial 22–24% reduction in milk yield and 20–23% reduction in milk solids yield (MSY)
- Immediate increase in production when cows return to TAD
- No difference in total lactation MSY with up to 6 weeks OAD milking
- Six and eight weeks early lactation OAD reduces yield compared to TAD
- No difference in SCC across full lactation
- Milking time reduced by 30% during the OAD period

Table 1. Milk solids yield (kg) production after 4, 6 and 8 weeks of once-a-day milking in early lactation compared to twice-a-day milking

	TAD	4 wks OAD	6 wks OAD	8 wks OAD
4 weeks (kg)	55	44		
6 weeks (kg)	87		72	
8 weeks (kg)	117			91
Total lactation (kg)	415	405	398	387

Late lactation OAD milking

An experiment was undertaken at Teagasc, Moorepark in autumn 2020 where cows, that had been milked TAD for the entire lactation, were milked OAD from either 11 or 7 weeks before they were dried off. Results showed that milking cows OAD in autumn significantly increased SCC compared to TAD milking. This suggests the SCC of the herd needs to be low before switching to OAD milking; good milking practices are also required to keep SCC as low as possible in late lactation. Milk solids yield was reduced by 25% during the period of OAD milking. In the 11 week treatment, there was a 4% reduction in milk solids, (Table 2).

Table 2. The effect of milking OAD for 7 (OAD7) and 11 (OAD11) weeks before dry-off compared to milking TAD for the entire lactation on milk (MY) and milk solids yield (MSY)

	OAD7	OAD11	TAD
Total lactation MY (kg)	5,868	5,634	5,846
Total lactation MSY (kg)	504	491	505

Fulltime OAD milking

Over the past two years a fulltime OAD herd has been created at Teagasc Moorepark. Research from New Zealand suggests that the largest decrease in production occurs in the first year of OAD milking. Results from the Teagasc Moorepark study show that medium production performance can be achieved with OAD milking and low concentrate input (Table 3). Milking OAD increased bodyweight (+ 70 kg) and body condition score (+ 0.5 BCS). While there was no difference in SCC in 2019, it was higher in 2020 when compared to the TAD herd.

Fertility performance in both herds was exceptional across the two years, but the empty rate was lower in the OAD herd. Overall, there were no negative impacts of OAD milking on milk processability in late lactation, OAD possibly having improved cheese-making characteristics.

Table 3. Comparison of fulltime OAD compared to TAD milking on milk solids yield in 2019 and 2020

	TAD	OAD	% change	Concentrate Input
2019 (kg)	511	396	-23	450
2020 (kg)	505	409	-19	330

Conclusion

While fulltime OAD may not be suitable for all herds short-term OAD milking has a role on all farms and especially in early spring.

Shinagh Dairy Farm sustainability challenge

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Summary

- Shinagh dairy farm began milk production in 2011 and has demonstrated over a 10 year period that a well-managed grass-based dairy farm can adequately remunerate all of the resources employed including land, labour and capital
- In the past Shinagh Dairy Farm has focused on managing the economic risks and challenges associated with dairy farm conversion, start-up, expansion and volatility; the current focus of the farm is on the challenges that the industry faces in terms of environmental and social sustainability.

Introduction

Shinagh Dairy Farm near Bandon in West Cork is a Teagasc-led project demonstrating efficient spring milk production from grass on a farm that was converted from beef in 2010. The first cows were milked in January 2011. The 78 ha farm is owned by the four west Cork co-ops and was leased at €450/ha for 15 years by Shinagh Dairy Farm Ltd. A further 18 ha were leased in 2020, of which 6 ha are adjacent to the milking platform. The farm currently has 250 milking cows at an overall stocking rate of 2.6 cows/ha. The labour on the farm is provided by two full time people: the farm manager, Kevin Ahern, and his second in command, Alan Murphy, with total labour costs of approximately €95,000/year.

Table 1. Physical performance of Shinagh dairy farm from 2011–2020

	2011	Average 2012–2018	2019	2020
No. cows milked	195	222	226	239
Stocking rate (LU/ha)	3.12	2.98	3.04	2.57
Grass grown (t DM/ha)	12.25	13.66	15.11	13.23
Grass utilised (t DM/ha)	10	11.2	12.6	10.9
Six-week calving rate (%)	58	85	93	91
Empty rate (%)	13	7.6	8.2	9.2
Mean calving date	28-Feb	20-Feb	20-Feb	19-Feb
Milk solids production (kg/ha)	817	1,157	1,272	1,113

Farm performance

Over the last 10 years, the focus 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 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 of less than 23 c/l. Because the farm has been operated to a very high level of efficiency with high genetic merit cows grazing over a long grazing season the farm environmental emissions have been significantly below the industry average. However, the farm will aim to further reduce emissions by adopting the key technologies within the Teagasc marginal abatement curve to demonstrate that an environmentally efficient farm can operate at a very high level of production efficiency and profitability.

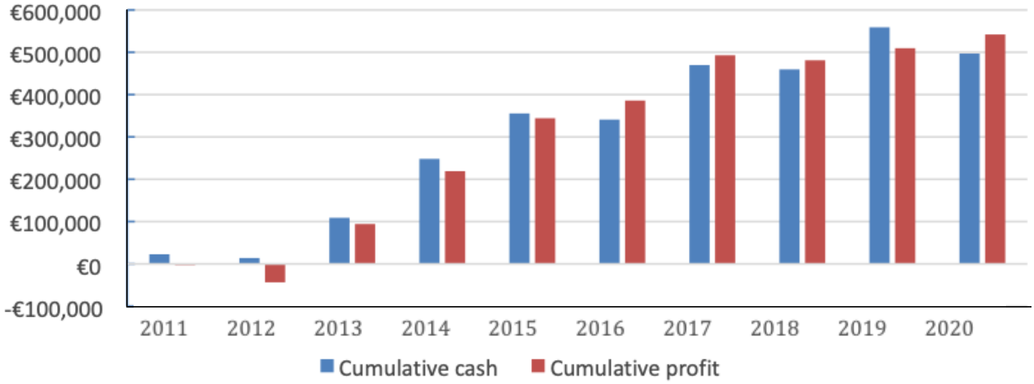

Figure 1. *Cumulative cash flow and profitability from Shinagh dairy farm from 2011–2020*

Shinagh environmental strategies

- Chemical nitrogen (protected urea only) use is being reduced to 150 kg/ha as white clover is being incorporated into the swards. Paddocks that are being reseeded are getting 5 kg clover seed/ha. All other paddocks are being oversown with clover at a similar rate
- High EBI Jersey×Friesian crossbred cows are being selected. Milk recording is used to identify inefficient animals. The target is that cows produce in excess of 95% of their bodyweight in annual milk solids production to increase N use efficiency
- All slurry is spread using low emission slurry spreading (LESS) equipment
- The milking cow's diet is balanced to 16% protein in the total diet. The protein content of the supplementary ration is 12% while the cows are on grass and when the milking cows are on silage the protein of the ration is 16%
- Currently 7.2% of the farm area is in biodiverse habitats. A plan is in place to increase this to 10% with minimal impact on the productive grazing area. Examples include maintaining and managing existing habitats such as hedgerows and field margins, and the inclusion of watercourse buffer strips
- The farm's main energy uses are milk cooling (31%), milking (20%) and water heating (23%). A plate cooler and variable speed drives on the vacuum and milk pumps have been installed which will reduce the electricity demand. The installation of solar panels is being investigated to complement the existing wind turbine power generation.

Extended grazing and stocking rate impacts within the Border Midlands Western region

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Summary

- Large quantities of high quality pasture can be grown and efficiently utilised within the Border Midlands Western region when appropriate grazing management practices are adopted
- Extended grazing supports high levels of milk production and reduced requirements for concentrate and silage supplementation when compared to the average grazing season length in this region.

Introduction

The Border, Midlands and Western Region (BMW) of Ireland consist of thirteen counties including the six border counties with Northern Ireland. Despite accounting for 44% of the total national land area, it presently accounts for only 20% of national milk production. 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 region. The objective of the current study was to investigate the effect of two grazing season lengths (GS; average (AGS; 205 days) and extended (EGS; 270 days)) and two whole farm stocking rates (SR; medium (MSR; 2.5 cows/ha) and high (HSR; 2.9 cows/ha)) over four years (2017–2020). The differences in grazing season length were achieved by turning the EGS treatments out to grazing from mid-February and keeping them at grazing until early November whereas the AGS were turned out in Mid-March and rehoused in early October each year. This is the first study to evaluate the combined impacts of extended grazing in both early spring and late autumn on a wetland soil type where impeded drainage makes grazing conditions considerably more challenging.

Results

All groups on the study had a similar mean calving date (March 11th). Total average annual herbage production over the four year period was 14,133 kg DM/ha and was unaffected by GS length or SR. Despite the overall similarity in DM production, grazed pasture production was greater in EGS (10,675 kg DM/ha) compared to AGS (9,917 kg DM/ha) whereas conserved silage DM production was greater for AGS (4,299 kg DM/ha) compared to EGS (3,583 kg DM/ha). Similarly, HSR increased grazed pasture production (10,673 kg DM/ha) and reduced conserved silage DM production (3,578 kg DM/ha) compared to MSR (9,919 and 4,304 kg DM/ha, respectively). Grazing season length had no significant impact on daily herbage allowance (17.6 kg DM/cow) and daily herbage removed (15.5 kg DM/cow) over the study and there were no significant differences in sward chemical composition. Concentrate and silage supplementation varied significantly between GS and SR treatments. Total concentrate supplementation was greater for AGS (702 kg DM/cow and 1,858 kg DM/ha) compared to EGS (598 kg DM/cow and 1,437 kg DM/ha, respectively). Similarly, when lactation and non-lactation pasture silage supplementation is combined, total pasture silage requirements were also greater for AGS (1,859 kg DM per cow and 5,025 kg DM/ha) compared with EGS (1,436 kg DM/cow and 3,873 kg DM/ha, respectively). Stocking rate had no significant effect on supplementary feed characteristics per cow, however, both total concentrate (+865 kg DM/ha; +116%) and pasture silage (+2,295 kg DM/ha; +125%) requirements per ha were greater for HSR compared to MSR (747 and 1,839 kg DM/ha, respectively).

The effect of GS and SR on milk production during the study is shown in Table 1. Based on similar mean calving dates, average lactation length was similar for all GS and SR groups (278 days). Neither GS nor SR had a significant impact on cumulative lactation milk and milk solids (MS) production per cow (5,039 and 440 kg, respectively). There were also no significant differences in the seasonal distribution of milk and MS production per cow between GS and SR treatments. While GS had no significant impact on milk and MS production per ha (13,755 and 1,188 kg, respectively), HSR produced more milk and MS per ha (14,681 and 1,283 kg, respectively) compared to MSR (12,828 and 1,093 kg, respectively). In addition, the seasonal profile of milk and MS production per ha varied significantly between SR with the majority of the additional milk (+66%) produced during mid-lactation.

Table 1. Effect of grazing season (GS) length and stocking rate (SR) on supplementary feed requirements and milk production

Grazing season	Average		Extended	
Stocking rate	2.5	2.9	2.5	2.9
Total supplementation				
Concentrate (kg DM/cow)	688	717	596	600
(kg DM/ha)	1,729	2,068	1,494	1,734
Pasture silage (kg DM/cow)	1,836	1,882	1,470	1,403
(kg DM/ha)	4,590	5,459	3,677	4,069
Milk production				
Milk (kg/cow)	5,022	5,058	5,018	5,057
Fat plus protein (kg/cow)	430	440	445	445
Milk (kg/ha)	12,594	14,693	13,062	14,669
Fat plus protein (kg/ha)	1,076	1,275	1,110	1,290

Conclusion

The current study has demonstrated that large quantities of high quality pasture can be grown and efficiently utilised on such soil types when appropriate grazing management practices are adopted. The results indicate that early commencement of grazing in spring supports similar levels of pasture production and quality and consequently, similar high levels of milk productivity with a significant reduction in the requirements for concentrate and silage supplementation when compared to average grazing season length treatments.

Johnstown Castle winter milk herd update

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Summary

- High EBI cows delivered excellent fertility and high milk solids across spring and winter calving systems alike
- Increased milk sales from autumn calving systems may be offset by additional costs
- A modest shift to autumn calving is unlikely to appreciably reduce summer milk volumes.

Introduction

The Johnstown Castle herd comprises 153 Holstein milking cows plus followers run on 54 grazing ha plus an additional 18 ha support block. Annual (five year mean) pasture growth is 14.9 t DM/ha and grazing is feasible from early February until mid-November. The herd calves approximately 65% in the autumn and 35% in spring. Autumn calving starts on September 12th and is complete by December 1st with 80% calved by October 25th (median calving date 5th Oct). A similar compact spring block is employed from early February until late April (median calving 23rd Feb). Herd average calving interval is 371 days with 0% of cows recycled between breeding seasons. Annual culling rate (voluntary and involuntary) was 22% in 2020. Herd EBI in 2021 stood at €180 (€242 in young-stock) which is balanced for milk and fertility sub-indices Table 1). Herd sire teams comprised primarily of high EBI genomic bulls, with some proven sires included also. Herd average yield in 2020 was 565 kg milk solids sold per cow.

Table 1. EBI profile for Johnstown Castle herd, May 2021

Animal Group	No. of Cows	Milk Kg Fat % Prot %	Surv % CI Days	Milk % Cont	Fertility % Cont	Calv % Cont	Beef % Cont	Maint % Cont	Mgmt % Cont	Health % Cont	EBI €
Cows with EBI	153	129		€67	€75	€34	-€7	€6	€3	€3	
Missing EBI*	0	10.8 0.10	2.2	34.2%	38.4%	17.7%	-3.7%	3.2%	1.3%	1.4%	€180
Total Cows	153	9.5 0.09	-3.8								

Genetic merit for milk production was identical for spring and winter groups; differences in production are therefore explained by feeding system and calving pattern. Mean annual concentrate input in 2020 was 783 kg for the spring calving groups and 1,491 kg for the autumn component. Herd annual milk fat content was 4.48% and protein 3.68% with no difference between the calving pattern groups. These profiles demonstrate that high EBI cows have good capacity for milk production within varying systems and are not simply a 'low input cow' as they are sometimes characterised to be. It also shows that production of high solids milk is largely independent of seasonality profile.

Comparison of calving pattern effects on milk seasonality profiles

A 3-year study comparing the effects of three calving pattern options (block spring, block autumn, and split 50:50) was concluded in 2020. Consistent stocking rate (2.9 cows/ha), herd genetics and grazing decision rules were implemented to isolate calving pattern effects.

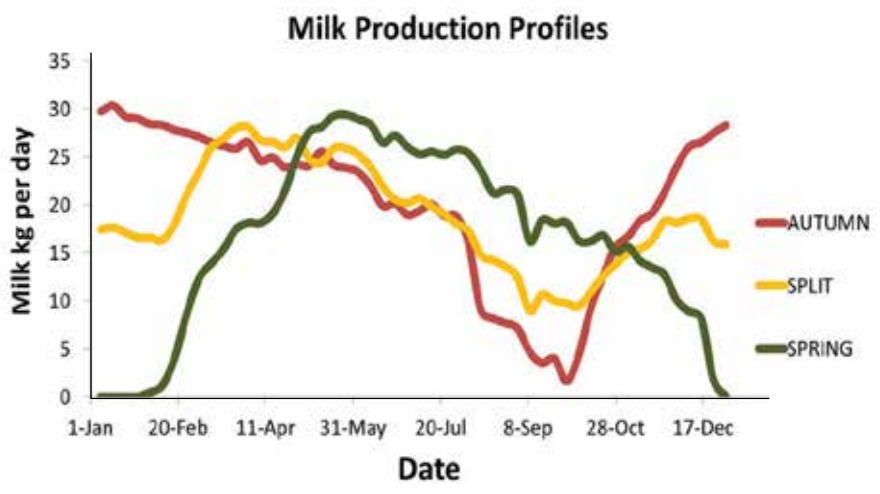

Figure 2. *Effect of calving pattern on annual milk production profiles*

The autumn calving system produced 15% higher milk solids annually than spring calving, and 6.5% more than split calving (601 kg, 522 kg and 556 kg milk solids for autumn, spring, split calving systems respectively). However, the spring calving herd were milked on 37 fewer calendar days per year due the herd being fully dried off in December. This has implications for labour and overhead costs. Relative to spring calving, summer peak volume was reduced by 8% by 50% calving in autumn and by 14% for block autumn calving. These were relatively modest effects given the scale of change in calving pattern. Notably, autumn and split calving reduced volumes by 76% and 31% respectively during the August-September period. The primary effect of partial or full autumn calving was therefore to shift milk supply from early autumn into winter, to a greater extent than from the summer period. There were no treatment effects on fertility. The extra milk revenues (ex-premia for winter supply) generated by autumn and split calving systems were offset by the additional cost of concentrates and conserved forages. In terms of system sensitivity, the spring system had greater relative margins where feed prices increased and/or milk price declined but rank changes were modest. Increasing grazed grass in the diet was important for profit in all systems.

Conclusions

High EBI cows utilising grazed pasture delivered good milk solids yield across a range of calving pattern systems. A modest shift to late autumn calving is unlikely to elicit significant reductions in summer peak volumes, particularly in a scenario of increased herd size. A more likely outcome would be moderate increases in winter supply secured against increased production costs across the supplier base. The full implications for winter and summer supply must be considered before imposition of pricing structures that incentivise a shift in calving pattern.

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

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Summary

- Recent studies suggest that the DM yield of swards incorporating additional plant species are comparable with perennial ryegrass (PRG) only swards in terms of DM yield, require fewer chemical fertiliser applications and support enhanced animal performance at grazing
- 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.

Introduction

Improved efficiency in dairy systems is a significant challenge for the future, to meet increased food demand while competing for inputs, adapting to climate change, and delivering ecosystem services. Future grazing systems can play a major role in the supply of healthier foods within systems with a reduced reliance on fossil fuels and chemical inputs, while also delivering environmental, biodiversity, and animal welfare benefits. Can we design lower-input systems that deliver efficient levels of output in addition to enhanced environmental outcomes?

As part of the management of simplified systems, monocultures of perennial ryegrass (PRG) have traditionally dominated grazing swards. The highly seasonal growth pattern of PRG, particularly in the context of increasingly variable weather conditions, and growing pressures to reduce both chemical fertiliser and herbicide use have brought this practice into question. Recent studies now suggest that the DM yield of swards incorporating additional plant species are comparable with PRG only swards in terms of DM yield, require fewer chemical fertiliser applications and support enhanced animal performance at grazing. Grass-legume mixtures such as PRG-white clover swards have been shown to reduce chemical nitrogen (N) fertiliser requirements and increase sward quality and animal intake. 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 which have been identified as valuable complementary forage species with high productivity and feed value. In extensive low input European grassland studies, increased plant diversity has also been linked to increased N use efficiency, elevated soil carbon sequestration, enhanced food product character and increased resistance to climate change and weed invasion.

Curtins Farm — The Multi-milk research project

The objective of the new project on Curtins farm is to compare the performance of three farmlets with PRG, PRG-White clover (WC) and a multispecies sward (MSS). Each of the three swards are grazed by high Economic Breeding Index Holstein-Friesian (HF) and Jersey Holstein-Friesian crossbred (JEX) cows. Each farmlet is managed with a stocking rate of 2.75 cows/ha and in line with the objective of reducing the chemical N fertiliser, the PRG will receive 250 kg N/ha per year while both the PRG-WC and the MSS will receive 125 kg N/ha year. To evaluate the performance of these three swards, detailed pasture productivity, nutritive value and botanical composition measures are undertaken at each grazing or cutting event. The performance of the cows is also measured in terms of milk production and quality, and detailed milk composition and technological proprieties including mineral, vitamin and antioxidant levels.

The preliminary results for the project up to August 2021 are presented in Table 1 below. To-date, milk yield and composition and pasture production are similar between sward types. The high EBI JEX genotype have achieved similar milk production, increased milk composition and increased fat and protein (milk solids) production compared to high EBI HF contemporaries. As the reduction in fertiliser N application for both low N swards is primarily based on reductions in N application from June onwards, there are no significant differences in N application between swards to date.

Table 1. First results of the study (February to July 2021)

Sward	PRG		PRG-WC		MSS	
Breed group	HF	JFX	HF	JFX	HF	JFX
Milk yield (kg/cow)	3,800	4,180	3,820	3,840	4,000	4,136
Fat content (%)	5.30	5.69	5.57	5.80	5.41	5.59
Protein content (%)	3.46	3.63	3.47	3.64	3.55	3.67
Milk solids (kg/cow)	335	395	350	370	365	390
Concentrate (kg/cow)	215	255	214	236	209	225
Pasture yield (t DM/ha)	8.4		8.3		8.3	
Fertilizer (Kg N/ha)	179		128		130	

NB: These are raw data that have not been statistically analysed and, therefore, no definite conclusions can be drawn from them

Conclusions

Pasture-based systems have many positive aspects in their production of healthy food from livestock fed on grassland forage which is not directly utilisable as food by humans. To further improve the efficiency of such systems, the incorporation of additional plant species within grazing swards is currently being evaluated and, based on previous research, has the potential to improve nutrient use efficiency, forage quality, biodiversity and long-term carbon sequestration in pasture-based systems.

Clonakilty update: The effect of sward type and nitrogen fertiliser application rate on milk and herbage production

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Summary

- There was an effect of nitrogen (N) fertiliser rate on sward white clover content
- Both sward type and N fertiliser rate had an effect on grass DM production
- Milk solids yield per cow was 26 kg/cow greater for cows grazing perennial ryegrass-white clover swards compared to perennial ryegrass-only swards.

Introduction

There has been renewed interest in the use of white clover in grazing systems due to its ability to biologically fix nitrogen (N), increase herbage nutritive value and improve animal performance. The previous experiment in Clonakilty achieved high sward white clover contents and found large increases in milk and grass production for perennial ryegrass (PRG)-white clover compared to PRG-only swards. This paper will present the results of the new Clonakilty Agricultural College research experiment from 2019–2020. The experiment entitled "The effect of sward type (PRG-only vs PRG-white clover) and N fertiliser level (150 vs. 250 kg N/ha) on the productivity of spring milk production systems" will investigate how reducing N fertiliser application levels on PRG-only and PRG-white clover swards will effect grass and milk production.

Clonakilty experiment 2019–2021

Four separate grazing treatments were utilised for this experiment; a PRG-only sward receiving 150 kg N/ha (GO-150), a PRG-only sward receiving 250 kg N/ha (GO-250), a PRG-white clover sward receiving 150 kg N/ha (GC-150) and a PRG-white clover sward receiving 250 kg N/ha (GC-250). There was a separate farmlet of 20 paddocks for each treatment. There were 30 cows in each treatment group, stocked at 2.75 cows/ha and target concentrate supplementation was 450 kg/cow for each treatment. In the previous experiment at Clonakilty from 2014–2017, sward white clover content declined over time due to a number of factors, including high fertiliser N use, silage management and autumn grazing management. However, little work was undertaken during the experiment to try to increase sward white clover content by either over sowing or reseeding swards. As part of the new experiment, a programme of reseeding and over-sowing was undertaken to increase sward white clover content at Clonakilty. In 2019, 20% of the farm was reseeded and in 2020, 15% of the farm was reseeded along with approximately 20–30% of the farm over-sown with white clover each year.

Results 2019–2020

Sward white clover content increased in 2019 (13.8%) and 2020 (16.4%) from the low levels (<10%) achieved in 2018, however there was a difference between fertiliser rates. The GC-150 treatment had greater sward white clover content (14.4% and 19.1%, in 2019 and 2020, respectively) than the GC-250 treatment (11.1% and 13.6%, in 2019 and 2020, respectively) each year. Both sward type and N fertiliser rate had an effect on grass DM production (Table 1). Perennial ryegrass-only swards grew 14.5 t DM/ha and PRG-white clover swards grew 15.0 t DM/ha and there was a 1.25 t DM ha difference between swards receiving 150 kg N/ha or 250 kg N/ha. Due to the lower total grass DM production on the 150 kg N/ha treatments, silage fed during lactation was greater for these treatments compared to the 250 kg N/ha treatments. Silage produced was also below target for all treatments on average over the two years but was lower for 150 kg N/ha treatments. When silage fed during lactation is accounted for the 150 kg N/ha treatments only made 36% of their winter feed requirement compared to 60% for the 250 kg N/ha treatments. Nitrogen fertiliser rate did not affect milk production but sward type had a significant effect. Cows grazing PRG-white clover swards produced 5,790 kg milk compared to 5,469 kg for cows grazing PRG-only swards, with similar fat and protein contents resulting in cows grazing PRG-white clover swards producing 490 kg milk solids compared to 464 kg for cows grazing PRG-only swards. Bodyweight was similar amongst all treatments but BCS was slightly lower for cows on PRG-only swards compared to PRG-white clover swards.

Table 1. The effect of sward type and fertiliser rate on herbage and milk production from 2019–2020

	GO-150[1]	GO-250	GC-150	GC-250
Nitrogen fertiliser spread (kg/ha)	152	250	152	250
Grass production (t DM/ha)	13.8	15.1	14.4	15.6
Concentrate (kg/cow)	611	614	613	612
Silage made (kg DM/cow)	796	944	844	1,034
Silage fed - lactation (kg DM/cow)	388	264	391	291
Silage deficit[2] (kg DM/cow)	792	520	747	457
Milk yield (kg/cow)	5,416	5,521	5,744	5,835
Fat content (%)	4.80	4.86	4.80	4.79
Protein content (%)	3.82	3.87	3.89	3.84
Milk solids yield (kg/cow)	457	470	487	493
Bodyweight (kg)	507	524	517	514
Body condition score	2.91	2.95	2.99	2.99

[1]GO-150 = perennial ryegrass (PRG)-only sward receiving 150 kg N/ha, GO-250 = PRG-only sward receiving 250 kg N/ha, GC-150 = PRG-white clover sward receiving 150 kg N/ha, GC-250 = PRG-white clover sward receiving 250 kg N/ha. [2]Silage deficit based on a winter silage requirement of 1,200 kg DM/cow (4-month winter)

Conclusion

Perennial ryegrass-white clover swards continue to show benefits in terms of milk and milk solids production compared to PRG-only swards. This milk response was evident even at lower sward white clover contents than previous experiments. In terms of grass production, sward white clover content was not high enough on the GC-150 treatment to fully offset the 100 kg reduction in N compared to the GO-250 treatment. The results from this experiment show that white clover will continue to play an important role in facilitating reductions in N use and improving N use efficiency on dairy farms.

Methane measurement and accuracy

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Summary

- Ruminants, unlike monogastrics, can digest grass with methane being a by-product of digestion
- Measurement of methane has traditionally been difficult in pasture-based systems
- New outdoor GreenFeed technologies allow methane to be measured with strong repeatability and accuracy in a grazing system.

Introduction

Ireland's agricultural industry currently contributes 34.3% of total national greenhouse gas (GHG) emissions. Within the agricultural industry, methane is the highest contributor at 59.3%. The Irish government have committed to reducing total GHG emissions by 51% by 2030, relative to the 2018 emissions. This will put pressure on all sectors within Ireland to play a role in reducing emissions. Although methane emissions contribute, over half of the agricultural industry's emissions there has been little research completed in pasture-based systems, mainly because the measurement process is complicated. Given the importance of methane in agricultural emissions, it is important that research is undertaken to evaluate the baseline methane emissions in pasture-based systems, as well as the potential for methane reduction through for example grass quality and animal characteristics as well as complimentary feed based solutions.

Methane measurement

The majority of methane emitted from ruminants is released through eructation or burping. Hence, methane measurement is focused on sampling air from the mouth. At Teagasc Moorepark, methane measurement is being undertaken using a device called the GreenFeed (Figure 1). Each GreenFeed can measure approximately 25–30 animals daily in a pasture setting. These GreenFeed machines rely on the animal to voluntarily visit the machine as many times as possible per day to ensure accurate results.

Figure 1. *GreenFeed machine used to measure methane emissions in a pasture based system*

When the cow puts her head into the feed bin in the machine, her electronic identification tag is recognised and sampling commences. While she has her head in the feed bin small amounts of concentrate (35 g) drop every 20 seconds over a 2–3 minute period. This encourages the cow to stay in the machine for the required period. While she is eating, air is sucked in through the feed manifold; air is then filtered and then sampled through the methane, carbon dioxide and hydrogen gas sensors that are on the machine. The machines are moved to follow the grazing rotation so cows have constant access to the GreenFeed.

Reliability of results

A big question related to methane measurement is the repeatability of the measurements, especially within pasture settings. In other words, would the measurements be robust. In order to evaluate how robust the approach was, data were collected in autumn 2020 (late lactation) over a 10 week study when animals were at pasture. Two measures of accuracy were evaluated including repeatability (how repeatable each measurement is to another) and the coefficient of variation (the amount of variation between measurements).

The repeatability of the methane results were similar to that of milk yield data collected from the same cows. The methane results were shown to have a repeatability of just 0.06 less than milk yield (Table 1). The coefficient of variation for methane is 7% less than that of the milk yield data. Therefore, this suggests that methane is showing less day-to-day variation than milk yield. The average methane produced in late lactation was 352 g methane/cow per day and the average milk solids produced was 1.62 kg/cow per day.

Table 1. Mean, repeatability and coefficient of variation of methane and milk yield in late lactation

	Mean	Repeatability	Coefficient of variation
Methane (g CH_4/day)	352	0.69	13%
Milk yield (kg/day)	17.42	0.75	20%

Conclusion

The GreenFeed technology is producing accurate and reliable methane production estimates for individual cows in pasture-based settings. This technology can be used to quantify methane baselines as well as identifying methane reduction solutions.

Greenhouse gas emissions from dairy production in Ireland

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Summary

- A new national average greenhouse gas (GHG) intensity of 0.99 kg CO_2-eq per kg fat and protein corrected milk (FPCM) has been calculated by a recently updated Teagasc life cycle assessment model
- Improving the efficiency of current dairy systems and the adoption low emission technologies can reduce the GHG intensity to 0.73 kg CO_2-eq per kg FPCM
- Further development and implementation of low emission technologies is necessary to reduce the GHG intensity and total GHG emissions of dairy systems.

Introduction

In the recent 2030 Climate Target Plan, the EU has increased their commitment to climate change mitigation by rising greenhouse gas reduction targets to at least 55% below 1990 levels by 2030 (previously 40%). Since the abolition of milk quotas in 2015, national GHG emissions have increased by 1.15 million tonnes. To meet Irelands international obligations to reduce GHG emissions, a suite of mitigation strategies have been identified and recommended for dairy farms. Additionally, in recent years, the recommended international methodologies for quantifying GHG emissions at a macro level have been refined. This work therefore aims to determine the effect of model updates on GHG emissions from an average dairy farm in Ireland and establish targets for 2030 based on potential levels of technology uptake.

Model updates and mitigation strategies

The Moorepark Dairy Life Cycle Assessment (LCA) model has been updated with the most recent recommended methodologies. Such updates are associated with the development of country specific emission factors, refinements to international recommended practices, and the adoption of new technologies. Average herd calving and fertility performance was obtained from the Irish Cattle Breeding Federation's (ICBF) annual dairy calving statistics report. National milk production data was obtained from the Central Statistics Office. Data for on-farm management practices were obtained from Teagasc's National Farm Survey. All emissions up to the point in which the products (milk and animals) leaves the farm were accounted for by the LCA model. The proportion of emissions attributed to milk and meat production was determined using the revenue generated by each product. For the target dairy system, specific mitigation strategies are broken into two categories for the average dairy farm, 1) improve efficiency and 2) adopt low emission technologies. The first mitigation strategy includes improvements in soil fertility, increases in grass growth and utilisation, increases in the economic breeding index (EBI), and improvements in herd health. The second mitigation strategy involves the adoption of low emission technologies such as protected urea and the use of low emissions slurry spreading equipment.

Future carbon footprint

The updated LCA model resulted in lower GHG emissions from an average Irish dairy farm (Table 1). Differences occurred in grazing and fertiliser emissions, due to the adoption of country specific and up-to-date emission factors. In the target system, the adoption of low emission technologies such as protected urea and low emission slurry spreading reduced GHG emissions and nitrogen losses. The trailing shoe places slurry directly onto the soil surface below the grass thus reducing ammonia emissions, while protected urea displaces nitrate fertilisers which emit relatively high quantities of nitrous oxide. Low emission technologies reduce emissions per ha and per kg milk. The incorporation of white clover and increasing forage production and utilisation through enhancing soil fertility and good grassland management reduces GHG emissions by efficiently utilising home grown forage and reducing reliance on synthetic fertilisers and concentrate feeds. Improving the EBI of a herd increases lifetime milk solids production and reduces the number of non-productive stock. Improving efficiency through grassland management and genetics reduced the increase in GHG intensity per kg milk. However, due to the increase in production minor reduction was reported per ha, the target system's GHG emissions are greater than the current system (new model). Further development and implementation of low emission technologies is necessary to reduce the GHG intensity and total GHG emissions of dairy systems.

Table 1. Performance indicators for current and future dairy systems

	Current old model	Current new model	Target
Stocking rate (LU/ha)	2.1	2.1	2.7
Fat plus protein (kg/ha)	866	866	1,222
Replacement rate (%)	26	26	18
Calving rate (% calved in six weeks)	65	65	90
Fertiliser N (kg N/ha)	186	186	150
Grass utilized (t DM/ha)	7.3	7.3	12.1
Concentrate intake (kg DM/cow)	1,025	1,025	450
LESS spreading (% slurry applied)	10	10	100
Protected urea (% N applied)	-	-	100
GHG intensity (kg CO_2-eq/kg FPCM)	1.12 (0.95)[1]	0.99 (0.82)	0.74 (0.62)
GHG intensity (kg CO_2-eq per ha)	10,714 (9,111)	9,465 (7,862)	10,498 (8,832)

[1]*500 kg carbon sequestered per ha*

Conclusion

Updates to the models and emission factors have resulted in the GHG intensity of Irish milk being reduced by over 10%. Technologies available for take up at farm level can reduce GHG intensity by a further 26%. It is important to highlight that the updates to GHG emission calculations will not be counted or credited against our GHG reductions targets. Only changes in management practices and adoption of technologies will be credited. To reduce footprints further will require investment in new research strategies around methane, nitrogen and carbon sequestration.

Teagasc Sustainability Report 2019

Cathal Buckley and Trevor Donnellan

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Summary

- Gross margin and income returns were 1.4–5 times higher on dairy farms versus non-dairy farms
- Emissions per hectare of greenhouse gas (GHG), ammonia (NH3) and N balances were between 2–6 times higher on dairy farms
- Emissions intensity of milk production declined between 2012–2019.

Introduction

The 2019 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 1.4–2 times higher than tillage and 3–5 times higher than that of other livestock systems respectively.

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, both were significantly higher than livestock systems as seen in Figure 1.

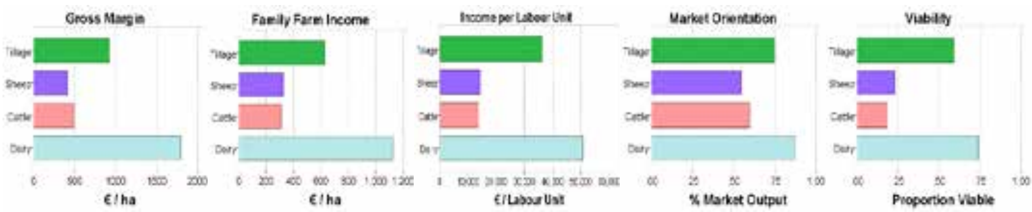

Figure 1. *Economic Sustainability: Farm system comparison 2019 (farm system average)*

Environmental Indicators: Dairy farms had the largest GHG emissions (CO_2 equivalent) on a per hectare basis, 2–4 times higher greater than the other systems. The trend was reversed for kg of CO_2 equivalent emitted per Euro of output generated. Ammonia (NH_3) emissions per hectare were also significantly higher (2–6 times) on dairy farms compared to other systems. In terms of NH_3 emission per Euro of output generated, cattle farm 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 N surplus per hectare) on dairy farms were circa three times higher than the other farm systems. Higher dairy emissions are a function of greater stocking rates, more energy intensive diets and more use of chemical fertilisers than the other livestock systems.

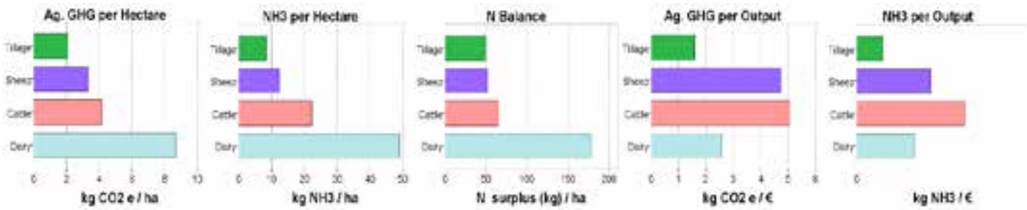

Figure 2. *Environmental Sustainability: Farm system comparison 2019 (farm system average)*

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 3).

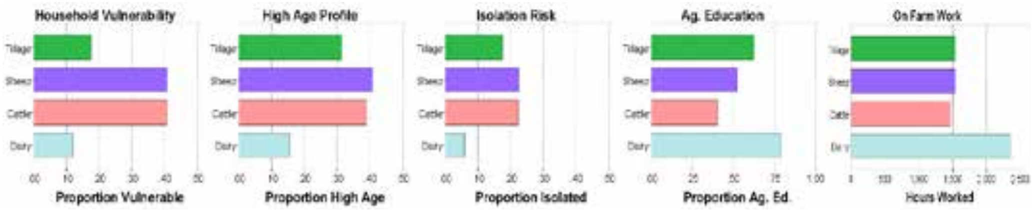

Figure 3. *Social Sustainability: Farm system comparison 2019 (farm system average)*

Emissions Intensity: Figure 4 illustrates that kg of CO_2 equivalent and NH_3 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 2012 and 2017 on a three-year rolling average basis. Additional milk output post milk quota has been produced at a lower emissions intensity.

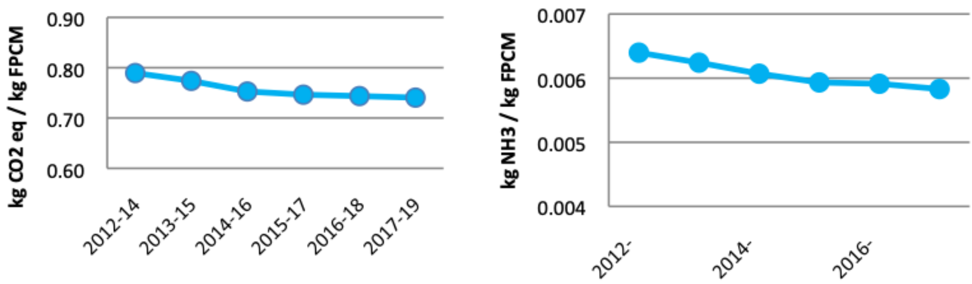

Figure 4. *Kg of CO_2 equivalent and NH3 per kg FPCM (Dairy Farms)*

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.

Reducing ammonia emissions: Switch to protected urea and low emission slurry spreading (LESS)

Dominika Krol[1] and William Burchill[2]

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Summary

- Ammonia emissions reduce the nitrogen value of fertiliser and slurry
- Switch from urea to protected urea and splash-plate to low emission slurry spreading (LESS).

Introduction

Ammonia is a gaseous form of nitrogen (N) which can be lost from slurry and fertiliser N. This can significantly reduce the N available for grass growth from N fertiliser and slurry. Ammonia is also a potent air pollutant which negatively impacts on human and animal health while also damaging ecosystems. Ireland has committed to reducing ammonia emissions through EU targets, however, we have been exceeding our targets in recent years. In Ireland, agriculture is responsible for 99% of all ammonia emissions so any national reduction in ammonia emissions will have to come from agriculture. Ammonia comes mainly from management of animal manures (housing, slurry storage and land spreading) but also from grazing animals and from the spreading of synthetic fertiliser. Therefore, to reduce ammonia emissions we must focus on how we manage our N fertiliser and slurry.

How do I to reduce ammonia emissions from my farm?

Teagasc recently assessed a number of options to reduce ammonia emissions on Irish farms using a Marginal Abatement Cost Curve (MACC; Figure 1). The MACC assesses ammonia reduction options based on cost to implement at farm level and effectiveness at reducing ammonia emissions. Options such as reducing crude protein of dairy rations, incorporating clover into swards, shifting to using protected urea and liming all reduce farm input costs while also reducing ammonia emissions (Figure 1). Protected urea and low emission slurry spreading (LESS) are the two most effective options to reduce ammonia emissions. If implemented fully on farms they would deliver up to 80% of the reduction required to meet our EU ammonia targets.

Protected urea

Trials conducted by Teagasc have shown that protected urea is consistently growing the same amount of grass as CAN while costing slightly less per unit of N and delivering on lowering ammonia and greenhouse gas emissions. See papers on protected urea elsewhere in this booklet for further details.

Low Emission Slurry Spreading

Shifting the timing of splash plate-applied slurry from dry and warm conditions to cooler periods reduces ammonia losses and improves slurry N availability by 20–30% at no extra cost. Alternatively, slurry can be spread using LESS techniques, such as trailing hose/dribble bar or trailing shoe. Dribble bar reduces the surface area of slurry exposed to the air by placing it in bands rather than a thin film on the grass (Figure 2). Trailing shoe is more effective than dribble bar at reducing ammonia loss, as slurry is placed in bands directly on the soil beneath the sward. Dribble bar will deliver up to a 30% reduction, trailing shoe a 60% reduction and injection up to a 70% reduction in ammonia loss. There is also a co-benefit of reduced sward contamination and increasing plant available units of N per 1,000 gallon of slurry (Figure 2).

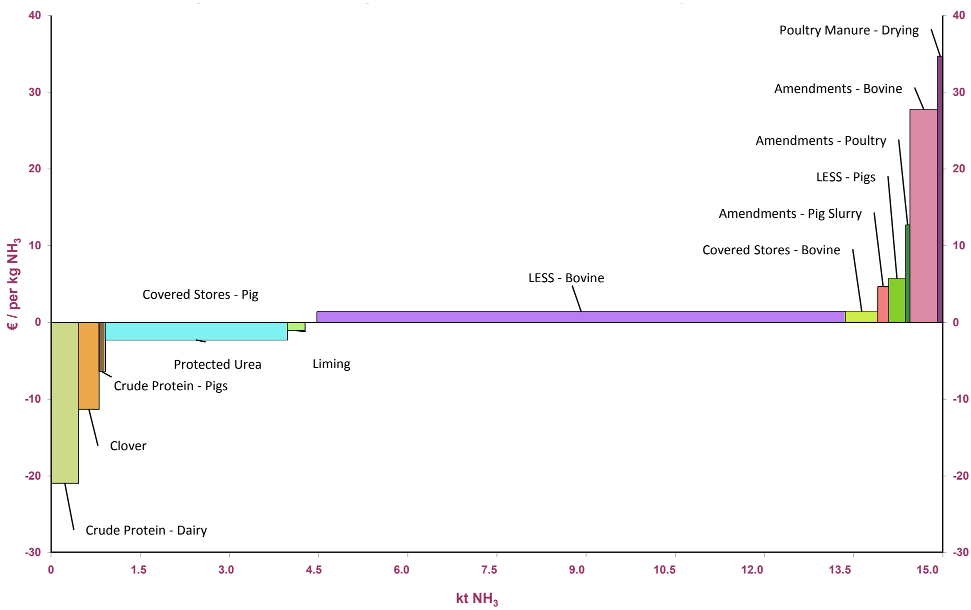

Figure 1. *Cost and abatement potential of ammonia mitigation from https://www.teagasc.ie/media/website/publications/2020/NH3-Ammonia-MACC.pdf*

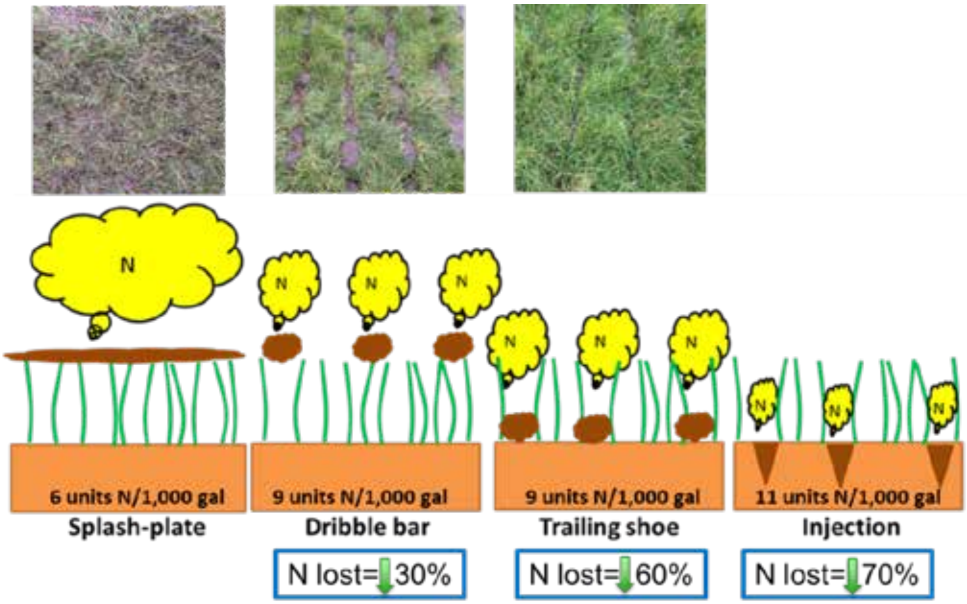

Figure 2. *Comparison of the effect of different slurry spreading techniques on N loss from slurry*

Conclusion

Implementing LESS and protected urea, reduces ammonia losses to help achieve our EU emission reduction targets and improve N use efficiency (NUE) on your farm. As you minimise loss and improve NUE, reduce synthetic fertiliser applications for maximum financial benefit. This will also help achieve the EU Farm to Fork Strategy target of 20% reduction in fertiliser use.

Protected Urea — maintaining yield with lower emissions

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Summary

- Extensive Irish trials show that protected urea delivers on yield
- Irish trials show protected urea giving a 71% reduction in nitrous oxide loss compared to CAN and a 79% reduction in ammonia loss compared to urea
- Use protected urea in the straight nitrogen (N) or N+S slots in your fertiliser programme.

Introduction

Protected urea (urea fertiliser protected with the urease inhibitors NBPT, NBPT+NPPT or 2-NPT) expands the farmer's toolbox of nitrogen (N) fertiliser options to grow grass. Protected urea is not a silver bullet to solve the N emissions challenge alone. However, it is an important tool to reduce farm emissions, while being relatively easy for the farmer to adopt. Adoption of protected urea along with reduced fertiliser N usage are key emission reduction measures of the AgClimatise roadmap published by the Department of Agriculture, Food and the Marine in December 2020.

Does protected urea deliver on yield?

Cutting and grazing trials conducted by Teagasc over multiple locations during the past eight years have shown that protected urea delivers the same yields as CAN and urea (Figure 1). When protected urea yields were disappointing, the same yield reduction occurred in the CAN plots. This is because reduced growth was due to moisture limitation or excess and/or cold temperatures. We see reduced growth occur sporadically in most growing seasons so bear this in mind when evaluating N fertiliser performance.

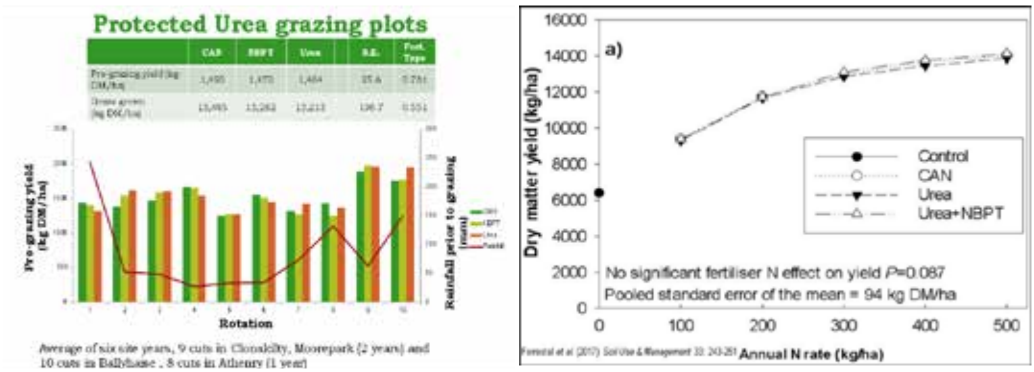

Figure 1. *Performance of protected urea matching CAN in a) cutting and b) grazing trials*

Does protected urea reduce emissions?

Extensive and published Irish trial work has shown that protected urea can reduce the emissions of the potent greenhouse gas (GHG) nitrous oxide (N_2O) by 71% compared to CAN (Figure 2). As a result, substituting protected urea for CAN is a key GHG measure of the Teagasc Marginal Abatement Cost Curve (MACC). The MACC provides farmers with a menu of options to reduce GHG.

Protected urea is also an effective tool for reducing ammonia-N loss from urea, cutting ammonia loss by 79% in published Irish trial work (Figure 2). For this reason, using protected urea in place of standard urea is a key ammonia loss reduction option on the Teagasc Ammonia MACC. Retaining N lost from urea by volatilization will contribute to increasing farm nitrogen use efficiency (NUE) over time.

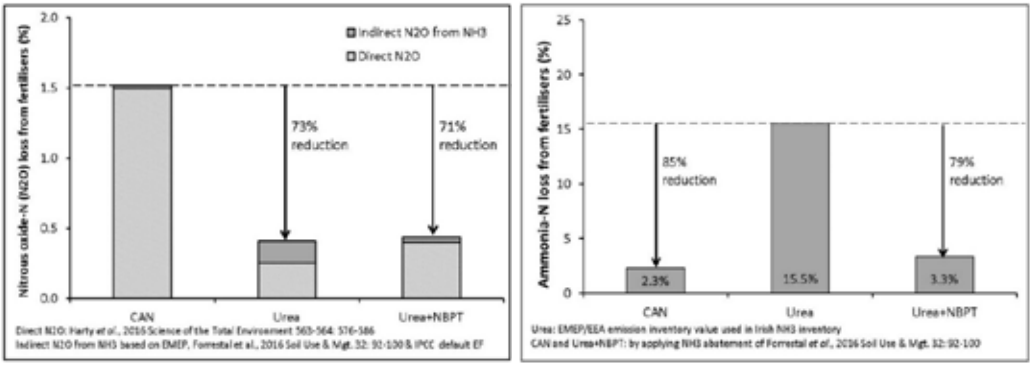

Figure 2. *Reductions in emissions of the greenhouse gas nitrous oxide (N_2O) and of ammonia using protected urea based on published Irish trial work*

Which product should I use?

Products with the urease inhibitors NBPT, NBPT+NPPT or 2-NPT. Currently, 17 products are available from six fertiliser companies:

- Six straight N products (46% N)
- Six N+S products (typically 35–38% N, 5–7.6% S)
- Five N+K+S products (typically 29–30% N, 14–15% K, 2–4% S).

Check out the most up to date list and other valuable soil fertility information at www.teagasc.ie/crops/soil--soil-fertility/

Conclusion

Protected urea is a straightforward emission reduction tool that most farmers can adopt, particularly where straight N or N+S slots exist in their fertiliser programme. Adoption of emission reduction technologies demonstrate the willingness of the farming community to be part of the solution for reducing emissions. Adoption also helps to safeguard Ireland's green credentials as a low carbon footprint producer of top quality food.

Increasing biodiversity on intensive farms

Daire Ó hUallacháin[1], Aoife Leader[2] and Stephanie Maher[1]

[1]Environment and Land-use Programme, Teagasc, Johnstown Castle, Wexford; [2]Teagasc, Advisory Office, Kilkenny

Summary

- Wildlife measures designed and targeted for intensive dairy systems can play an important role in halting the decline of biodiversity and achieving the goals of sustainable agriculture
- The quality of existing farmland habitats should be maintained or enhanced, before new biodiversity measures are established
- New biodiversity measures should not replace existing habitats.

Introduction

Many farmland plants and animals are dependent on agricultural practices, and changes in these practices affect farmland ecology. Whilst there is a need to increase production to cope with increasing food demands, the environment and ecosystem services need not be compromised. Emerging research and policy agendas are based on sustainable management of agricultural land. The Farm to Fork Strategy and the Common Agricultural Policy include the need for effective methods for biodiversity conservation, as part of the development of sustainable production systems. Incorporation of such measures could provide a very important contribution to the reversal of biodiversity decline; in addition, this can offer a marketing opportunity to Irish farmers and retailers in terms of capitalising on Ireland's reputation for sustainable production systems.

Measures to enhance biodiversity on dairy farms

Grass-based farming systems in Ireland are well positioned in terms of the wildlife they support. It is estimated that natural and semi-natural habitats constitute over 6–7% of intensive grass-based farm area. Appropriately designed wildlife measures, targeted for intensive grass-based systems, could play an important role in halting the decline of biodiversity, along with improving water quality, reducing greenhouse gas emissions and achieving the goals of sustainable expansion.

Maintain and manage existing habitats

Optimise the biodiversity value of existing farmland habitats before new biodiversity measures are established. Existing habitats, including woodland plots, ponds and wetlands should be protected from more intensive agricultural management. These areas should be appropriately managed and avoided when sites are being selected for 'new' biodiversity or carbon initiatives. Many of these semi-natural habitats benefit from farm management that prevents the area from scrubbing over (e.g. light grazing of woodland plots in spring and autumn can help improve the ecological quality of the area).

Hedgerow and field margin management

Hedgerows are the dominant habitat feature on Irish farms with the average dairy farm (56 ha) having over 6 km of hedges. However, the ecological quality of many of the hedgerows is low. High quality hedgerows provide multiple benefits, including shelter for stock and improving biosecurity; improving water quality; sequestering Carbon; and acting as a refuge for biodiversity. Optimal management includes:

- The sides of hedges could be trimmed less frequently, with the top allowed to grow taller. This provides greater shelter and shade for animals, and improves the diversity and quality for wildlife

- Fill in escaped or 'gappy' hedgerows with native species (e.g. hawthorn). Native species support a greater abundance and diversity of wildlife than non-native species
- Leave occasional trees or bushes to mature. Mature trees and bushes provide greater feeding and nesting habitats for birds, pollinators and a variety of insects
- Reduce management in field margins adjacent to hedgerows, allowing vegetation to grow naturally. Avoid cultivation, fertiliser, slurry and herbicide and cut in autumn to prevent scrub.

Ensure appropriate management (highlighted above) is undertaken outside the closed period, i.e. the closed period runs from March 1st to August 31st.

Watercourses and buffer zones

Riparian buffer zones are areas of permanent vegetation adjacent to rivers and streams that are excluded from intensive farming practices. Appropriately managed buffer zones play an important role in maintaining water quality, ensuring bank stability and providing a habitat for biodiversity. As with the previous measures, there is no one-size fits all, however:

- Avoid fertiliser, slurry or herbicide application in the buffer zone
- Allow vegetation to develop, but avoid becoming dominated by scrub (e.g. gorse, bramble)
- Exclude livestock fully from watercourses
- If cleaning the channel-bed, the spoil should be deposited away from the buffer strip.

Consult with Inland Fisheries Ireland prior to undertaking any in-stream management.

Establishing new habitats

New biodiversity measures play an important ecological role where there is a lack of existing habitats. New measures could be targeted to less productive areas of the farm. However, replacing existing habitats with newly created habitats is poor practice and typically results in a reduction in farmland wildlife.

- Wider field margins provide a habitat for a wide range of plants and animals, can prevent undesirable plant species from encroaching into the field, and more easily facilitate the desired management of hedgerow
- Awkward field corners could be left uncut following silage removal. This temporary measure provides food and cover for a variety of species such as farmland birds and small mammals. Corners could be grazed-off when animals are re-introduced to the field
- Woodland groves could be planted with a variety of native deciduous trees such as Oak, Crab Apple, Willow and Rowan, to provide a diverse habitat for a range of plants and wildlife.

The greenhouse gas marginal abatement cost curve (GHG MACC)

Trevor Donnellan[1] and Pat Murphy[2]

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Summary

- The Teagasc greenhouse gas (GHG) marginal abatement cost curve (MACC) for Irish Agriculture shows the realistic potential for reducing agriculture's GHG emissions using a range of actions (technologies and management strategies) on farm
- The GHG MACC indicates the size of the contribution each action can deliver and the cost that would be associated with applying or implementing those actions
- Many of the actions identified in the GHG MACC have a low or negative cost and are, therefore, priorities for implementation
- The GHG MACC provides important guidance to policy makers on the potential policies and regulation required to support the reduction of GHG emissions.

Introduction

Agriculture is responsible for 33% of Ireland's GHG emissions. These gasses are damaging to our climate and international agreements require that production of these gasses are reduced. Achieving GHG emissions reduction targets requires agriculture to play its part. However, dealing with agricultural GHGs is extremely complicated. Three GHGs, **methane**, **nitrous oxide** and **carbon dioxide**, occur in farming. Reducing methane in agriculture is difficult. Methane emissions from ruminant digestion alone accounts for approximately half of Ireland's total agricultural GHG emissions. There are also methane emissions from slurry storage. To date the focus in reducing methane has been on increasing the efficiency of our ruminant production systems to ensure maximum product output relative to the methane emissions produced. The second most important agricultural GHG is nitrous oxide, accounting for about 30% of agricultural GHG emissions, largely from the application of chemical and organic nitrogen fertilisers to land. These emissions can be reduced using low emission slurry spreading technologies (trailing shoe and trailing hose) and switching fertiliser type from calcium ammonium nitrate-based fertilisers to protected urea. Carbon dioxide accounts for a small proportion of agricultural GHG emissions, mainly associated with energy use. While there is significant scope for reduction of energy use on farms, this will have limited impact on overall agricultural GHG emissions levels. Farmers also have a huge role to play in combating global warming through sequestration of carbon and the replacement of fossil fuels elsewhere in the economy with renewable energy sources produced on farms.

Teagasc greenhouse gas marginal abatement cost curve

The Teagasc greenhouse gas (GHG) marginal abatement cost curve (MACC) for Irish Agriculture shows the realistic potential for reducing agriculture's GHG emissions using a range of actions (technologies and management strategies) on farm. For each of the technologies and practices in the GHG MACC, an assessment was made as to the level of practice change that could realistically be achieved and from this a calculation of the level of mitigation that is possible. The cost of achieving this was also assessed. A number of emerging technologies are not currently included in the MACC. Such technologies, once their efficacy, cost effectiveness and safety are established will be included in new versions of the MACC. The Teagasc GHG MACC is broken down into three separate categories of actions. The first focuses on **agricultural** mitigation, the second on **land-use** mitigation and the third on **bioenergy** based mitigation. The GHG MACC ranks the mitigation measures on the basis of cost from cost-beneficial measures (below zero cost on the left of Figure 1) to high cost measures (towards the right hand side in Figure 1). The width of each bar indicate the magnitude of the abatement potential of each measure. For example, in Figure 1, Dairy EBI has a negative cost of €200/tonne of GHG (meaning it would save the farmer money) and could mitigate half a million tonnes of GHGs. Fertiliser type, referring to the replacement of CAN with protected urea has a small associated cost and significant mitigation capacity. Low emissions slurry spreading has a high cost and a relatively small impact. However, the cost is significantly borne by the state in the form of grants for equipment purchase.

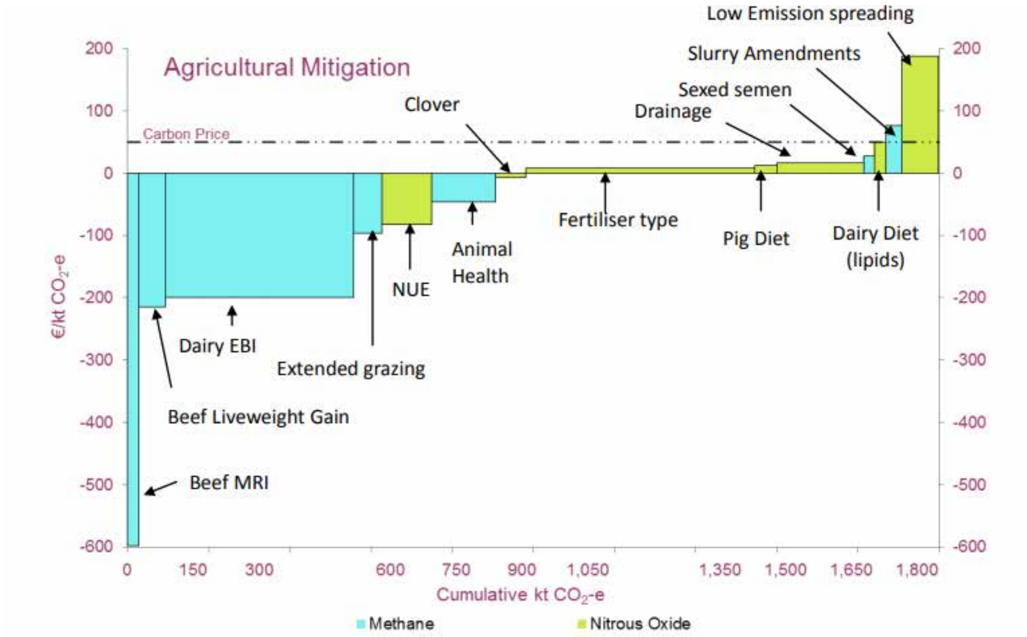

Figure 1. *Teagasc GHG MACC- Agricultural Mitigation*

Conclusion

The Teagasc GHG MACC sets out the options available to agriculture to mitigate GHG emissions. However, the level of reduction required will mean that all measures in the MACC will need to be fully implemented. As our knowledge improves and as more technologies become available, new measures will be added to the GHG MACC.

New research areas — environment

Karl Richards and John Finn
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Summary

- Increasing pressure to improve environmental sustainability
- New research on practical ways to improve sustainability on farms
- Translate research in to practice: Signpost farms/ASSAP.

Introduction

There is considerable focus on environmental sustainability and dairy farming, which has been linked to rising greenhouse gas emissions (GHG) and declines in water quality and biodiversity. The focus has moved from efficiency of dairy systems to absolute emissions per hectare. Nationally, the Teagasc National Farm Survey has highlighted that while the carbon footprint of milk has been reducing, the emissions per hectare has been increasing due to expansion and increasing animal numbers. Achieving the environmental targets set in the Climate Action Plan or the Water Framework Directive will require farmers to take action to reduce absolute emissions. New research in Teagasc Johnstown Castle is focusing on a range of new measures that can reduce emissions from our farms.

Reducing greenhouse gas and ammonia emissions

The Teagasc GHG and ammonia marginal abatement cost curves (MACCs) outline a large number of measures that farmers can undertake to reduce emissions and these are being implemented across farms on the Signpost Programme. New research is focusing on whether practices such as liming or phosphorus fertilisation can reduce emissions through effects on the soil microbiome, low emission compound fertilisers, manure acidification/amendments (Figure 1).

Figure 1. *Johnstown Castle research quantifying the effect of fertiliser type, soil phosphorus and soil pH on greenhouse gas emissions*

Carbon sequestration

There is a large programme of research underway to quantify management practices that farmers can apply to increase sequestration of Carbon in their soils. FarmCarbon is quantifying hedgerow sequestration. The Signpost Programme farms are quantifying a range of management practices to increase soil Carbon sequestration on mineral and peat grassland soils.

Water quality

Water quality research continues to investigate the effect of management practices on nutrient and sediment loss to water. The ASSAP programme is providing farmers with free practical advice and the latest research on how to improve and protect water quality on their farms. Weekly advice on when to target fertiliser to avoid application in cold/wet or warm/dry periods when growth is restricted by temperature or soil moisture is available. New research is looking at practical solutions to reduce water pollution.

Soil fertility and soil health

Soil fertility is the foundation for grassland production and an important part of sustainably maintaining soil health. Soil biology is a new and expanding area of research, which is focusing on understanding the link between farm management and soil biological health. Soil specific fertiliser advice is being incorporated into the sustainable fertiliser planner within Nutrient Management Planning (NMP) online to help farmers tailor fertiliser application to underpin both production and sustainability goals.

Biodiversity and multispecies swards

There are challenges around the level of biodiversity on many Irish grassland farms. Most farms have a number of important habitats that can be improved through straightforward low-cost methods. There is a separate paper on this in the open day book. The benefits of multispecies swards (MSS) are being investigated. Ongoing systems trials demonstrate that MSS can be as productive and withstand drought better than conventional perennial ryegrass systems. Research is underway to further optimise MSS on intensive farms and further quantify their environmental benefits.

Conclusion

There are many steps that a farmer can take to improve the environmental sustainability of their farms. The Signpost Programme will provide farmers with the practical advice to implement the latest research to improve the environmental sustainability of farms. Research is working hard to find new tools to further improve environmental sustainability.

The Signpost programme

Siobhán Kavanagh[1] and Seamus Kearney[2]

[1]Teagasc, Crops Research Centre, Oak Park, Carlow; [2]Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Cork

Summary

- The Signpost programme will provide leadership to farmers as we move towards more sustainable farming systems
- Ambitious targets have been set for dairy farmers to reduce gaseous emissions through increased efficiencies in areas including fertiliser use, soil fertility, pasture utilisation, slurry management, replacement rate, protein content of concentrate feeds as well as biodiversity and profitability.

Introduction

The Signpost Programme (Figure 1) is a partnership of almost 50 companies and organisations from across the Irish agricultural sector working with farmers to reduce greenhouse (GHG) emissions, improve water quality and enhance biodiversity. There are 54 dairy Signpost farmers and 12 dairy calf-to-beef farmers as part of the programme.

- The primary objective is to reduce GHG emissions on Signpost Farms by 10–15% by 2025. The target for all farms nationally is a 10–15% reduction by 2030.
- The Signpost Programme will take a holistic view of sustainability, encompassing economic, social and environmental sustainability.
- Signpost Farmers will be central to the programme and will point the way forward for all farmers. Steven Fitzgerald, Teagasc Glanbia Signpost Farmer said "*Farmers look over the ditch to the next door neighbour's farm all the time. So it's my turn for people to look over our ditch (as a Signpost Farmer). Where we can, we have always trusted science, trusted research and brought it home. It has worked for us and has got us to where we are today.*"
- The Signpost Programme will be delivered by Teagasc and industry advisors. The education of the next generation of farmers as well as training of all farmers will be important in the programme.

Figure 1. *A Schematic of the Signpost Programme*

While the solution for each farm will be somewhat different (and will be tailored to suit the individual farmer and his/her farm), we expect that the dairy Signpost Farmers will be striving to achieve the type of targets listed in Table 1. Teagasc Advisers will work with and support the Signpost Farmers as they change how they farm.

Table 1. Indicative key indicators of success for Dairy signpost farms

Area	Target
GHG emissions	• Reduce GHG emissions to 0.7 kg CO_2 eq per kg fat and protein corrected milk
Pasture productivity and stocking rate	• Identify and reseed unproductive swards — target an increase of 2 t DM/ha utilised over five years • Stock the farm appropriately: <250 kg organic N/ha (whole farm)
Reduced fertiliser use	• Reduce chemical N fertiliser usage by 10% over five years • Increase average sward clover content to 20% over five years • Spread at least 50% of chemical N as protected urea and all slurry using LESS
Optimum soil fertility	• 90% of soils to have optimum soil fertility status • Develop nutrient management plans to correct soil nutrient deficiencies
Adequate slurry storage	• Adequate slurry storage available for all livestock • No slurry spreading during closed period
Replacement rate	• Target 18–20% for stable herd • Target average herd lactation number of 4.5 • Increase herd EBI by €10 per year
Concentrate crude protein	• Reduce concentrate crude protein content to 14% (main grazing season)
Biodiversity	• Target 10% of high value biodiverse area per farm • Increase quantity and quality of biodiversity on the farm
Costs and returns	• Reduce costs/save money • Target net profit >€800 per cow or >€2,000 per ha

Conclusion

The Signpost Programme is a first step in the target towards net zero greenhouse gas emissions by 2050 and there will be further policy changes, regulations and incentivisation to achieve that target. Teagasc and the partners will work with the Signpost Farmers to reduce their environmental footprint, while also improving both the profitability of their farming businesses.

Key mitigation actions to reduce greenhouse gas emissions on dairy farms

Siobhán Kavanagh[1] and Seamus Kearney[2]

[1]Teagasc, Crops Research Centre, Oak Park, Carlow; [2]Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

Technology	How it works	Impact at farm level	Benefit to the environment	Actions needed by Dairy farmers
Use of protected urea	Slows the rate at which urea is converted to ammonium, reducing nitrous oxide emissions	Protected urea is slightly cheaper than CAN and grows similar grass yields to CAN	Protected urea has 71% lower nitrous oxide emissions than CAN. Reduces footprint & total emissions[1,2]	Replace all straight nitrogen (N) with protected urea
Improving EBI	Better fertility, reducing GHG emissions from non-milk producing animals and improved efficiency	Every €10 change in herd EBI will increase profit by €20/cow	For every €10 increase in EBI, GHG emissions decline by 1% per unit of product. Reduces footprint	Increase the EBI of your herd by €10 per year
Grazing management	Animals grazing better quality forage produce less GHG (less silage in the diet)	Every extra tonne of grass dry matter (DM) grown and utilised/ha is worth €173 to the farmer	Every additional week at grass reduces total GHG emissions by 1%. Reducing pre-grazing herbage mass from 2,000 kg DM/ha to 1,300 kg DM/ha reduces GHG emissions by 15% per day. Reduces footprint	Walk your farm weekly Measure grass Use PastureBase Ireland Improve infrastructure Avoid poaching

Technology	How it works	Impact at farm level	Benefit to the environment	Actions needed by Dairy farmers
Improved animal health	Increased animal performance, reduced replacement rate and reduced number of non-milking animals, reduced mortality	Reducing health problems will improve efficiency, reduce costs and increase profitability	Improvements in health will reduce GHG emissions per unit of milk. Reduces footprint.	Use the EBI sub-index for health Implement a health plan/ vaccination programme Implement good stock importing practices
Low emissions slurry spreading equipment	Less nitrogen (N) volatilisation Increases the N fertilizer value of slurry Reduces the total chemical N inputs	Retains an extra three units of N/1,000 gallons of cattle slurry. Worth €3.30/ cow	Reduces ammonia emissions from slurry by up to 30% and nitrous oxide emissions through reduced chemical N use. Reduces footprint and total emissions	Switch to using LESS equipment for all slurry spreading
Reducing chemical N fertiliser use	Reduces nitrous oxide emissions	Reduction in farm profitability unless soil fertility is optimised, lime is spread, clover is incorporated and LESS is used	Reduce nitrous oxide emissions and nitrate losses to water. Reduces footprint and total emissions	Get lime right first. Soil sample your farm, identify fields that need lime, P & K, make a nutrient management plan
Incorporating white clover	Nitrous oxide emission reduction is achieved from lower chemical N fertiliser use (up to 100 kg N/ ha)	Increased milk solids production 20–48 kg/cow per year Increased net farm profit by €108-€305/ha	Can reduce nitrous oxide emissions by up to 40% due to reduced chemical N fertiliser use. Reduces footprint and total emissions	Over a five year period aim to have white clover in at least 30% of your paddocks (at a minimum average annual sward clover content of 20%)

[1]*Reduces footprint = reduces GHG emissions per kg of fat and protein corrected milk;* [2]*Total emissions = reduces total GHG emissions from the farm*

Does nitrates derogation farming impact water quality?

Edward Burgess, Bridget Lynch and Per-Erik Mellander
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Summary

- Fertiliser nitrogen (N) readily converts to a soluble form (nitrate) that does not bind to soil and is easily leached to ground water
- Weather and soil type have a significant influence on nitrate losses to water and can override high stocking rates and N application on water quality
- While the most intensive dairying areas in the country correspond with the rivers and estuaries showing higher nitrate concentrations, mitigating actions must consider all influencing factors.

Introduction

Every four years the Nitrates Directive (ND) is reviewed and changes are made to the regulations. 2021 is such a year, and when the new regulations are agreed Ireland will then apply to the European Commission for permission to have a derogation from the ND, allowing famers keep livestock stocking rates above the 170 kg N/ha ND stocking rate limit. In Teagasc, the Agricultural Catchments Programme (ACP) is studying water quality in six contrasting catchments across the country, each having different soil types and/or farming systems (Figure 1). Results are used to substantiate Teagasc's submission to the ND review and to monitor the impact of derogation farming.

Figure 1. *Catchment location and farming land use and soil type*

Contrasting catchments

The land in derogation in Timoleague has increased from 54% in 2010 to 66% in 2018. In Ballycanew, the area farmed in derogation increased from 22% to 30% in the same time period. The lowest organic N loading was found in the Castledockerell catchment where only 5% of the land was stocked above 170 kg N/ha. Ten minute water monitoring at the six catchment outlets has shown that there was no clear link between the percentage of land in derogation and nitrate concentration in the stream (Table 1). For example, the catchment with the highest stream nitrate concentration (Castledockrell; 7 mg/l) has the lowest livestock stocking rate. This catchment has a large amount of tillage, with a shorter growing season than grassland. This contributes to nitrate loss, but the free draining Clonroche soil type and soil cultivation are also major factors.

Table 1. Catchment descriptions, annual average stocking rate, annual rainfall and stream nitrate concentration (N mg/l)

Catchment characteristics			Annual Inputs		Annual output	
Name	Primary land use	Drainage type	Annual rainfall (mm)	Organic N (stocking rate; kg N/ha)	River Flow (mm)	N (mg/l)
Corduff	Grass	Poor	1,050	87	625	1.39
Dunleer	Arable	Moderate	869	67	445	5.34
Ballycanew	Grass	Poor	1,037	101	496	2.62
C'dockerell	Arable	Well	1,020	41	548	7.06
Timoleague	Grass	Well	1,120	166	678	6.10
Cregduff	Grass	Well	1,460	90	-	1.32

Nitrate dissolves easily and most losses are by ground water entering streams via springs. Heavier soils, such as in Ballycanew, are more likely to have waterlogged conditions with surface water run-off. This leads to lower N in streams for two reasons: (i) water flowing on top of land does not pick up N from the soil below the surface, and (ii) anaerobic conditions in the soil favour denitrifying bacteria that transform dissolved nitrate into N2 gas that is released to the air. Nitrate levels in the Ballycanew stream are typically around 2.5 mg/l, almost a third that of Castledockrell, despite the higher organic N loading. Weather is also a significant factor impacting the nutrient concentration of water. During the 2018 drought, soil bacteria continued to break down organic matter releasing mineral N. However, due to drought grass was not growing and there was little or no uptake of N released from the soil or from applied fertiliser N. When the rain did eventually come in the autumn, much of this unused N was washed through the dried out soil and into ground water. The water tables then rose and the streams started to flow with concentrations of N that were significantly higher than that found in previous drought free years.

Conclusion

Mitigating actions and regulation to improve water quality could focus simply and solely on limiting the source of nutrients. However, recent weather events such as drought in 2018 and "Storm Emma" in 2018 also influence the release and transport of nutrients to our water courses. Differing soil properties can result in contrasting responses to changing weather patterns. For agri-environmental measures to be effective they must be cognisant of factors influencing the link between the land use and the water quality.

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.

ASSAP — Supporting farmers to minimise nitrate losses

Pat Murphy[1] and Noel Meehan[2]

[1]Teagasc, Johnstown Castle, Wexford, Co. Wexford; [2]Teagasc, Deerpark, Ballinasloe, Co. Galway

Summary

- Ireland has been set a target by the E.U. Water Framework Directive (WFD) of achieving 'Good Status' for all waters
- Recent EPA water quality reports highlight deteriorating water quality due to increasing nutrient levels, including nitrate, in waters
- The Agricultural Sustainability Support and Advisory Programme (ASSAP) service is available in 190 Priority Areas for Action (PAA's) and provides advice and mitigation actions to farmers to help minimise nutrient losses to waters.

Introduction

In Ireland, all water policy and management is led by the Water Framework Directive. Under this Directive, Ireland has been set a target of achieving 'good status' for all waters in Ireland by 2027. However, despite a lot of good work over the last 20–30 years we are falling short in achieving this target and water quality has declined in recent years.

Nitrate

One of the areas of concern highlighted by the EPA is the elevated levels of nitrate in waters. Estuaries, coastal waters and groundwater drinking supplies, particularly in the south and east of the country, are at risk with agriculture providing 85% of the nitrate load in rural catchments. Estuarine waters are in the poorest condition with only 38% of these meeting the WFD water quality targets, and are especially sensitive to elevated nitrogen concentrations.

There are a number of factors influencing the quantity of nitrate lost to waters. These include the type of land (free draining/poorly draining soil), the management of the land (intensive/extensive farming and enterprise type) and the weather (soil temperature, rainfall and drought). Typically, in Ireland the catchments where elevated levels of nitrate occur are in the freer draining and more intensively farmed catchments in the south and east of the country. It is in these catchments that the EPA have indicated that reductions in the overall tonnes of nitrogen lost to waters is required (Figure 1).

ASSAP — providing advice to minimise nitrate losses

The ASSAP programme is made up of a group of 30 advisors (20 Teagasc jointly funded by the Department of Housing, Local Government and Heritage, the Department of Agriculture, Food and the Marine, and 10 funded by the dairy processing co-ops). These advisors are available to provide a free and confidential advisory service that farmers in a PAA can avail of on a voluntary basis.

Where nitrate is a pressure on water quality in a PAA the advisors will discuss options for mitigating the diffuse losses of nitrate with farmers. To minimise nitrate losses, farmers can focus on improvements in nitrogen use efficiencies, applying nitrogen fertilisers at the right times with particular attention given to weather conditions and soil temperatures, applying nitrogen at the right locations on the farm by avoiding critical source areas and focusing on fields that have recently been reseeded and have good soil fertility, and applying the right fertiliser type, as well as utilising low emissions slurry spreading equipment, protected urea, incorporating white clover and matching the rates of nitrogen applied to crop demand.

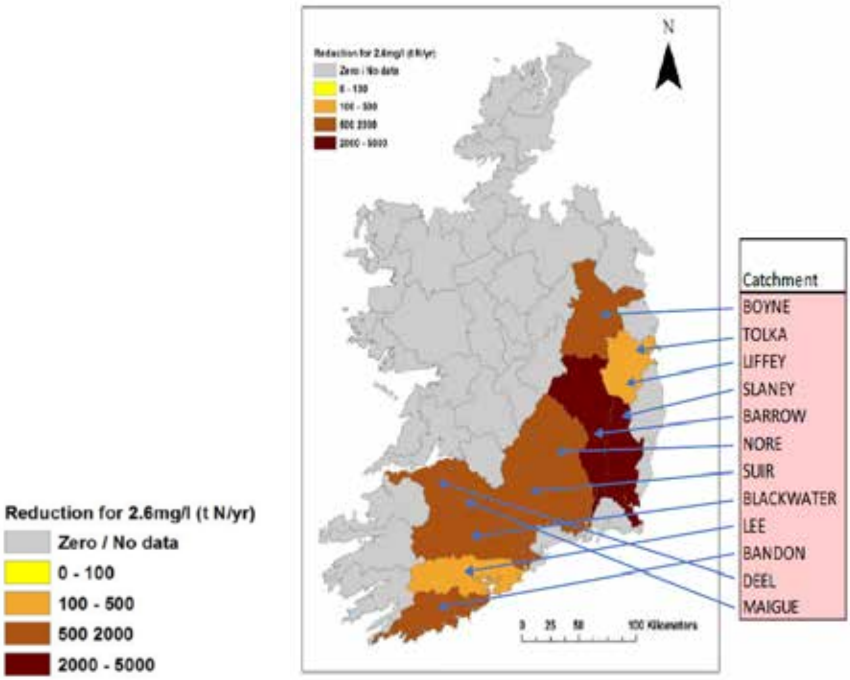

Figure 1. *Map indicating catchments where a reduction in nitrogen losses is required. Source: EPA*

Conclusion

Ireland has been set a target of 'good status' by the EU Water Framework Directive for all waters by 2027. However, data from the EPA indicates that water quality is declining with elevated nitrate levels prevalent in catchments located in the south and east of the country. The ASSAP advisory service is free and confidential and is available to farmers in 190 PAAs with advice provided to farmers to minimise the impacts of agriculture on water quality.

Organic dairy production

Joe Kelleher[1] and Elaine Leavy[2]

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Summary

- Organic dairy production can be profitable
- There is currently strong market demand for organic milk
- Good clover sward content and soil fertility are key to maintaining a higher stocking rate.

Introduction

Organic dairying is a relatively small but growing sector within the dairy industry in Ireland. Latest figures from the Department of Agriculture, Food and the Marine (DAFM) show that there are 62 organic dairy operators with an average herd size of 79 cows (2019). Organic dairy farming offers an excellent opportunity as a profitable enterprise option but success is dependent on the adoption of best practice organic methods and having a market price secured for organic milk. Important issues include grassland management, winter feeding (especially for winter milk producers), housing and cow health.

Market

The market for organic milk looks positive. There are five main processors (Arrabawn, Aurivo, Glenisk, The Little Milk Company and The Village Dairy) handling most of the organic milk. Some individual farmers also bottle and sell direct. Demand at present exists for both organic summer and particularly winter milk. Premium prices are available for organic milk compared to conventional milk with relatively larger premiums available for winter milk. Contracts are available from some of the processors. In recent years winter milk price has been 55–60 c/litre for five months. Summer milk price has ranged from 35–44 c/litre.

Profitability

Organic dairy farming compares favourably to conventional systems. On a return per litre basis, some of the most profitable dairy farmers in the country are farming organically. This is clearly in evidence at Teagasc/DAFM organic demonstration farm walks. Maintaining high output levels, coupled with lower production costs, and achieving a premium market price for milk contribute to higher margins on organic farms.

Stocking rate

There is a stocking limit of 170 kg nitrogen (N)/ha for organic dairy production. Organic farming is being practiced successfully in Ireland at stocking rates up to this level. Average stocking rate is in the region of 1.4 LU/ha. The level of clover grown on-farm correlates strongly with the stock carrying capacity of the farm.

Organic conversion period

Grass based farms go through a 24-month conversion period on the land during which time it must be managed to full organic standards but milk cannot be supplied to an organic market. All producers must register with an organic certification body at the start of the conversion period. The cows must be managed to full organic health and welfare/housing standards and fed to full organic standards (100% feed from organic sources) for at least the last six months of conversion. Note: from the conversion start date, all feed must be GMO-free.

Housing and bedding

More space is generally required compared to conventional standards. In organic farming, animals must have access to a bedded area. A 100% slatted area is not permitted. Cubicles are also permitted but they must have dry bedded material on top of the cubicle. Rubber mats alone on cubicle beds are not a substitute for bedding. Straw, sawdust (un-treated) and woodchips for bedding of animals are permitted.

Animal health

An animal health plan is prepared by your veterinary surgeon and submitted as part of the conversion plan prior to conversion. In essence, animals are treated if a treatment is required but under more formal arrangements. Withdrawal periods may have to be doubled or trebled under organic standards. For mastitis, antibiotics can be used in clinical cases with supervision from a vet and where no other treatments would be effective. Two courses of antibiotics within 12 months are permitted, otherwise the cow is removed from the milking herd.

Soil fertility

Good clover swards (especially white clover for grazing and red clover for quality silage), and targeted use of lime, farmyard manure and slurry mean that coping without chemical fertiliser can be managed effectively. Cattle slurry (from conventional grassland based farms), dairy sludge, organic/free range poultry manure and certain mineral fertilisers are amongst the fertilisers that can be imported onto organic farms.

Conclusion

Organic farming can be very profitable. There is currently strong demand from some processors for organic milk. With good levels of clover, stocking rates can be maintained at 1.4 LU/ha. Soil fertility is important in establishing good clover sward content.

Forestry — farm planning and integrating forestry

Tom Houlihan

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Summary

- When deciding to plant, setting clear objectives and timely planning are essential
- A rang of suitable DAFM planting categories can be considered to meet financial, social and environmental enhancement objectives
- Comprehensive decision supports are available from Teagasc.

Introduction

New farm forest and woodland creation can deliver a range of future benefits on your farm. Whether small or larger areas are involved, setting clear objectives and timely planning are central to success. The current Department of Agriculture, Food and the Marine (DAFM) Forestry Programme includes 12 Grant and Premium Categories (called GPCs). These planting options include productive conifers and broadleaves, native woodland and agroforestry (Figure 1).

GPC 3: 70% spruce, 15% diverse
€510–520/ha/yr (15 years)

GPC 4: Scots pine
€590–€600/ha/yr (15 years)

GPC 6: Oak
€645–660/ha/yr (15 years)

GPC 8: Birch/alder
€605–620/ha/yr (15 years)

GPC 9/10: Native woodland
€665–680/ha/yr (15 years)

GPC 11: Agroforestry

Figure 1. *Examples of available GPCs with current annual premium rates and payment durations*

Selecting suitable planting categories

New farm forests can incorporate either individual or a mix of planting categories, which are suited to prevailing site conditions. For example, combining even a small native woodland parcel with a transition area of natural vegetation adjacent to a watercourse can provide a feature that intercepts nutrients or silt runoff from adjacent land uses, thereby protecting and enhancing water quality (Figure 2). This '**Woodland for Water**' measure provides an ideal buffer against potential nutrient or sediment reaching sensitive watercourses. It can easily work in combination with and facilitate adjoining land uses such as mainly commercial forests (e.g. GPC 3) or productive agriculture.

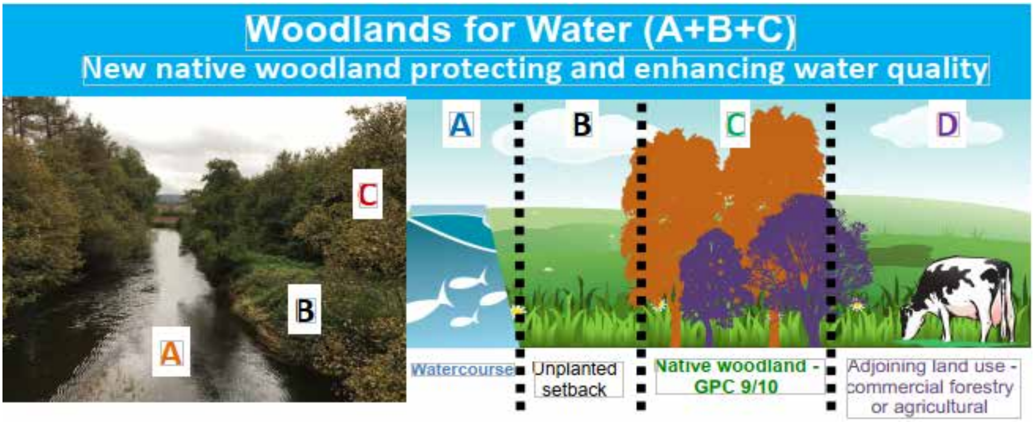

Figure 2. *Woodland for water measure combing an unplanted setback and new native woodland (GPC 9/10)*

Financial fitness

Forestry can play a significant role in enhancing financial viability on the farm. As well as attractive establishment planting grants and annual premia, gaining an appreciation of potential high financial returns from future harvests is critical. The returns from a forest enterprise will depend on a range of factors, including the tree species selected, the growth rate (yield class) and the forest management approach adopted. In general, productive conifer species with a relatively short forest cycle (rotation) provide the highest financial returns. The Teagasc Forest Investment Valuation Estimator (FIVE) is a beneficial tool used by forestry advisors in collaboration with clients to help inform decision-making in relation to potential land use and forestry. FIVE provides indicative analysis and decision support, particularly in relation to reviewing pre-planting options and comparing criteria such as species, yield classes and forest rotation lengths according to landowners' preferences and objectives.

Carbon benefits

The planting of new forests is also a significant land-based measure to help address the effects of climate change. While not a silver bullet, farm forests and woodlands, in appropriate locations, can significantly benefit the carbon efficiency and green credentials of farm businesses including reducing their carbon footprint. Teagasc, in conjunction with DAFM and Forest Environmental Research and Services (FERS) Limited, has developed an online Forest Carbon Tool (www.teagasc.ie/forestcarbontool). The tool is particularly useful when considering the relative carbon-removal merits of different forest categories and planting combinations.

Further information

The forestry option has many benefits but it is important that farmers and landowners are fully aware of all implications for the farm in advance of informed decision-making. Teagasc forestry staff provide independent and objective advice that supports whole farm planning and the appropriate forest options tailored to your objectives and farm characteristics. Contact your local Teagasc forestry staff and log onto www.teagasc.ie/forestry for further information.

ONE HEALTH APPROACH

Comparing the options for screening herds for Johne's disease

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Summary

- Testing individual cattle for Johne's disease is unreliable due to the poor sensitivity of available tests
- Herd-level testing is better than individual animal testing but is dependent upon test characteristics and available resources
- Research at Moorepark is evaluating herd-level testing options for suitability in a national Johne's disease control programme.

Introduction

Johne's disease is an infectious disease of cattle and other ruminants caused by the bacterium *Mycobacterium avium* subspecies *paratuberculosis* (MAP). Tests for MAP typically have low sensitivity (Se - proportion of diseased animals that test positive on testing) and/or low specificity (Sp - proportion of healthy animals which test negative on testing) which leads to low confidence in the result of a test conducted at individual animal level. Control programmes, therefore, are based on testing and infection classification at herd-level. This paper summarises the published estimates for the Se and Sp of these tests at herd-level (herd sensitivity and herd specificity).

Herd-level testing methods for Johne's disease

Whole-herd ELISA

This involves blood or milk sampling of all adult animals, usually over two years old. The samples are tested by ELISA to detect antibodies to MAP. A positive herd may be considered as such when at least one animal is positive on ELISA testing, or an arbitrary proportion of animals are positive on ELISA testing (e.g. >2%).

Whole-herd ELISA + ancillary PCR

Similar to the 'whole-herd ELISA scenario (above), blood or milk samples are taken from adult animals and are tested by ELISA. Any positive animals are subsequently faecal-sampled and samples are tested for MAP using culture or PCR.

Bulk milk tank ELISA

A sample of milk is taken from the bulk milk tank and tested by ELISA to detect antibodies to MAP.

Bulk milk PCR/culture

A sample of milk is taken from the bulk milk tank and tested by culture or PCR to detect MAP bacteria directly.

Pooled faecal testing

Individual faecal samples are taken from adult animals and distributed into pools of 5–10 samples per pool. The pooled samples are then tested by culture or PCR for MAP bacteria. A positive herd has at least one positive pool result.

Environmental sampling

Multiple samples of manure and slurry are taken from adult animal housing and handling areas. The samples are combined and mixed well to form composite manure samples which are tested by culture or PCR for MAP bacteria. A positive herd has at least one positive composite sample.

Table 1. Summary of Johne's disease test characteristics		
Screening test	Herd sensitivity (%)	Herd specificity (%)
Whole-herd ELISA[a]	56–95	0–96
Whole-herd ELISA + PCR[a]	60–86	100[c]
BMT ELISA	8–30	95–100
BMT PCR/culture	0–77	100[c]
Pooled faecal testing[a]	54–94	100[c]
Environmental sampling[b]	24–79	100[c]

[a]From field studies using culture methods as a reference test; [b]From studies evaluating a protocol using six composite samples; [c]Herd specificity can be assumed to be 100% due to direct detection of MAP bacteria

The reported herd-level test characteristics for MAP demonstrate considerable differences in test accuracy. For example, whole-herd ELISA testing has potentially high herd Se (56–95%) but low Sp. This will result in many non-infected herds being classified as infected. In contrast, pooled faecal testing has shown similarly high herd Se but has 100% Sp due to direct detection of MAP bacteria. The poor Sp of whole-herd ELISA testing can be overcome by ancillary faecal testing of ELISA-positive animals, with an associated reduction in herd Se. Bulk milk tank ELISA has poor Se but requires only one sample per herd, with no animal handling required. Similarly, environmental sampling requires no animal handling and has relatively high herd Se (24–79%). Decision-makers must balance the test characteristics with the resources available (funding, laboratory capacity) to identify the most suitable herd test method(s) in a population. Research at Moorepark is currently evaluating herd-level testing options for Johne's disease.

Conclusion

While testing individual cattle for Johne's disease is unreliable, testing a herd is better but there are numerous options for herd-level testing. Choice of testing option is dependent upon test characteristics and available resources.

Herd environmental sampling to detect Johne's disease in dairy herds

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Summary

- The performance of herd environmental sampling (HES) was compared to the current standard herd test for detecting Johne's disease
- The current standard herd test (blood and faecal testing) detected more infected herds than herd environmental sampling
- More analysis is required to estimate the herd sensitivity and herd specificity of HES in Irish dairy herds.

Introduction

Diagnostic tests for Johne's disease generally have low herd sensitivity (Se - proportion of infected herds that test positive using the test) and/or low herd specificity (Sp - proportion of non-infected herds that test negative using the test). The current method of testing herds for Johne's disease in Ireland involves whole-herd blood or milk sampling and testing of the samples by ELISA for antibodies to *Mycobacterium avium* subspecies *paratuberculosis* (MAP). An animal that tests positive by ELISA must have a faecal sample tested by PCR or culture to confirm infection with MAP. This test method has a herd Se of approximately 60% and herd Sp of 100% in Irish herds. Herd environmental sampling (HES) is an alternative method of screening herds for Johne's disease. It is a form of faecal pooling whereby samples of manure and slurry from animal housing are mixed together to form a number of composite manure samples. These composite samples are then tested in a lab for the bacterium that causes Johne's disease, MAP, by culture or PCR. A herd is identified as infected if at least one of the composite samples tests positive for MAP.

In order to determine whether HES could be part of the Irish Johne's Control Programme (IJCP), an experiment was conducted by Teagasc Moorepark to compare HES with the current IJCP herd MAP testing method.

Materials and methods

One hundred and twenty-two dairy herds were recruited from the IJCP for the study. The farms were visited between 2019 and 2021 to conduct herd environmental sampling and blood sampling during winter housing.

HES

The most common HES protocol published in the scientific literature was used, taking six composite manure/slurry samples per farm. A composite sample consists of mixing together at least four separate "grabs" of manure or slurry from different sites at a specific location. Six composite samples in total were taken per farm from areas of high cow or manure concentration:

- Two composite samples from main cow housing
- Two composite samples from slurry storage
- Two composite samples from other areas e.g. collecting yard, calving pen, sick cow pen.

If no other areas available, then extra samples taken from main cow housing.

The samples were tested by faecal PCR for MAP in an approved laboratory. A herd was defined as positive if at least one sample was positive on faecal PCR.

Serum ELISA + ancillary faecal PCR (sELISA +fPCR)

The herd testing protocol of the IJCP was followed for whole herd ELISA testing: in each herd all animals over two years old were blood sampled and the samples tested by ELISA for antibodies to MAP. Any animal that tested positive by ELISA was faecal-sampled and the faeces tested by PCR to confirm MAP infection. A herd was defined as positive if at least one animal tested positive on faecal PCR.

Results

The results for both herd test methods are illustrated in Table 1. Ninety-seven herds had complete test results for both test methods. Seventeen herds were identified as infected overall (three positive on both tests, 12 positive on serum ELISA + faecal PCR (sELISA + fPCR) only and two positive on HES only). Fifteen herds were identified as infected using sELISA + fPCR. Of these, only three herds were also identified as infected by HES. Five herds were identified as infected by HES, but two of these herds were negative on sELISA + fPCR. The majority of herds (82%) tested negative on both tests.

Table 1. Comparison of herd environmental sampling (HES) with standard blood and faecal herd testing for MAP using sELISA + fPCR (no. herds)

HES	sELISA + fPCR		Total
	Positive	Negative	
Positive	3	2	5
Negative	12	80	92
Total	**15**	**82**	**97**

Conclusion

HES is a potentially useful alternative herd testing method for Johne's disease due to the low number of samples required per herd and the fact that there is no animal handling involved. However, in this study, HES detected fewer infected dairy herds than the current standard method of testing herds for MAP in Ireland. Neither test detected all of the infected dairy herds. Further analysis is required to accurately estimate the herd sensitivity and herd specificity of HES in Irish dairy herds to determine if it is suitable for use as a herd screening test.

Ensuring milk and dairy products are free of chlorine related residues

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Summary

- Eighty-three percent of commercial milk samples tested during 2020 were within the TCM target of 0.00124 mg/kg and 97% of samples were within the chlorate maximum residue limit (MRL) of 0.01 mg/kg
- Residues in bulk tank milk have been reduced through good management practises and gradual removal of chlorine containing products from milking equipment cleaning protocols
- Chlorine based products should not be used for cleaning of milking equipment or processing plants since 01 January 2021.

Introduction

The significance of residues in dairy food production is increasing as evidenced by complex legal, regulatory and guiding recommendations on acceptable levels in dairy products. This is supported by highly sensitive detection methods applied to milk, which can detect residues at low limits of quantification. Research has focused on residues associated with use of chlorine-based detergent products on-farm, the entry of their by-products into milk/dairy products and strategies for their mitigation. Good cleaning and disinfection practices are essential to ensure bacteriological quality of milk during production on-farm. However, disinfection by-products formed and their potential for accumulation within dairy products such as butter and milk powders (often used as ingredients in infant milk formula) has led to trichloromethane (TCM) and chlorate emerging as residues of concern.

TCM

Contact of chlorine with milk can result in the formation of TCM, which accumulates in the fat fraction in milk and, hence, is enriched in high fat derivatives such as cream and butter. Germany is one of the most important export markets for Irish butter and German standards on TCM levels in food govern specification compliance of countries exporting there. The main control strategies on the use of chlorine on farms included adherence to recommended chemical usage rates, adequate rinsing (as part of the washing protocol) and limited reuse of detergent solutions. Routine testing of milks at the Teagasc laboratory together with advice by milk quality personnel and implementation by milk producers of the above guidelines facilitated reaching the initial national TCM target of 0.002 mg/kg, and subsequent targets of 0.00155 mg/kg and more recently 0.00124 mg/kg in milk, with a corresponding target of 0.0124 mg/kg in butter. This is now further assisted by the removal of chlorine from cleaning protocols.

Chlorate

The presence of chlorate in milk arises primarily from the use of chlorinated detergents and water for cleaning and sanitation of equipment on the farm and within processing plants. Degradation of hypochlorite and formation of chlorate occurs during storage of concentrated hypochlorite solutions and is dependent on concentration, storage temperature and pH of the solution. Thus, entry of chlorate into the dairy chain through cleaning/disinfection practices depends on the level of chlorate formed in the stored hypochlorite solution and on the efficiency of removal of chlorate residues during rinsing after disinfection. While total removal of chlorine detergents at farm level was considered initially as a strategy to solve the chlorate residue problem, potential negative implications for the microbiological quality of milk also had to be considered. Subsequent studies demonstrated that chlorine free cleaning was effective when examined for a three month period, while detergent usage rates, water temperature and rinsing protocols were closely monitored. New cleaning protocols were subsequently developed together with guidelines on the key steps required for cleaning milking equipment in a chlorine free environment (https://www.teagasc.ie/animals/dairy/milk-quality/chlorates/); this allowed an initial transition to chlorine-free cleaning on-farm without creating microbiological challenges. A further study showed improved microbial quality of milk on farms using chlorine-free cleaning protocols compared to those that continued to use chlorine based cleaning. Ireland has instated a resolution to remove all chlorine based detergents from cleaning protocols on-farm and within processing plants from January 2021. This involves replacing chlorine based detergent products with alternatives such as inorganic acid cleaning. But it is crucial that parameters of this chlorine-free washing protocol be carefully adhered to, e.g. use of the recommended volume of water at the recommended temperature, appropriate volumes and combinations of cleaning products used properly, and strictly controlled water disinfection, with, for example, peracetic acid (if necessary). This should ensure full compliance, and quality milk production, in terms of microbial load and TCM/ chlorate residue levels. Most milk processing plants have now invested in chlorine gas treatment systems for disinfecting water, in place of the traditional method using sodium hypochlorite, in order to avoid any potential risk of water containing chlorate coming in contact with product. Adequate training of personnel in milking plant cleaning is important and support is available from milk quality and Teagasc advisors, chemical and equipment suppliers.

Conclusion

More than 40,000 milk samples were analysed for TCM (by Teagasc) during 2020 with 83% of samples within the TCM target of 0.00124 mg/kg. Continued routine monitoring of milk supplies show the milks to be consistently within target. Just 3% of samples exceeded the chlorate MRL of 0.01 mg/kg. This has been achieved in parallel with the gradual removal of chlorine containing products from the cleaning protocols of milking plants. While the risk of chlorine residues has largely been eliminated from the dairy supply chain, it is critical that microbial hygiene and quality is not compromised, and that there is an ongoing vigilance regarding the emergence of other potential residues from the use of replacement (for chlorine) cleaning products.

Strategies to reduce lameness on your farm

Natasha Browne and Muireann Conneely

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Summary

- Lameness prevalence in dairy cows in Ireland is 7.9% at grazing and 9.1% when housed
- Regular mobility scoring and footbathing, and selecting cows with a negative PTA for lameness should be considered
- Reducing stones in paddock gateways, avoiding slats on roadways and avoiding sharp turns at the parlour exit are key to preventing lameness
- Lame cows should be treated promptly and provided with pain relief.

Introduction

Lameness is a painful disease that results in suffering for dairy cows, and damages the sustainable and welfare-friendly image of Irish agriculture. Lameness also has negative financial implications due to reduced milk yield and fertility rates, and increased culling and treatment costs.

Teagasc lameness study

A study was carried out by Teagasc to determine the prevalence of dairy cow lameness during the grazing and housing periods, and to identify potential risk factors for lameness. Ninety-nine pasture-based Irish dairy farms were visited when cows were at grass (April–September 2019), and 85 of those farms were visited on a second occasion when the cows were housed (October 2019–February 2020). At each visit, all cows in the dairy herd were mobility scored. Mobility scoring involves scoring each cow individually from zero (good mobility) to three (severely impaired mobility) as they walk. Alongside daily lameness detection, regular mobility scoring enables early detection of lameness (and therefore prompt treatment), and enables farmers to compare lameness prevalence in their herd with others and to observe how lameness prevalence is changing in their herd over time. A questionnaire was completed with the farmer at each visit to determine lameness prevention, detection and treatment methods currently used on Irish dairy farms. Infrastructural measurements and observations were made of milking facilities, housing and cow roadways. Individual cow data (age, parity, days in milk, yield, breed, EBI) were provided by ICBF. All questionnaire, infrastructural and ICBF data were included in the risk factor analysis.

Lameness prevalence

Average lameness prevalence was 7.9% during the grazing period and 9.1% during housing (Figure 1). The number of severely lame cows observed during the grazing and housing periods was 0.7% and 0.8%, respectively. The most prevalent lesion types found in lame cows were white line disease, sole haemorrhages and overgrown claws.

Lameness detection and treatment

Only 1% of farmers mobility-scored their herd, and over half of farmers were unfamiliar with mobility scoring. Prompt treatment is vital for lameness recovery, yet 28% of farmers usually waited more than two days to treat a lame cow once detected, and 21% waited for multiple cows to become lame before treating. Less than 10% of farmers reported giving pain relief to severely lame cows and only 3% to mildly lame cows. Providing pain relief to all lame cows, alongside hoof trimming where necessary, dramatically improves the rate of recovery and improves the welfare of the animal. Twelve percent of farmers maintain severely lame cows in a separate group near the milking parlour. Minimising walking distances for lame cows is advisable to reduce discomfort.

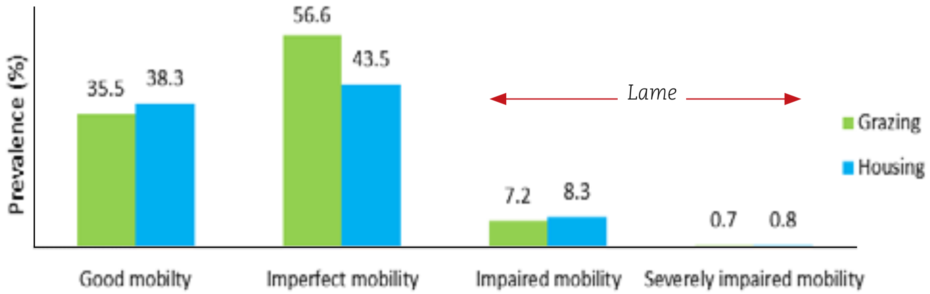

Figure 1. *Average lameness prevalence during the grazing (99 farms) and housing (85 farms) periods on Irish pasture-based dairy farms*

Lameness prevention — management and infrastructure

Cows with a negative predicted transmitting ability (PTA) for lameness (i.e. lower genetic susceptibility) had a reduced risk of lameness compared to a positive PTA. Lameness PTA can be found in the EBI health sub-index. This indicates the importance of bull selection as a long-term lameness prevention method. Despite 44% of farmers reporting that they have digital dermatitis (Mortellaro) on their farm, only 31% of farmers regularly footbath (>12 times per year). Footbathing is a key measure in the control of digital dermatitis. Farmers should communicate with their vet to determine the best footbathing protocol.

Results showed that the presence of stones in paddock gateways and slats on roadways near the collecting yard were risk factors for lameness. Stony and uneven surfaces may damage the hoof and result in the formation of white line lesions. Gateways may be high-risk areas due to crowding and pushing as cows enter or leave the paddock, resulting in cows not being able to choose their hoof placement. This study also showed that when cows had to make a sharp turn as they leave the milking parlour, lameness risk increased. This should be considered in the construction and maintenance of parlours.

Conclusion

Early detection and treatment is recommended to reduce lameness. Optimal infrastructure and management practices are also key to preventing lameness and reducing herd lameness prevalence.

Acknowledgements

Dairy Research Ireland and the Walsh Scholarship Programme.

How well does your farm compare? Benchmarking indicators of welfare on Irish dairy farms

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Summary

- Good dairy cow welfare is essential for a sustainable and productive herd
- Lameness, body condition, skin damage, tail injury, nasal discharge and reaction to humans are indicators of dairy cow welfare that can be used to create benchmarks
- Benchmarks for comparing your farm welfare performance against that of other farms can help you to identify areas for improvement.

What is welfare and why is it important?

Good welfare is a key factor in maintaining a sustainable and productive dairy herd. Health is an important aspect of good welfare, but a cow must also be able to perform important natural behaviours (e.g. lying and grazing) and avoid negative emotional states (e.g. hunger, fear and pain). Problems with individual aspects of welfare can impact the cow overall and lead to unnecessary pain, suffering and reduced productivity. Additionally, consumers increasingly want to know that their food comes from content and well-cared for animals, and maintaining consumer confidence in the dairy sector is vital to safeguard its future. So in order to ensure a sustainable and productive dairy sector, it is important that we continually monitor dairy cow welfare and improve it whenever possible. Monitoring the prevalence of key welfare indicators, such as lameness, body condition score (BCS), skin damage, tail injury, nasal discharge and reaction to humans, is an effective method of assessing welfare. Establishing benchmarks for such indicators of welfare can be a useful tool in helping to achieve this goal.

What are benchmarks and how can they help improve welfare?

A benchmark is a standard against which other measures are compared in order to determine how well something is performing. By measuring particular welfare indicators on farms we can identify the current range in their prevalence, and use this information to determine the best achievable level for each welfare indicator according to current practices. Farms that excel in a particular welfare indicator can serve as a benchmark for other farms to compare with, helping to identify where the most improvement is necessary.

Establishing benchmarks for welfare on Irish dairy farms

A welfare assessment on 82 Irish dairy farms recorded the herd prevalence for common welfare indicators: lameness, BCS outside seasonal targets (2.75–3.25 during grazing), skin damage (hair-loss, lesions or swelling), tail injury (breaks and lacerations), nasal discharge and human avoidance response (retreat at >1 m from an approaching observer). The average prevalence of each indicator was calculated across all farms. Additionally, the prevalence observed on individual farms was ordered from lowest (best) to highest (worst) and the top and bottom performing 20% of farms in each welfare indicator were identified (Figure 1).

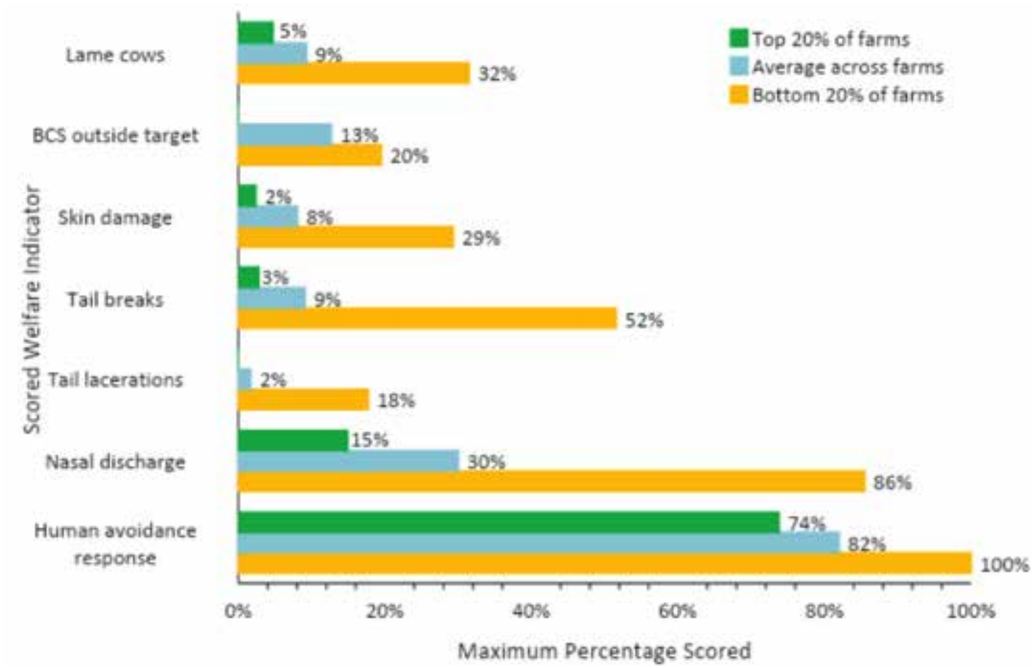

Figure 1. *The maximum percentage of cows scored for each welfare indicator on the top- and bottom-performing 20% of farms as well as the average across all 82 Irish dairy farms visited during the grazing season*

The level of the top 20% of farms represents the best performance achieved for each indicator, which can serve as an attainable target benchmark for other farms in the Irish dairy system. Farms outside these targets, particularly those within the bottom performing 20% of farms, are capable of the most improvement. These farms may benefit from evaluating their current management practices in consultation with their vet and farm advisors to identify areas for potential improvement. Even those farms within the upper benchmark range are capable of continued improvement, in turn raising the benchmark for the highest achievable level of each welfare indicator.

Conclusion

The prevalence of key indicators of welfare on the top performing farms can be used to establish achievable welfare targets for Irish dairy farms. Conducting a simple assessment of these welfare indicators in your own herd will allow you to use the benchmarks identified here as a tool for comparison to identify areas for improvement of dairy cow welfare.

Acknowledgements

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Chlorine-free cleaning of milking equipment

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Summary

- With hot wash cleaning, the recommended temperature of the detergent solution at the start of circulation is 75/80°C and at the end of circulation is >45°C
- If cold wash cleaning is used, higher detergent levels are required to compensate for the absence of hot water
- Automatic washing systems must be recalibrated when new detergent products are introduced.

Introduction

The cleaning of milking equipment using chlorine-based detergents can lead to two residues in milk (Trichloromethane and Chlorate). The removal of chlorine from cleaning routines significantly reduces the risk of these residues being detected in milk and subsequently in dairy products. Chlorine-free cleaning was introduced to dairy farms in Ireland in 2019 after initial research studies demonstrated that microbiological quality could be maintained and residue levels minimized in the absence of chlorine. Further studies on commercial farms indicated a positive impact of chlorine-free cleaning on milk quality, when protocols were adhered to and guidance was given to farmers on best practice. Successful cleaning without chlorine requires changes to previous cleaning protocols. Five new chlorine-free protocols for milking machine cleaning and three such protocols for bulk milk tank cleaning have been developed. The protocol chosen will depend on the level of automation, the size of the milking plant and the availability of hot water. Details of each individual protocol can be found at this link: https://www.teagasc.ie/media/website/animals/dairy/research-farms/Chlorine-free-wash-routines_2020.pdf

Steps involved in changing to chlorine-free cleaning

When changing from chlorine based detergent steriliser products to chlorine-free products, it is critical that the automatic detergent dosing systems for both machine and bulk milk tank **are re-calibrated**. This is necessary to ensure the correct uptake of the different detergent products, as uptake rates may be lower for products that do not contain chlorine (due to a higher sodium hydroxide content than the products previously used). It is also important to check if the correct quantity of detergent product is being used; the quantity used should be as indicated on the drum label and is based on the quantity of water being used. The recommended water usage rate for the detergent solution is nine litres per milking unit. A detergent rate of 0.7% is recommended with hot water, while 1% is recommended if cold water is used. The exact quantity of water being used can be established by measuring the dimensions of the water trough.

What is different about chlorine-free products?

Chlorine-free cleaning protocols involve the use of various combinations of caustic detergent (sodium hydroxide), acid (phosphoric/nitric), peracetic acid/hydrogen peroxide and hot water. It is recommended not to recycle liquid based sodium hydroxide detergents, however powder based detergents may still be recycled on one occasion due to the higher sodium hydroxide levels (60/80%) contained in these products. It is advised that liquid based products have a minimum sodium hydroxide content of 21%. Powder based products are most suitable where manual washing is normally used and for small to medium sized plants, and are less suitable for automatic cleaning, whereas, liquid sodium hydroxide and acid based products (acid descale or milk-stone removal) are ideally suited for automatic cleaning. All of the new chlorine-free protocols require more regular use of acid products for the removal of mineral deposits from milking equipment surfaces. A number of new acid based 'all for one' products are now available, which can descale, sterilize and clean and are chlorate-free.

Peracetic acid: a replacement for chlorine

Cleaning protocols can include the use of peracetic acid in an additional rinse and can be used twice daily. It is advised that the caustic detergent solution be rinsed thoroughly from the plant before the additional rinse containing the peracetic acid. This is important because of (i) safety concerns and (ii) the caustic alkaline solution would neutralize the acid solution making it less effective. Further rinsing of the plant after the rinse containing the peracetic acid is not required provided that (i) the manufacturer recommended usage rate is adhered to (generally 60 ml/45 L) and (ii) the routine is completed at least one hour prior to the next milking occasion.

Hot water for daily cleaning

Hot water is a key component of chlorine-free cleaning. A minimum of seven hot washes per week are required with liquid chlorine–free cleaning and the cleaning protocols are designed to target the hot washes after AM milking, using night rate electricity which is approximately 50% cheaper than day rate. The recommended temperature of the detergent solution at the start of circulation is 75/80°C and at the end of circulation is >45°C. The inclusion of a warm water post milking rinse (25°C) would help to maintain the required temperature for the wash cycle. Furthermore, allowing the first 20 L of the hot wash solution to run to waste before the remainder of the solution is circulated would also assist in maintaining the detergent solution temperature. The length of the hot wash cycle should not be greater than 8/10 minutes.

Conclusions

Successful chlorine-free cleaning requires increased use of hot water, acid based products and re-calibration of automated detergent dosing equipment. While choosing a good quality detergent product is important, following the steps of one of the recommended wash protocols is critical.

Evaluating the effectiveness of commercial teat disinfectant products sold in Ireland

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Summary

- Effectiveness of specific products/ingredients is dependent on the bacterial strain
- There is a range of alternative teat disinfectant ingredients available which are comparable to iodine-based products.

Introduction

Teat disinfection is a proven mechanism by which transmission of bacteria (from cow to cow and within the environment) can be reduced, which in turn can reduce or prevent mastitis incidence. Previous studies have demonstrated that cows receiving post-milking disinfection had a lower rate of intra-mammary infections (IMIs) caused by *Staph. aureus* and *Str. uberis* than cows that did not receive post-milking disinfection. But the degree of success of teat disinfection in reducing new IMIs may be influenced by the product active ingredient. Iodine is a broad-spectrum disinfectant and has been shown to be highly effective against mastitis. However, there is now a focus on teat disinfectants with alternative ingredients to iodine, due to concerns about iodine residues in milk. The disc diffusion method used to measure the effectiveness of antibiotics was adapted to determine the ability of a teat disinfectant product to inhibit the growth of a range of bacterial organisms.

Teat disinfectant information

Ninety-six commercially available teat disinfectant products with different active ingredients of varying concentrations were tested against the three main mastitis-causing bacteria in Ireland, *Staph. aureus*, *Str. uberis* and *E. coli.*, using the disc diffusion method. This method involved soaking blank 6 mm paper discs in the test disinfectant for 30 s, the discs were then placed onto the agar test bacteria and plates were then incubated at 37˚C for 24 hours. After incubation, the zones of inhibition were measured using an electronic caliper. The higher the zone of inhibition the more effective the disinfectant was against the test bacteria. These ingredient groups included; chlorhexidine, chlorine dioxide, diamine, iodine, iodine combined with lactic acid, lactic acid, lactic acid combined with chlorhexidine, lactic acid combined with hydrogen peroxide and lactic acid combined with salicylic acid.

Results

Disinfectant groups (Table 1) and individual products within groups differed in effectiveness depending on the bacteria present. The lactic acid combined with hydrogen peroxide disinfectant group which contained just one product achieved the largest zones of inhibition for all three bacterial strains (*Str. uberis* [27.9 mm], *Staph. aureus* [25.1 mm] and *E. coli* [19.3 mm]), followed by the chlorine dioxide group (*Strep. uberis* [21.3 mm], *Staph. aureus* [19.9 mm] and *E. coli* [18.1 mm]). The chlorine dioxide ingredient group consisted of five different teat disinfectant products with a range in concentrations from 0.0157% to 0.038% w/w. The product within this group containing the highest level of chlorine dioxide (0.038% w/w), resulted in the largest zones of inhibition of 22.8 mm, 22.4 mm and 21.5 mm for *Str. uberis*, *Staph. aureus* and *E. coli*, respectively. Twenty-one products tested contained a combination of lactic acid and chlorhexidine. These products ranged from 1% w/w to 5% w/w lactic acid and 0.03% w/w to 1.5% w/w chlorhexidine. The individual product containing lactic acid combined with 0.6% w/w chlorhexidine resulted in the largest inhibitions against *Str. uberis*, *Staph. aureus* and *E. coli* of 22.3 mm, 21.7 mm and 20.3 mm, respectively. Twenty-five products belonged to the chlorhexidine group. These products ranged in chlorhexidine concentrations from 0.42%-1.49% w/w. Within this group, the product containing 0.74% w/w chlorhexidine resulted in the largest zone of inhibition of 21.4 mm for *Str. uberis*. Fifteen products with a range in lactic acid concentration from 1.76% w/w to 8% w/w lactic acid were tested. Within this group, the product containing 4% w/w lactic acid resulted in the largest inhibition of 22.4 mm and 18.2 mm for *Str. uberis* and *E. coli*, respectively. Based on these findings, if lactic acid is used as the main ingredient then ≥4% w/w concentration is advised and when combined with chlorhexidine a ≥2.5 % concentration is satisfactory. Likewise, when chlorhexidine is the sole ingredient then a ≥0.5% concentration is advised, whereas, a ≥0.3% is sufficient if combined with lactic acid.

Table 1. Zones of inhibition (mm) for *Str. uberis*, *Staph. aureus* and E. coli across each ingredient group tested using disc diffusion

Ingredient group	*Str. uberis*	*Staph. aureus*	*E. coli*
Chlorhexidine	17.9	16.3	16.2
Chlorine dioxide	21.3	19.9	18.1
Diamine	16.1	14.5	13.6
Iodine	19.4	14.6	11.5
Iodine and lactic acid	21.2	14.3	10.9
Lactic acid	19.7	16.6	12.4
Lactic acid and chlorhexidine	19.5	17.5	15.7
Lactic acid and hydrogen peroxide	27.9	25.1	19.3
Lactic acid and salicylic acid	18.5	13.2	11.5

Conclusion

Different products/ingredients are more effective against specific strains of bacteria. The concentration of ingredients recommended (as guidelines for use) will depend on the ingredient existing as a sole ingredient or combined with another disinfectant ingredient.

Production of top milk quality on Irish Dairy farms — what's achievable?

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Summary

- Top milk quality is being achieved on Irish dairy farms
- High standards of cleanliness must be maintained to produce top quality milk
- All farms achieving top milk quality use milk recording.

Introduction

Standards of milk quality produced on Irish dairy farms are improving every year, as observed by the reduction in bulk tank milk somatic cell count (SCC). Sixty-five percent of herds now have an SCC less than 200,000 cells/ml compared to 35% of herds in 2013 (*CellCheck*). The National Dairy Council & Kerrygold Quality Milk Awards is a competition that promotes the high standards of milk quality being achieved on Irish farms. Individual farmers are selected by each milk processor as nominees for the competition. These farmers, in most cases, are the overall milk quality award winner within that Co-op. Those nominated undergo a detailed assessment based on milk quality test results and technical reports over a 12-month period. In that assessment, the following key areas are also considered: milk hygiene, dairy and parlour facilities, animal health & welfare, sustainability and the environment. This paper will focus on farm milk quality data including bulk tank SCC, total bacterial counts (TBC) and milk hygiene practices obtained from the top commercial farms with credible quality standards.

Standards presented by milk quality award nominees

The data was gathered over two years (2019 and 2020; n=24 farms). In this study, the farms had an average herd size of 144 cows, which is higher than the national average of 81 cows/dairy herd (Teagasc National Farm Survey, 2019). Dairy farmers in the study produced, on average, 6,095 litres/cow, while the national average was 5,608 litres/cow. Milk composition on these farms displayed an average butterfat of 4.35% and a protein of 3.63%, which are above the national average of 4.20% and 3.55%, respectively. Based on a 30c/L milk price with standard butterfat and protein percentages at 3.6% and 3.3% respectively, a farmer will receive 0.43c/L for every 0.1% increase in butterfat and a 0.65c/L increase for every 0.1% increase in protein.

Regarding milk hygiene, dairy farmers should aim for a TBC monthly average of 15,000 cfu/ml milk or less and levels should not exceed 50,000 cfu/ml milk. The annual weighted TBC average for the farms nominated for this competition was 7,593 cfu/ml, indicating excellent milk quality with consistent milk quality observed across all production months. The national average SCC for 2020 was 178,000 cells/ml (*CellCheck*) with a requirement not to exceed 400,000 cells/ml. The monthly average for the nominated farms was 103,085 cells/ml, which indicates excellent mastitis and SCC control. Milk recording was practised on all farms; this helps farmers to identify optimum performing cows which leads to increased milk production and assists in identifying cows for culling, thus reducing herd-level SCC. Milk recording also allows farmers to identify cows suitable for teat sealing, without the need for antibiotics. The majority (92%) of farms in the study used some level of teat sealing.

Table 1. Milk hygiene and milk composition of nominated farms		
	Average	National Average (2020)
SCC (cells/ml)	103,085 ± 40,745	178,000
Butterfat (%)	4.35 ± 0.27	4.20
Protein (%)	3.63 ± 0.18	3.55
Total milk solids (kg/cow)	491 ± 70	425

Mastitis control and prevention was prominent on these farms with farmers paying great attention to mastitis identification, prevention of cross transfer by cluster disinfection between infected cows on 62% of farms and with all farms implementing some pre-milking teat preparation procedure (Table 2). Milking equipment cleaning practices carried out by farmers in this study included implementing at least 4–5 hot washes per week and an acid descale wash at least once a week. Each farm exercised 'chlorine-free' wash routines which reduces the risk of chlorine related residues.

The Economic Breeding Index (EBI) is a tool to help identify profitable animals. The National average animal EBI in 2019 was 106. In this study, the average animal EBI was 143, putting this group of farmers into the top 25% nationally. The benefit of a high EBI is improved profitability and a reduced environmental footprint per unit of milk produced through a combination of improvements in milk solids output and reproductive performance/ survival.

Table 2. Milking procedures and cleaning practices on nominated farms	
Mastitis control and prevention	% of farms
Stripping daily	54
Pre-milking teat preparation	100
Cluster dipping/cluster flush	62
Equipment cleaning procedure	
Hot water ≥ 4/5 per week	100
Descale ≥ twice/week	77
Water Temp ≥70˚C	92

Conclusion

Top quality milk is being produced on Irish dairy farms. These farms maintain high standards of cleanliness and attention to detail. Milking practices such as milk recording are beneficial for maintaining high levels of milk quality and mastitis control.

Effect of using internal teat sealants only at dry-off on udder health in five commercial dairy herds

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Summary

- Use of an internal teat seal only (without accompanying antibiotics) at dry-off may result in a higher somatic cell count in the following lactation
- Success of selective dry cow therapy is dependent on the level of infection and on the mastitis control measures on-farm
- Using internal teat seal only at dry-off requires a high level of hygiene, proper teat end preparation and use of the correct infusion technique.

Introduction

Blanket antimicrobial dry cow therapy has been successfully implemented in the control of mastitis on the majority of herds in Ireland. This strategy involves infusing all teats of all cows with antimicrobials at the end of lactation to treat existing infections and prevent new infections from occurring during the dry period. However, public concern over antibiotic use and its implication with antimicrobial resistance has led to the development of new regulations that will come into effect from 28th January, 2022. These regulations will restrict the preventative use of antimicrobials in complete herds. An alternative strategy is selective dry cow therapy; this involves only treating cows that have infected quarters or are at a higher risk of infection during the dry period with antibiotics at dry-off. The remaining cows are treated with an internal teat seal only. At the end of lactation in 2018, a study was carried out in conjunction with Kerry Agribusiness on five spring calving dairy herds to evaluate the effect of using internal teat seal only at dry-off on cows with low somatic cell count (SCC).

Selective dry cow therapy trial

A total of 842 cows were recruited across five herds and all herds had an average bulk tank SCC of less than 200,000 cells/mL in 2018. At dry-off, cows that had not exceeded 200,000 cells/mL were randomly treated with an internal teat seal only (TS) or an antibiotic plus an internal teat seal (AB+TS). Quarter level samples were collected on the day of dry-off, after calving in 2019 (between 4–15 days in milk) and in mid-lactation 2019 (average 100 days in milk). These samples were analysed for bacteriology and individual quarter SCC. Individual cow SCC data (captured during milk recording) and bulk tank SCC data were also collected in the 2019 lactation.

Results

Individual cow SCC data was transformed to somatic cell score (SCS) for analysis. Overall, the SCS of the cows in the TS group was higher than the cows in the AB+TS group (P <0.001). The raw unadjusted mean SCC was 125,151 cells/mL for the TS group and 75,713 cells/mL for the AB+TS group. The odds of an infected quarter after the dry period in the cows treated with TS was 5.08 (3.31–7.81) times higher than the cows in the AB+TS group. *Staphylococcus aureus* was the major pathogen present (~90%) on all five farms. When herds were analysed independently, the SCS of the cows in the TS group in Herd 4 was similar to cows in the AB+TS group. Herds 1, 2, 3 and 5 were similar to the overall result; cows in the TS groups had higher SCS compared to the AB+TS group. The raw unadjusted mean SCC for each treatment group in the individual herds can be seen in Table 1. In Herd 2, the SCC of the TS only group was greater than 200,000 cells/mL, which was likely influenced by the high percentage of infected cows within that herd at dry-off (see Table 1).

Table 1. The percentage of infected cows at dry off 2018, calving 2019 and mid-lactation 2019, the average bulk tank SCC at the end of lactation 2018, in the lactation in 2019 and the raw unadjusted mean SCC of TS only and AB+TS cows in the lactation of 2019.

	Herd 1	Herd 2	Herd 3	Herd 4	Herd 5
% of infected cows at dry off 2018	33.3	46.0	10.1	25.0	22.7
% of infected cows at calving 2019	8.9	20.5	3.5	7.0	2.3
% of infected cows at mid-lactation 2019	13.1	25.6	6.0	10.0	6.8
Mean bulk tank SCC at the end of lactation 2018 (Oct-Nov) (cells/mL)	119,000	192,000	121,000	111,000	111,000
Bulk tank SCC in 2019 lactation (cells/ mL)	112,000	180,000	94,000	75,000	75,000
Mean SCC TS only cows (cells/mL)	125,760	221,095	113,831	61,771	99,739
Mean SCC AB+TS cows (cells/mL)	46,936	114,330	82,221	69,919	71,600

Conclusion

The success of selective dry cow therapy is strongly dependant on the ability to correctly identify cows with infection so that the appropriate treatment can be administered. In the current study, the success of using internal teat seal differed by herd; in Herd 4, cows that received internal teat seal had the lowest average SCC in the following lactation, whereas, Herd 2 cows that received internal teat seal had the highest. This study shows that herd prevalence of infection and mastitis control measures need to be taken into consideration when implementing selective dry cow therapy. Routine milk recording and the recording of clinical mastitis cases in the previous lactation is required to correctly identify cows suitable for teat seal only at dry-off. Additionally, a high level of hygiene, proper teat end preparation and using the correct infusion technique are critical when considering teat seal only as a dry-off practice.

Comparison of the effect of two teat seal products on prevention of infections over the dry period and on SCC

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Summary

- There were no differences on quarter somatic cell count (SCC), the probability of having an infected quarter or the chances of a high SCC quarter at calving when using Boviseal or Sureseal at dry-off
- There were eight and four quarters with SCC >200,000 cells/mL at calving when treated with Sureseal and Boviseal, respectively
- This trial should be repeated with more cows to see if there is an impact of teat seal product on the number of high SCC quarters at calving.

Introduction

The use and misuse of antibiotics can contribute to the development of antibiotic resistance. This has led to the development of regulation on the use of veterinary medicines by the European Union (EU) that includes a regulation on the preventative use of antibiotics in groups of animals. A strategy to reduce this preventative use could be to treat cows that demonstrably have infected quarters or are at higher risk of infection with antibiotics at dry-off, while the remaining cows could be treated with teat seal (TS) only. International studies have mostly shown that there is no negative impact on somatic cell count (SCC) when the application of antibiotics are replaced by a TS at dry off in uninfected cows. In Ireland two studies have shown that cows treated with TS only had a higher average SCC and odds of infection in the following lactation compared to cows that received antibiotic and TS.

In this context, it is important to test the ability of different TS products to prevent new intramammary infections over the dry period. A study was undertaken to compare the effect of using two TS products at dry-off in uninfected cows on the level of infections and SCC at calving.

Materials and methods

Twenty-nine low SCC cows (<200,000 cells/mL) from the Teagasc Moorepark herd were enrolled in the study. Quarter samples were collected at dry-off and at calving. The two TS products contained 2.6 g of Bismuth subnitrate (Boviseal Zoetis, Parsippany NJ, USA and SureSeal Norbrook, Newry, UK). The TS were used without antibiotic at dry-off. One brand of teat seal was randomly assigned to one diagonal pair of quarters (e.g. right front and left back) of each cow and the other brand to the remaining pair of quarters in a split udder trial design (Figure 1).

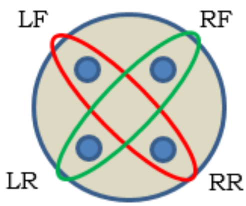

Figure 1. *Schematic of diagonal treatment allocation (red and green circles represent the two types of teat seal)*

Quarters with a bacteria detected at calving were considered infected quarters. Quarters with a high SCC, regardless of bacteria presence were classified as high SCC quarters. The effect of type of TS on quarter SCC at calving and the odds of having an infected quarter and a high SCC quarter at calving were evaluated.

Results and discussion

A total of 115 quarters (one cow had one dry quarter) were treated. Fifty-eight quarters were treated with Boviseal and 57 with Sureseal. One cow had two infected quarters at dry-off determined by bacteriology (treated with Sureseal), however, that cow was uninfected at calving. At dry-off, there were seven high SCC quarters treated with Boviseal and six high SCC quarters treated with Sureseal. Average SCC at dry-off was 158,240 cells/mL and 168,070 cells/mL for quarters treated with Boviseal and Sureseal, respectively.

Table 1. SCC at dry-off and at calving and number of infected quarters at calving for the two teat seal products

	Treatments	
	Boviseal	Sureseal
SCC at dry-off (cells/mL)	158,240 (±564,000)	168,070 (±660,000)
SCC at calving (cells/mL)	229,000 (±1,300,000)	498,000 (±1,800,000)
Number of quarters infected at calving	5	6

At calving, four quarters treated with Boviseal (6.8%) and eight quarters treated with Sureseal (14%) had SCC >200,000 cells/mL . Six quarters treated with boviseal and five quarters treated with Sureseal were infected (had a bacteria detected).

Overall, there were no differences in quarter SCC between the two types of TS. There were no differences between TS products on the probability of a high SCC or an infected quarter. Further research with more cows is necessary to evaluate if there are differences in the proportion of high SCC quarters between the two TS brands.

Conclusion

The two teat seal products were not different in the number of infections at calving nor in the average quarter SCC. However, there was a higher number of high SCC quarters when using one product, which requires further investigation.

Milking management and drying-off procedure survey of 22 farmers implementing selective dry cow therapy

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Summary

- Surveyed farmers were positive about selective dry cow therapy
- The importance of milk recording, selection of cows and recording of clinical mastitis cases was highlighted as necessary for the success of selective dry cow therapy
- There is variation in the milking routine followed by farmers.

Introduction

The public concern regarding the use of antimicrobials in animal production systems and its relationship to the development of antimicrobial resistance has led to the exploration of strategies to reduce the use of antibiotics on dairy farms. Dry cow therapy (treatment with antimicrobials of all the quarters of the cow at the end of lactation) is the most common use of antibiotics on dairy farms. Selective dry cow therapy (SDCT), the practice of treating uninfected cows with teat seal (TS) only at dry-off instead of antibiotics, can help to substantially reduce their use. This is important because of a European Union (EU) regulation on the use of veterinary medicines that will include a regulation on the use of preventative antimicrobials in groups of animals.

In Ireland, two studies have shown that uninfected cows treated with TS only had a higher average SCC and odds of infection in the following lactation compared to cows receiving antibiotic plus TS. It is important to understand the management practices of farmers that are implementing SDCT to understand their attitude towards it and to assess potential risk factors. Therefore, the objective of this research was to assess the milking and drying-off practices of a sample of farmers conducting SDCT.

We conducted an online survey of 22 farmers in the south of Ireland (Cork, Kerry and Limerick) that were implementing SDCT. The survey consisted of 48 questions (a combination of multiple choice and open). The survey was sent out to farmers in February 2021. The average herd size was 123 cows with a range between 50 and 307. Farmers culled an average of two cows due to mastitis and high SCC in 2020 (range 0–8).

Milking and mastitis management practices

Parlour size of the surveyed farmers was 13 units on average (range 8–20) and the majority (72%) conducted the milking themselves. Twenty farmers had automatic in parlour feeding systems and 50% had cluster removers. Seven farmers had a milk measuring system (electronic milk meter or recording jars). All farmers responded that they wore latex gloves for milking for every milking or most of the time. Figure 1 shows responses for pre-milking routine practice.

Fifty-five percent of farmers dry the cows teats with a paper towel, while the rest either did not wash the teats or did not dry them after washing. Every farmer reported applying teat disinfectant after milking. The two most commonly adopted practices for mastitis management were "keep a record of clinical cases" and "use a physical identifier for clinical mastitis cases" (77.3% of farmers). Milking clinical cows to a bucket (63.6%) and keeping a record of high SCC cows (59%) followed as the most common practices.

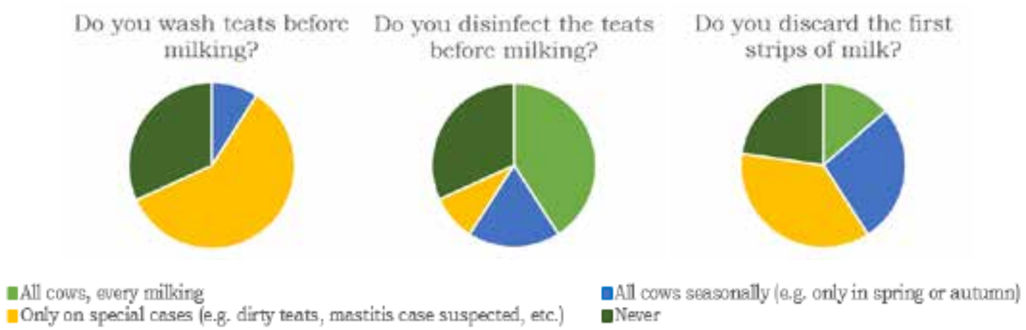

Figure 1. *Pre-milking routine practices*

Selective dry cow therapy practices

The most common practices for dry-off and SDCT were restricting the cows' diet near dry-off (68.2%), drying-off cows abruptly (54.6%) and applying an antibiotic to all teats before applying teat seal (54.6%). The more common practices at drying-off were drying-off cows immediately after milking (95.5%), disinfecting teats with an alcohol swab (95.5%), massaging the udder after antibiotic infusion (91%), applying teat spray/dip after dry-off (91%) and pinching the base of the teat when applying teat seal (86.4%). On average, farmers started implementing SDCT four years ago. The most common reason for farmers implementing this practice was to reduce antibiotic use or they questioned the necessity of treating healthy cows with antibiotics, and that less labour was required. Seventy-three percent (73%) of farmers said they did not implement any new practices in order to start with SDCT. Farmers pointed out that the most helpful practices to successfully implement SDCT were milk recording/selection of cows, cleanliness and hygiene of the procedure and facilities, and recording of clinical mastitis cases. All farmers responded that they would recommend this practice to other farmers. Future research will evaluate whether any of these practices are associated with a better outcome from SDCT.

Conclusion

Surveyed farmers had a positive attitude towards SDCT. We saw differences between farms in milking routine, mastitis management and drying-off procedure. Further work is required to clarify which practices are associated with a better outcome when using SDCT.

Suboptimal mobility. Is it costing me money?

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Summary

- Suboptimal mobility refers to any abnormality of a cow's gait causing a deviation from the optimal walking pattern of a cow
- Using the DairyCo four-point mobility scoring scale, dairy cow mobility can be categorised as good, imperfect, impaired or severely impaired
- Cows with impaired and severely impaired mobility have reduced production and reproductive performance
- Increased prevalence of imperfect, impaired and severely impaired mobility within a herd substantially reduces overall farm net profit.

Introduction

Suboptimal mobility has a negative impact on cow welfare, production performance and farm net profit, and is therefore considered as one of the major problems associated with dairy production. Since the removal of the EU milk quota restrictions, expansion of the Irish national dairy herd has been evident. This has led to increased concerns among veterinarians regarding the potential increased risk of suboptimal mobility for dairy cows walking longer distances within larger herds. While it is known that access to pasture is beneficial to reduce the risk of a cow having severely impaired mobility, the prevalence of imperfect and impaired mobility within typical spring calving, pasture-based dairy herds is an area that has not been studied as extensively.

Production and reproductive impacts of sub-optimal mobility

A recent study of ~10,000 dairy cows on 62 Irish dairy farms found that just over 30% of cows observed had imperfect mobility, 6% of cows had impaired mobility, and less than 1% of cows had severely impaired mobility. The prevalence of impaired and severely impaired mobility is comparable to other pasture-based systems. The prevalence of imperfect mobility in pasture-based systems has not been reported previously.

Milk yield (corrected for a 305 day lactation), somatic cell count (SCC), calving interval length, and likelihood to be culled were examined for the ~10,000 dairy cows spread across the 62 dairy herds. This study found that reduced milk yield and longer calving interval were associated with cows with impaired and severely impaired mobility. While the risk of being culled and the average SCC for the lactation was higher for cows with all forms of suboptimal mobility compared to cows with optimal mobility (Table 1).

Economic impact of sub-optimal mobility

The physical and financial performance of a typical spring calving, pasture-based dairy production system was simulated using the Pasture Based Herd Dynamic Milk model (PBHDM) and the Moorepark Dairy Systems Model (MDSM) based on the production performance results in Table 1.

Table 1. Estimates of the effect of mobility score (good, imperfect, impaired and severely impaired) on 305-day milk yield, average somatic cell count (SCC), calving interval length and culling risk				
Production performance	Good mobility	Imperfect mobility	Impaired mobility	Severely impaired mobility
Milk yield (kg)	-	-	-100	-300
SCC	85,616	91,491	95,398	107,375
Calving interval length (days)	-	-	+3.7	+6.0
Culling risk (% increase)	-	+54	+61	+78

A new sub-model to predict claw disorders and the resulting mobility score, as well as the performance effects and treatments costs was developed within the PBHDM. The resulting herd level prevalence of suboptimal mobility presented in Table 2 depended on 1) a genetic predisposition for mobility issues (PTA for lameness) at the cow-level, and 2) management practices and farm infrastructure at the herd level. As the prevalence of suboptimal mobility increased, there was a substantial negative impact on overall farm net profit (Table 2).

Table 2. Estimates of the economic loss (in euro) due to the prevalence of suboptimal mobility within a 100 cow herd based on a base total farm net profit of €79,000 based on effects on milk yield, culling rate, treatment costs and total farm net profit loss				
Herd level prevalence of suboptimal mobility	Milk yield loss (€)	Increased culling (€)	Treatment cost (€)	Total farm net profit loss (€)
8%	95	179	1,535	1,714
19%	275	480	1,657	2,138
37%	621	1,179	1,880	3,059

Conclusions

Suboptimal mobility in spring calving, pasture-based systems is associated with significant milk yield loss, elevated SCC, increased calving interval, and an increased culling risk. These, and additional treatment costs associated with cows with suboptimal mobility, result reduced overall farm net profit on farms with a higher prevalence of suboptimal mobility.

Acknowledgements

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Investigating the potential for wearable sensors to monitor grazing behaviour and activity in pasture-based dairy cows

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Summary

- Irish dairy herd size is increasing while the pressures on labour and time are also increasing
- Wearable sensors to automate dairy cow monitoring and management are being investigated as potential tools to reduce some labour requirement.

Introduction

The average herd size has increased from 68 cows in 2015 to 80 cows in 2019. With this continued expansion of herd size, the issue of the availability of skilled labour and the time a farmer has to spend on each cow decreases. These factors put increased pressures on the skillsets of operators. This is where automated wearable sensors can play a role and even have the potential to be part of a solution to this problem. The ITIN + HOCH Rumiwatch sensors are currently being tested at Teagasc to monitor both the grazing behaviour and activity of pasture-based dairy cows in order to explore their potential for use on commercial farms.

ITIN+HOCH Rumiwatch noseband sensor and pedometer

Rumiwatch is a system that automates the measurement of rumination, grazing, water intake and mobility for research purposes. The Rumiwatch system incorporates a noseband sensor, data logger with online data analysis, pedometer and evaluation software. The shape of the noseband changes based on the cow's jaw movements, thus causing the pressure to change in the silicone tube (Figures 1 and 2). Jaw movements and the resulting pressure changes are automatically classified as ruminating (Figure 3), grazing, drinking or other activity.

Figure 1. *Protective casing of ITIN+HOCH Rumiwatch noseband sensor opened*

Figure 2. *Cow with ITIN+HOCH Rumiwatch noseband sensor fitted*

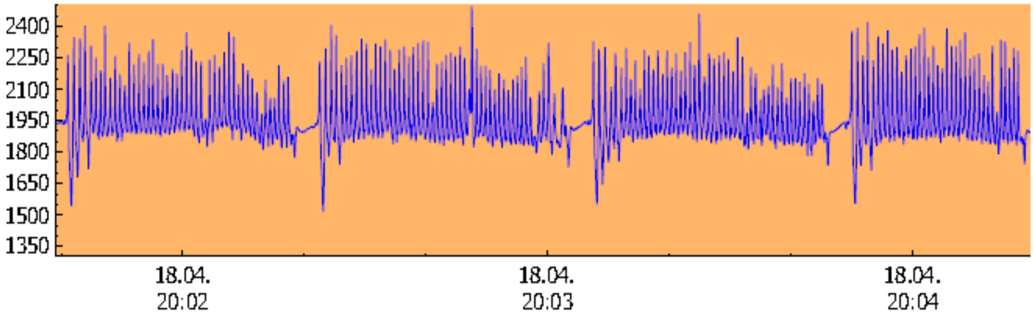

Figure 3. *Identified ruminating events using the ITIN + HOCH Rumiwatch noseband sensor*

The data logger registers the pressure in the noseband sensor at a constant logging rate of 10 hertz (Hz) or 10 readings per second, and saves this raw data to a SD memory card. The data can be transmitted from the SD memory card to the evaluation software. The power supply is stored in another protective black box on the left side of the halter. Presently the Rumiwatch system is suitable for research purposes only, as the data is not wirelessly transmitted and the lifetime of the battery is quite low (300 days). However, this current study is investigating the potential of the Rumiwatch technology for use on commercial farms to record rumination, grazing, water intake and mobility with increased accuracy.

Figure 4. *ITIN+HOCH Rumiwatch pedometer*

The pedometer measures a cow's motion states via a three-dimensional accelerometer (Figure 4). Similar to the noseband sensor, the pedometer consists of a data logger, data storing and transmission, logging rate and power supply. Different cow motions states such as walking, and standing can be identified from the data recorded by the pedometer. These motion states could potentially be associated with specific mobility scores and could therefore automate the identification of 'lame' cows.

Conclusion

Currently data collection and analysis to investigate the potential benefits of wearable sensors like the Rumiwatch system on commercial farms is on-going. The results of this study could be utilised to retrain wearable sensors already commercially available to record and to monitor dairy cow behaviour and activity with more accuracy.

Acknowledgements

The authors gratefully acknowledge funding provided by 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 and the Irish Dairy Levy administered by Dairy Research Ireland.

Which is the more labour efficient — manual or automatic calf milk feeding?

Alison Sinnott, John Paul Murphy and Emer Kennedy
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Summary

- Automatic feeders are 39% more labour efficient than manually feeding calves
- No difference in calf health, behaviour or weight gain between feeding systems.

Introduction

As the average herd size in Ireland continues to grow, the number of replacement heifer calves reared increases. Rearing calves is a labour intensive process, particularly on seasonal calving dairy farms. As it has become increasingly difficult to source farm labour in recent years, alternatives for human work, such as the automation of farm tasks (e.g. calf feeding) warrant investigation. If calf-rearing systems are adapted to use automatic milk feeders, it is important to ensure that progress is not made at the expense of calf health, behaviour, growth and overall welfare.

Study

In spring 2019, a study was undertaken at Teagasc, Moorepark to investigate the effect of feeding calves using automatic and manual milk feeders on labour, health, behaviour, growth rates and overall welfare. At birth, 60 heifer calves were divided into two treatment groups balanced for breed, birth weight, and birth date. The two treatments were: i) automatic milk feeding and ii) manual milk feeding.

Colostrum and transition milk management were the same for all calves. Heifers were grouped from three days and moved to a pen with either an automatic feeder (Volac Vario Feeder; 2 pens × 15 calves) or manual milk feeding (Wydale compartment feeders; 2 pens × 15 calves). Each calf was fed 26% crude protein milk replacer at a rate of 6 L/heifer/day (reconstitution rate 15%). Automatic calves were allocated three feeds of 2 L spaced evenly throughout the day. Manual calves were given two feeds of 3 L/day (morning and evening). Ad-libitum water, concentrate and hay were offered to all calves from three days of age. Calves were gradually weaned based on weight; 90 kg for Friesian and 85 kg for Jersey crosses.

The time required for food preparation, feeding inspection, cleaning, bedding, health observations (included as feeding inspection for manually fed calves) and training calves to their respective feeders were measured three days per week. Measurements were taken by observing one labour unit completing each task. Calves were health scored twice weekly, and weighed and observed for behaviour weekly.

Significant differences in labour were recorded between the feeding systems. Automatic feeding systems had a lower total labour requirement of 00:00:45 per calf/day (hh:mm:ss) compared to manual feeding systems with a requirement of 00:01:50 per calf/day. The average time taken to complete various tasks per day differed between automated and manual systems (Figure 1). Additionally, training calves to use the automatic and manual feeders had labour requirements of 00:02:14 and 00:00:08 per calf/day, respectively, for a period of three days after calves being introduced to the feeding system for the first time.

Regardless of treatment, the majority of calves (98%) were healthy with no significant differences found. Calves in each treatment carried out normal behaviours such as lying, standing, drinking water, eating concentrates and forage similarly, with no significant differences between treatments.

There were no differences in relation to the average number of days to weaning (calves on automatic feeder 81 days (11.6 weeks); calves fed manually 80 days (11.5 weeks)). Weaning weight (92.9 kg) and average daily gain (ADG) from birth to weaning (0.74 kg/calf/day) were similar for both treatments.

Conclusions

Calves in both the automatic milk feeder and manual milk feeding treatments showed good health, normal behavioural patterns and similar growth rates, which are all indicative of positive calf welfare. Automatic feeders were more labour efficient; however, considerable costs are associated with the system (i.e. unit cost, servicing) and due to a lower level of human to calf contact compared to manual feeding regular calf health inspection is essential. The saving of labour is a distinct advantage that automatic feeders have over manual feeding when rearing calves.

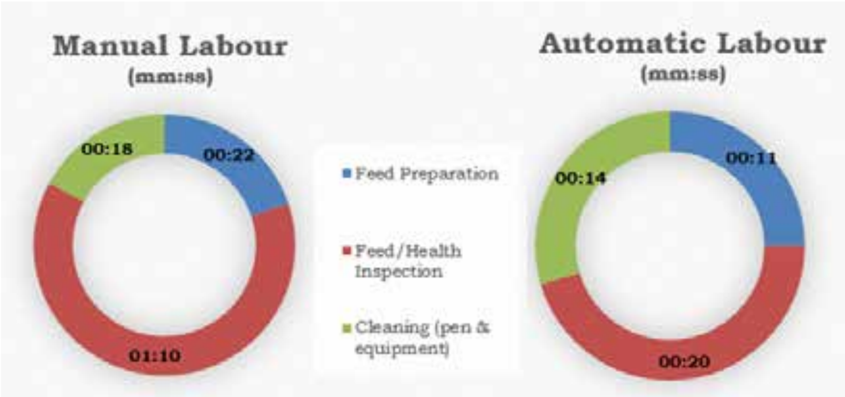

Figure 1. *Average time/calf/day for tasks related to manual versus automated feeding systems*

Calf housing on commercial farms in Ireland

Alison Sinnott and Emer Kennedy

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

Summary

- The majority of calf sheds surveyed were purpose built for calf rearing, with 79% of farms making/planning modifications to ensure shed suitability for calf rearing
- Forward planning is needed to ensure sufficient space allowance to cater for all calves, particularly at peak calving
- One third of sheds had excessive wind speed and insufficient light and 90% of pens had an insufficient floor slope
- Familiarisation with guidelines for calf shed specifications is important before building or renovating housing facilities.

Introduction

Dairy expansion has led to increased herd sizes, resulting in more calves being born on Irish dairy farms. Fit for purpose calf rearing facilities which have appropriate ventilation and space allowance are linked to improved calf health and welfare, thus maximising an animal's potential in later life.

Calf housing and welfare study

A Teagasc Moorepark study was conducted in 2020 to investigate calf housing and welfare on 19 commercial Irish dairy farms. This study aimed to provide information regarding the current calf housing in Ireland and identify areas for improvement in terms of calf welfare. To ensure farms on the study reflected current Irish dairy systems, a number of criteria were used to select the farms:

- minimum herd size of 78 cows
- calve >90% of their herd in spring (Feb–April)
- subscribe to HerdPlus
- member of an active discussion group.

Each farm was visited twice. The first visit was conducted pre-calving (December–January) with the principle calf rearer and involved a comprehensive questionnaire regarding calf housing and management practices, and a facility evaluation with no calves present. The second coincided with peak calving for each farm (January–March) and involved a short interview with the calf rearer, environmental-based measurements of each calf house with calves present and area measurements of each pen to assess the conditions in which calves were accommodated.

Results

The average space allowance per calf among farms surveyed was 2.6 m^2 which was greater than the legal minimum space allowance of 1.5 m^2 per calf. Twenty percent of calf sheds surveyed provided less than 1.7 m^2 per calf; allowances greater than 1.7 m^2 per calf are strongly encouraged due to the association of disease transmission with high stocking densities. Of the sheds surveyed, 68% were purpose built, with 79% of farms having at least one shed build for the purpose of calf rearing. Over 68% of farms have made modifications to their sheds to improve their suitability for calves (i.e. ventilation, drainage, pen design) and a further 11% plan to make such modifications in the near future.

One third of farms housed calves in shared air space with older stock and had calves in groups greater than 12. To reduce the risk of development of disease, calves should be separated from older stock and housed in groups of 12 or less calves, where possible (Animal Health Ireland: Design of New Calf Accommodation). In line with guidelines to remove sick calves from a healthy group pen, the large majority of farmers remove sick calves from group pens (21% using individual pens; 52% using group isolation pens).

A maximum wind speed of 0.5 m/second is recommended to ensure air flow through a shed while minimising the risk of calves losing excessive body heat due to draughts. However, one third of sheds had an air flow greater than this. At least 50 LUX of light (natural and artificial) must be provided for eight hours of the day, although 38% of sheds surveyed did not provide sufficient levels of light to achieve this, it is a relatively straight forward issue to rectify on-farm.

A minimum floor slope of 1:20 is recommended for hygiene and drainage purposes, however less than 10% of calf pens meet this specification. With that being said, 63% of farms clean out and re-bed pens at least once per week, which may aid with the shortfall in appropriate drainage facilities.

Conclusions

The majority of calf sheds surveyed were purpose built for calf rearing, with 79% of farms making/planning modifications to ensure shed suitability for calf rearing. Many farms had issues with draughts and floor slopes within shed structures, which can have a knock on effect on calf health. However, the majority of farms in the study provided sufficient space allowance and demonstrated good management practices (such as the frequent cleaning of pens). Although lighting was insufficient on many farms, modifications to the shed can easily rectify this issue.

Calf hutches: a viable housing alternative?

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Summary

- Group hutches are more labour intensive than indoor housing
- Individual hutches may negatively affect calf wellbeing and are more labour intensive than group hutches or indoor housing
- All housing options investigated indicated positive calf health and weight gain.

Introduction

As Irish dairy herd size increases, the requirement for calf housing increases. Calf housing should be comfortable, creating an environment to allow calves grow to their potential, while minimising the requirement for veterinary assistance, labour, morbidity and mortality.

Study

A study was conducted in spring 2020 at Teagasc, Moorepark to compare the labour requirements, health, behaviour and growth of calves that were reared indoors in groups (fed with automatic or manual feeders) compared to those reared outdoors in individual or group hutches (fed manually). Seventy-six dairy heifer calves were divided into four treatment groups balanced for breed, birth date and birth weight. The four treatments were i) indoor grouped, fed with automatic feeder (2 pens × 12 calves), ii) indoor grouped, fed with manual feeder (2 pens × 12 calves), iii) outdoor group hutch, fed with manual feeder (2 pens × 8 calves), and iv) outdoor individual hutch, fed with manual feeder (12 pens × 1 calf).

Colostrum and transition milk management were similar for all calves. All calves were moved to an indoor group pen from three days old with their respective feeding system (i.e. automatic or manual feeder). At approximately three weeks of age, calves assigned to the hutches outdoors were moved to that accommodation. Each calf was fed 26% crude protein milk replacer at a rate of approximately six litres/heifer/day (reconstitution rate 15%). Calves on the automatic feeder were allocated three feeds, spaced throughout the day, and manually fed calves were given two feeds per day; morning and evening. Ad-libitum water, concentrate and hay were offered from three days old. Calves were gradually weaned based on age (eight weeks old; as calves cannot be individually housed when older than eight weeks).

The time required for food preparation, transportation, feeding, cleaning, and feed/health observations were measured twice weekly. Calves were health scored twice weekly, weighed weekly and observed for behaviour weekly.

Indoor automatic systems had the lowest labour requirement at 00:00:49 per calf/day (hh:mm:ss), followed by indoor manual (00:01:56 per calf/day), outdoor group hutch (00:03:19 per calf/day) and outdoor individual hutch (00:05:10 per calf/day) (Figure 1).

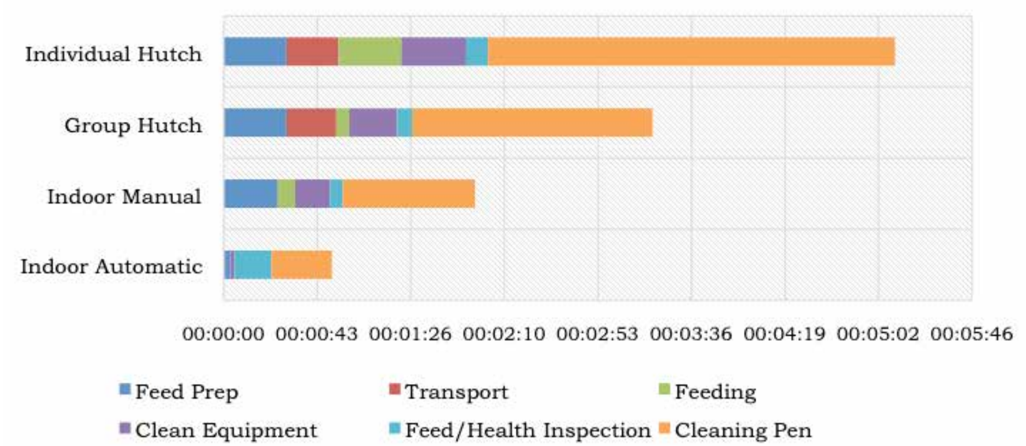

Figure 1. *Percentage of total time per calf (hh:mm:ss) required for tasks related to indoor group housing (automated or manual feeding) and outdoor group or individual hutches (manual feeding)*

Health and growth patterns across all treatments were consistent with positive calf development and were not significantly affected by housing type (indoor or hutch). Calves in individual hutches spent less time lying (35.3%) compared to the other treatments, which were similar (56.6%). This was considered abnormal because calves usually spend approximately 50–70% of their time lying down, decreasing gradually as the calf gets older. Herd animals, such as calves, are social and feel secure in groups, however when the individual hutch calves lay down, they could not see or touch other calves. The reduced lying time suggests calves in the individual hutches preferred to carry out alternative behaviours, such as self-grooming, scratching, rubbing and stretching, in the outer-pen area where they had the company other calves.

Conclusion

Indoor calf housing is most labour efficient, particularly with automatic feeders. Outdoor group hutches do not negatively impact calf welfare but offer a less labour efficient alternative. Individual hutches were the least labour efficient and calves had reduced lying time in individual hutches, which may indicate compromised wellbeing. If considering hutches, it is important to be mindful of the cost, and the location of these structures, as the changeability in Irish weather means that calves are more exposed to different environmental conditions.

The effect of different rearing strategies on heifer growth and the achievement of target weights

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Summary

- Post-weaning feeding regime had a greater effect on body weight (BW) throughout the rearing period than weaning age
- At nine and 14 months, heifers should be approx. 40% and 50% of mature BW
- Meeting these targets will ensure heifers have achieved puberty prior to breeding when they should be approx. 60% of mature BW.

Introduction

Increasing the length of the milk-feeding period takes advantage of high feed efficiency in early life; however, it may not be economically viable. Alternatively, different feeding strategies post-weaning can ensure that BW targets, which are important key performance indicators in heifer rearing systems, are achieved. If heifers are 30%, 60% and 90% of mature BW (approx. 575 kg) at six, 15 (breeding) and 24 (pre-calving) months, respectively, they will have improved milk production, reproduction and survivability. However, these targets assume a linear growth trajectory, which is difficult in pasture-based rearing systems due to seasonal variation in grass growth and quality. Creating additional BW targets would be beneficial for pasture-based farmers to optimize heifer growth prior to breeding.

Study

A study took place at Teagasc Moorepark from February 2018 to November 2020. There were 177 Holstein-Friesian (mean birth BW of 34.6 ± 4.36 kg) heifers in the study. Experimental treatments are outlined in Figure 1. Heifers were weighed twice a month from birth until housing for the first winter and monthly thereafter.

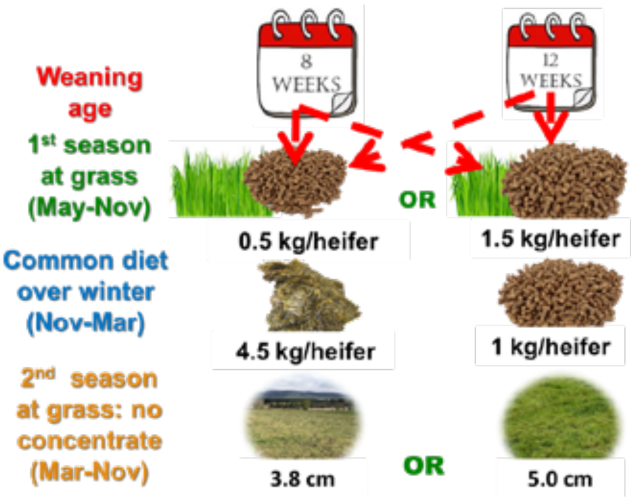

Figure 1. *Schematic outline of the different weaning ages and post-weaning feeding regimes*

Results

The growth trajectories, from birth to calving, of the pasture-based heifers are outlined in Figure 2. The accelerating phase in early life corresponds to the high feed efficiency in the milk-feeding period. The curve then plateaus slightly during the first over-winter period. This lag is followed by exponential growth as the heifers are turned out to their second grazing season. All treatment groups achieved target BW at six months (30% of mature BW). However, with the exception of the group that received 12 weeks milk feeding and a high level of feeding post-weaning, all heifers were slightly behind target BW at 15 months. Irrespective of weaning age or post-weaning feeding regime, all heifers were ahead of target at 24 months (90% of mature BW). New weight-for-age targets, such as 40% of mature BW at approx. nine months of age, and 50% of mature BW at approx. 14 months of age, will help farmers better manage pasture-based heifer growth. With these targets, farmers can decide if concentrate supplementation is required during the over-winter period, or whether to allocate more grass to heifers after turnout.

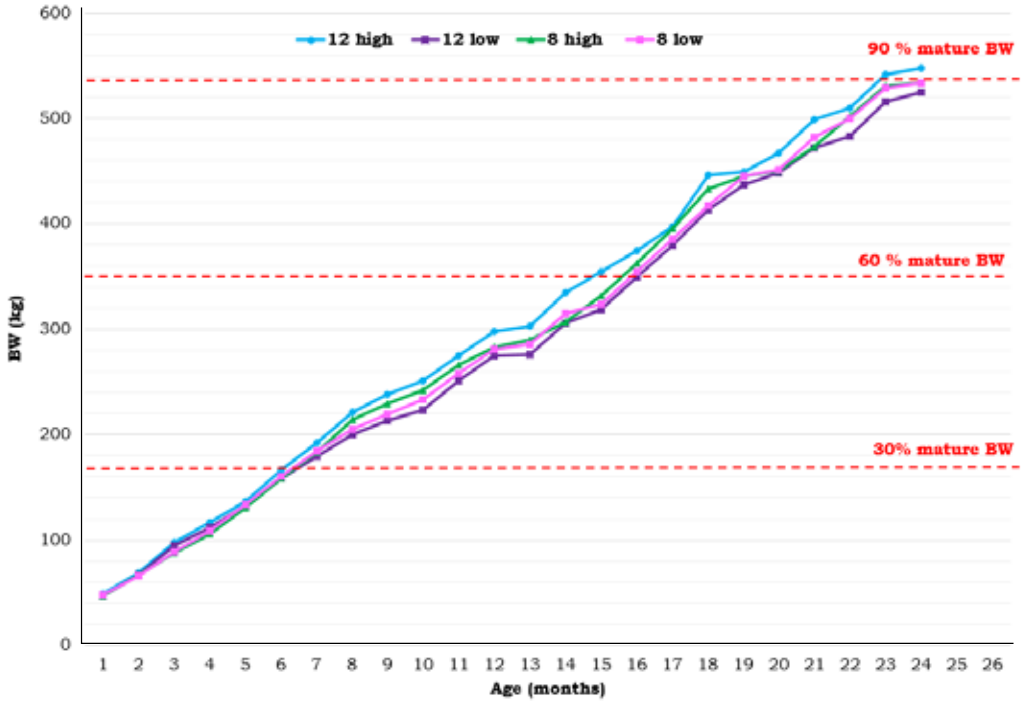

Figure 2. *The effect of weaning age and post-weaning feeding regime on body weight (BW) from birth until 24 months*

Conclusion

Post-weaning feeding had a greater effect than weaning age on BW from birth to calving. Heifers should be approx. 40% and 50% of mature BW (approx. 575 kg) at nine and 14 months, respectively, so that they have gained the BW necessary to achieve puberty before the breeding season. Having heifers ahead of target at calving may increase the risk of calving difficulty, therefore over-winter feed management should be optimized.

Acknowledgements

This work was funded by the Irish Government through the Department of Agriculture Food and the Marine Research Stimulus Fund (15 S 696).

Heifer dry matter intake throughout the rearing period

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Summary

- Post-weaning feeding had a greater impact on dry matter intake (DMI) than weaning age
- DMI of pasture-based heifers was approximately 2.2% of body weight (BW) throughout the rearing period
- Jersey (JE) heifers had a higher intake as a percentage of BW compared to Holstein-Friesian (HF) heifers.

Introduction

Heifer DMI provides the foundation for BW gain and so is an important part of heifer rearing. Commonly expressed as a percentage of BW, DMI ranges from 1.8–2.9% throughout the rearing period. Previous heifer DMI research was undertaken in confinement rearing systems where feed of consistently good quality was offered year round. In pasture-based systems, such as those in Ireland, grass growth and quality are variable, and this may influence DMI. The objective of this research was to quantify the DMI of pasture-based heifers; this would benefit heifer management and grass allocation.

Study

Holstein-Friesian and JE heifers were weaned at either eight or 12 weeks, and offered either high (H) or low (L) feeding regimes post-weaning. In the first grazing season, H and L heifers were offered the same herbage allowance (4.5 kg/day) but different levels of concentrate (1.7 and 0.6 kg, respectively). In the second grazing season, post-grazing heights (5.1 and 3.7 cm, for H and L heifers respectively) were used to create differences in daily herbage allowance. A common diet of silage and concentrates was fed over-winter. The DMI of 60 heifers was determined on nine occasions throughout the rearing period (Table 1). Heifer body weight (BW) was monitored during each DMI estimation period.

Table 1. Ages, weights and dry matter intakes (DMI) of pasture-based Holstein-Friesian (HF) and Jersey (JE) heifers

Age (months)	Weight (kg)		Feed offered	DMI (kg/heifer per day)	
	HF	JE		HF	JE
6.8	174	129	Grass and concentrate	4.0	3.9
8.3	214	167	Grass and concentrate	4.2	4.3
9.0	212	157	Grass and concentrate	4.6	4.4
11.6	274	215	Silage and concentrate	5.3	4.7
13.8	287	225	Grass	6.0	5.5
17.4	395	310	Grass	7.7	7.3
17.4	408	321	Grass	8.1	7.5
19.5	466	369	Grass	9.8	8.9
19.9	449	359	Grass	10.1	9.1

Results

Heifer DMI is outlined in Table 1. Although almost all heifers achieved target BW at six and 24 months, the L heifers were slightly behind target at 15 months. Concentrate supplementation in the first grazing season had a greater effect on DMI than weaning age. Heifer DMI during the second grazing season was reduced from 8.3 kg to 7.7 kg when post-grazing height was reduced from 5.1–3.7 cm. Therefore, heifers behind target BW should not graze to low post-grazing heights, as it will slow their daily BW gain. Dry matter intake was similar for HF and JE in the first grazing season, in the second grazing season HF DMI was approximately 0.6 kg/day higher than JE (Figure 1). Although, DMI as a percent of BW decreased as BW increased, mean intake as a percentage of BW across the rearing period was 2.23% (2.53% and 2.09% for JE and HF, respectively).

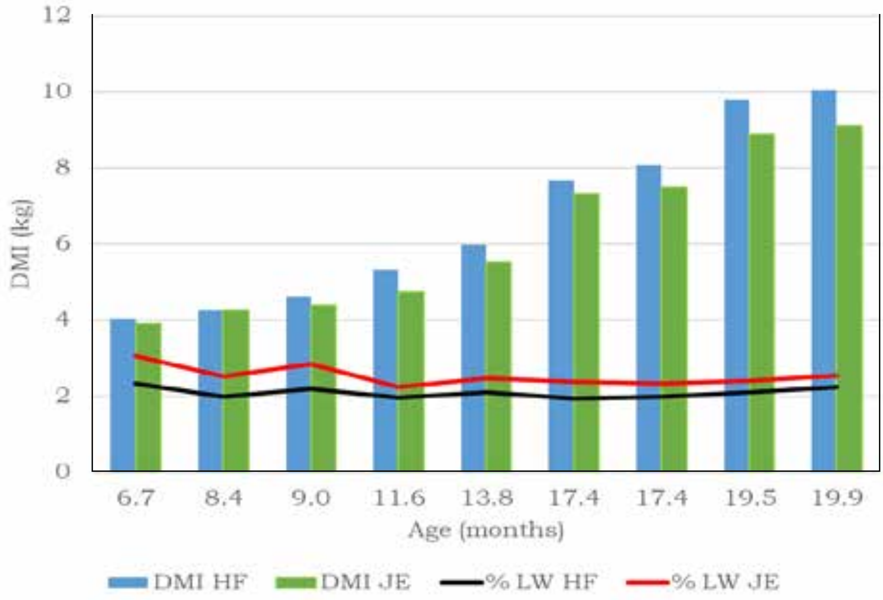

Figure 1. *The effect of breed on dry matter intake (DMI) and intake as a percentage of body weight (BW) of Holstein-Friesian (HF) and Jersey (JE) heifers*

Conclusion

Heifers weaned at 12 weeks and subsequently offered a high feeding regime had superior DMI, and therefore BW, throughout the rearing period. When DMI was expressed as a percentage of BW, JE had higher DMI than HF. High DMI from grass is essential to keep heifer rearing costs down. Lighter heifers should graze to approximately 5 cm post grazing sward heights so that live weight gain is not negatively impacted.

Acknowledgements

This work was funded by the Irish Government through the Department of Agriculture Food and the Marine Research Stimulus Fund (15 S 696).

Infectious disease prevalence in bulk tank milk samples from Irish dairy herds

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Summary

- Vaccination rates for endemic infections are high in dairy herds
- Large, expanding unvaccinated dairy herds are endemically infected with BRSV, BVD, IBR, *Salmonella* Dublin and Leptospira Hardjo
- The prevalence of exposure to infectious diseases was not higher in herds sending heifers to contract rearing vs. home rearing.

Introduction

Infectious diseases of importance to herd health in the Irish dairy cow population include BVDv (bovine viral diarrhoea virus), IBR (infectious bovine rhinotracheitis), leptospirosis, salmonellosis, neosporosis, mycoplasmosis and Johne's disease. Since milk quota abolition in 2015 there has been no research on the prevalence of these conditions in Irish dairy herds. Given the consequent herd expansion, often by purchasing animals, there was a need for this research. Hence, the aim of this study was to establish the endemic infectious diseases status of dairy herds using bulk tank milk (BTM) sampling. A further objective of this study was to identify potential differences in herd prevalence of common infectious agents between farmers engaged in contract-rearing of replacement heifers and those rearing heifers at home.

Materials and methods

A total of 120 dairy farms were recruited in 2018 into a nationwide study to identify the animal health implications associated with contract-rearing (CR) of heifers. Approximately half of the dairy farmers (source dairy farmers: SDFs) were sending heifers to a contract-rearing farm and half were rearing heifers at home (control farmers: CFs). Between 2018 and 2020, BTM samples were collected thrice, annually, from each herd over a 2-month period using a standardized kit. Information regarding vaccine use during each of the sampling periods was also recorded. All samples were analysed to detect antibody levels to a range of eight common endemic pathogens using ELISA and PCR techniques (FarmLabs, Roscommon). Overall herd prevalence was calculated based on the percentage of herds recording a positive result against total unvaccinated herds tested.

Results and discussion

Of the recruited dairy farmers, 100, 92.5 and 83% returned a milk sample for testing in 2018, 2019 and 2020, respectively. Almost all herds (93%) had undergone expansion in the period between 2013 and 2018. Most frequently, SDFs sent heifers to a contract-rearing unit taking heifers from their farm only i.e. single origin rearing unit (70%). Across both groups (SDF and CF), the majority of farmers were vaccinating against IBR (>83%), leptospirosis (>81%) and salmonellosis (>80%). Use of vaccination for IBR was consistently greater on SDFs than CFs. The overall prevalence of antibodies to each infectious agent are shown in Figure 1. There were no consistent trends over the three years in antibody prevalence. No differences in herd prevalence of infectious agents were observed between farm types (SDF vs CF).

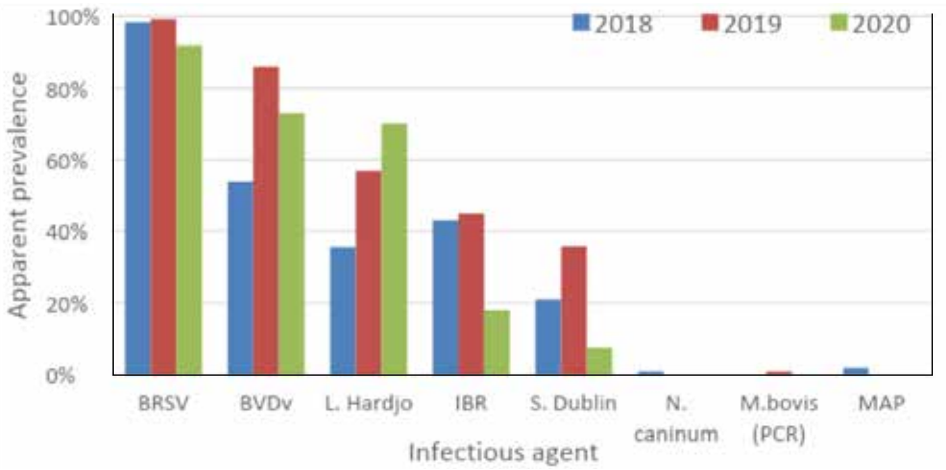

Figure 1. *Prevalence of BRSV (bovine respiratory syncytial virus), BVDv, L. Hardjo (Leptospira Hardjo), IBR, S. Dublin (Salmonella Dublin), N. caninum (Neospora caninum), M. bovis (Mycoplasma bovis) and MAP (Mycobacterium avium subspecies paratuberculosis) on 120 unvaccinated dairy farms between 2018 and 2020*

Results from this study demonstrate that vaccine adoption rates are high on large, expanding Irish dairy herds. However, vaccination alone will not eliminate disease transmission; biosecurity involves much more than just using a vaccine. The BMT results show that almost all herds were infected with BRSV; this virus can cause severe calf pneumonia. There was also a high prevalence of BVD antibodies in unvaccinated herds; this may reflect lifetime antibody status following pre-eradication programme virus exposure. The high prevalence of antibodies to leptospira in unvaccinated herds is a concern given the zoonotic nature of this infection. Antibodies to IBR were detected in a substantial proportion of unvaccinated herds demonstrating the case for a national IBR control programme, as under investigation by AHI. While neospora, mycoplasma and MAP was only detected infrequently, the sensitivity of BTM to detect some of these infections is limited. Serial within-year sampling, as practised by many dairy farmers, may detect higher prevalences of these infections. It is reassuring that no differences were observed between the farm types (SDF and CF), given the potential for greater disease transmission associated with contract heifer rearing.

Conclusion

Vaccination rates are high in Irish dairy herds. Infections of economic and public health importance are common in dairy herds that are not vaccinated. Herds from which contract-reared heifers originate have the same infectious disease status as herds where heifers are home-reared.

Comparing the health status of contract- and home-reared dairy heifers

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Summary

- Overall, there were few differences in the health status of contract- and home-reared heifers up to 18 months of age
- Most disease problems were diagnosed in heifers less than six months old
- The most common disease problems in these young heifers were high temperatures (12% of heifers), abnormal navel (7–10%) and diarrhoea (4–5%).

Introduction

Contract rearing may present an increased disease challenge to dairy heifers. To-date, there has been no research comparing the health of Irish dairy heifers that are contract- or home-reared. Hence, a national research study was conducted on biosecurity and health aspects of contract rearing. Here we report on heifer health.

Materials and methods

A total of 120 farms were recruited in 2018 into a nationwide study. Approximately half of these farmers were engaged in CR (source dairy farmers: SDFs) and half were rearing their heifers at home (control farmers: CFs). During 2018 and 2019, each farm was visited twice annually, in spring and in autumn (after the first farm visit heifers were examined at the contract-rearing farm). At each of the four visits, heifers born in spring 2018 (n=5,532) were clinically assessed and assigned a score for the following clinical parameters: ocular and nasal discharge, rectal temperature, presence of cough, navel abnormalities, appearance of joints and faecal consistency.

Results and discussion

Farmers engaged in CR sent an average of 64 heifers to the rearing unit. Control farmers reared an average of 47 heifers. The most common CR arrangement was one SDF sending heifers to one rearing unit (70%). The majority of heifers in each period and across farm types were healthy (assigned a score of 0 for each health characteristic). Abnormal health scores (>1) for all parameters were most common during the first farm visit period in spring when heifers were approximately one month old (Table 1). Over the course of the three remaining visit periods, the number of calves exhibiting signs of ill-health declined across farm types. During the first farm visit period, significantly more abnormal nasal discharge and joint scores were recorded for heifers on SDFs than CFs while abnormal navel scores were more common among CF heifers than SDF heifers. During the second farm visit period in autumn (heifers approx. eight months of age), SDF heifers had significantly more abnormal nasal and faecal scores than home-reared heifers. However, more home-reared heifers had abnormal temperature scores during the second and third visit periods than contract-reared heifers. During the final visit period (heifers approx. 18 months of age), no significant differences in health scores were observed between heifers on either farm type.

Table 1 Distribution frequencies of health scores (% of heifers) across four farm visit periods for contract-reared versus home-reared heifers (SDF: source dairy farm, CF: control farm) (n= 5,532 heifers)

Year	Farm type	Temp score ≥39.5°	Nasal score ≥1	Faecal score ≥1	Eye score ≥1	Cough score ≥1	Navel score* ≥1	Joint score* ≥1
Spr. 2018	CF	11.9	1.5	4.7	1.1	1.5	9.8	0
	SDF	11. 7	3.3	4.3	1.7	2	7.3	0.2
Aut. 2018	CF	14.9	2.2	0.2	0	0.9		
	SDF	8.3	3.9	0.9	0	1		
Spr. 2019	CF	4.9	0.6	0.6	0	0.2		
	SDF	2.7	0.8	0.8	0.1	0.1		
Aut. 2019	CF	2.3	0.2	0	0	0		
	SDF	3.2	0.2	0	0.1	0		

**Navel and joint scores were not recorded in older heifers due to safety concerns*

Results from this study demonstrate that the health of heifers was not compromised by sending them to a contract-rearing farm. Despite these findings, dairy farmers considering contract-rearing should be aware that the majority (70%) of contract-rearing farms in this study took heifers from one dairy farm only. The risk of disease transmission between heifers is likely to be higher on multi-site rearing units where heifers are co-housed or grazed. Farmers sending heifers to these farms should have a robust herd biosecurity plan in place. From the outset, heifer calves should be provided with an adequate quantity of good quality colostrum as soon as possible after birth. In advance of moving heifers to the contract-rearing farm, they should be inspected for signs of ill-health. Calves with clinical signs of ill-health should not be transported to the rearing farm until clinical signs have resolved. Additionally, farmers should consider implementing a vaccination program appropriate to the infectious disease status of their herd. Finally, testing/quarantine procedures should be implemented for returning heifers.

Conclusion

The health status of home- and contract-reared heifers did not differ greatly. However, the majority of heifers were sent to single origin contract rearers. Where heifers are sent to a multi-origin rearing unit, farmers need to have a biosecurity plan to mitigate higher disease risks.

Biosecurity practices related to calf rearing on dairy farms engaged in contract heifer-rearing

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Summary

- Few differences were evident in the calf rearing biosecurity measures adopted by dairy farmers engaged in contract-rearing (source dairy farmers; SDFs) compared to farmers rearing their own heifers (control farmers; CFs)
- Structurally, SDFs had larger than average, more specialised and less fragmented farms than control farms
- Across both farm types, there was significant scope for improvements in calf rearing biosecurity practices.

Introduction

With dairy herd expansion, contract rearing of dairy heifers may become more common. Current estimates indicate that 5% of dairy farmers send their heifers out to be reared. In the absence of a robust biosecurity plan, contract-rearing (CR) poses a threat to the health status of dairy herds. Commingling of heifers from multiple dairy herds of unknown health status facilitates transmission of infectious disease between susceptible animals, with significant economic and welfare implications. Additionally, transmission of infectious agents between returning heifers and naïve cows in the milking herd represents a further animal health risk of CR. However, to date there has been no research on the biosecurity risks and practices of farmers who engage in contract rearing. Hence, the aim of this study was to describe the biosecurity measures undertaken by dairy farmers engaged in CR and to determine if these farmers took more or different disease prevention precautions than farmers rearing their own heifers. In the interests of brevity, only calf rearing biosecurity practices are presented.

Materials and methods

A total of 120 dairy farms were recruited to a national research study in 2018 to investigate the wider animal health implications of CR. Approximately half of these farmers were engaged in CR (source dairy farmers: SDFs) and half were rearing heifers at home (control farmers: CFs). During 2018, each farmer was surveyed using a purpose-designed postal questionnaire to ascertain the management and biosecurity practices undertaken on their farm. Survey responses were then analysed to identify potential differences in disease prevention measures taken by farmers in each group.

Results and discussion

The overall survey response rate was 93% (SDF; 94%, CF; 93%). The CFs were less specialised and more fragmented than SDFs, with 30% operating a non-dairy enterprise (compared to 11% of SDFs) and 94% farming more than one land block (compared to 68% of SDFs). The SDFs had larger herds than CFs with a median herd size of 195 cows compared to 121 cows for CFs.

Few differences in calf rearing biosecurity practices were observed between farm types; a selection of responses is shown in Table 1.

Table 1. Calf rearing biosecurity practices adopted by dairy farmers (%) engaged in contract-rearing (source dairy farmers; SDFs, n=65 and control dairy farmers; CFs, n=55)			
Biosecurity practice	SDF	CF	p-value
Vaccinated cows for at least one infectious disease	100	94.3	0.083
Colostrum within one hour of birth to all calves	15.8	30.6	0.069
Colostrum from own dam only (i.e. not pooled) to all calves	22.4	24	0.845
Colostrum quality assessed (visual/other)	50	46	0.678
Waste milk fed to calves	73.3	80	0.413
Exposure of calves to cow manure in housing areas	8.3	20	0.076

Given the increased biosecurity risks associated with CR, it was hypothesised that greater implementation of disease prevention measures would be evident on SDFs. The results of this research do not support this hypothesis. While all SDFs had a herd vaccination protocol in place, vaccination alone is not sufficient to mitigate the risk of disease introduction and spread.

Appropriate management of heifer calves during the neonatal period prepares them for potential disease challenges during the neonatal period and thereafter. Colostrum management practices were suboptimal on both farm types. While most farmers fed a sufficient volume of colostrum, prompt feeding of this colostrum was poorly implemented. The majority of farmers did not conduct any assessment of colostrum quality (e.g. visually/refractometer/colostrometer) and fed pooled colostrum (sourced from cows other than the calf's own dam), a risk factor for transmission of several pathogens.

Conclusion

Despite the increased biosecurity risks associated with contract-rearing, dairy farmers engaged in the practice did not have better biosecurity than farmers rearing their own heifers. There is considerable scope for improvement in adoption of calf rearing biosecurity practices on both farm types (SDF and CF).

Abomasal bloat in dairy calves — how to investigate an outbreak

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Summary

- Abomasal bloat is a frustrating problem in unweaned dairy calves
- Investigation of outbreaks involves a farm visit to gather a detailed case history, examine the calves and their environment and collect relevant samples
- Systematic investigation is best conducted using a purpose-designed questionnaire.

Introduction

Abomasal disorders (bloat, twists, infections and ulcers) are a common problem in primarily unweaned dairy calves. While each problem (e.g. bloat) may occur independently, they are inter-related ailments and they may also be misdiagnosed. They accounted for some 12% of all cattle deaths in March 2021, and ~6% of deaths in calves (1–5 months) submitted to the regional vet labs annually, with no change over a decade. The clinical signs include reduced milk/milk replacer (MR) intake, dullness, colic, bloat (often recurrent), diarrhoea, dehydration, cold, collapse, and sudden death ('perfectly healthy, found dead'). The onset of bloat is thought to be precipitated by a combination of many factors but the main cause/s of the condition are often feeding and hygiene-related. Abomasal disorders can occur as an isolated case or as an outbreak with severe losses year after year, even on well-managed farms. Here we outline how best to troubleshoot outbreaks of abomasal disorders in dairy calves from farmer, advisor and veterinary practitioner perspectives.

Investigating an abomasal bloat outbreak

An investigation starts with recognising and defining the problem and attempts to record and interpret both risk factors and possible causes of the outbreak through a calf-management audit checklist.

Questionnaire

Relevant background information should be recorded in a standardised questionnaire. Sample investigative questions (referring to the period prior to and during the outbreak and any recent changes) which should be asked during a farm visit include;

- *Case definition* — What is the problem (e.g. just bloat or bloat plus calves dying suddenly)? Which calves were affected [heifers/bulls, breeds, fed milk/MR, from teated/open buckets/automatic feeder (AF)]? At what ages? How many were affected/died and how many were at risk? When did the problem occur (what was the weather like?) and is this the first year of it? Has the vet examined/treated/sampled the calves? Are there any sample results?
- *Farm background* — what is the enterprise type, staff, calving pattern, number of calves at risk and calf management (e.g. if heifers and bulls are managed differently and number of heifers retained/when are bulls sold)?
- *Newborn calf care* — Describe colostrum (volume, quality, hygiene, storage, pooling, timing and methods of feeding) and navel (cord antisepsis) management
- *Calf housing* — Detail of different calf ages, house/pen types, ventilation, bedding, calf groups, age ranges, stocking rates, disinfection, water sources and AF layout

- *Calf health and performance* — Outline preventive medications (e.g. cow/calf vaccines, antimicrobial use (AMU), anti-crypto/cocci), vet involvement, number of treated calves, lab reports and whether/how often calves are weighed and ADG
- *Environmental hygiene* — Describe cleaning/disinfection and replacement routines and hygiene score of colostrum and milk feeding equipment (condition of stomach tubes, buckets, teat/tubes, nipple bars, AF), housing (bedding, fittings, water sources, passageways) and feed (colostrum, milk/MR, water, ration, hay, silage, straw)
- *Calf feeding* — How (AF/manual), how much (volume/feed/day, milk curve), how often (frequency), how warm (temperature at mixing/teat) and what (milk/waste milk/MR/additives (e.g. electrolytes, antimicrobials/anti-cocci/anti-crypto)/water) liquid feed is offered (teat/no teat) and withdrawn (weaning policy, age, weight)? If MR is fed, what is the product, composition, mixing rate and total solids percentage (in normal/cold weather)? If AFs are used, view service/calibration reports and feeding/cleaning programmes. Detail water (source, type, availability, number of water points, quality), roughage and ration feeding management (type, provision, appearance, protein content).

In addition to these questions, a farm visit will involve examination of the calves (especially feeding behaviour, health and weights), their environment, feed and feeding equipment and, as necessary, collection of appropriate samples.

Samples/testing

Depending on the questionnaire responses, the following sampling may be warranted. From the calf, blood samples (to check colostrum management), faeces (if diarrhoea), nasal mucus (if pneumonia), body weights (weighband/scales) and carcass (postmortem examination). Feed samples including colostrum/milk/MR [milk solids percentage as fed/refractometer reading, microbiology/adenosine triphosphate (ATP) swabbing, water (microbiology)]. Biofilm swabs from feeding equipment (e.g. teats, mixing bowl, tubes, buckets) for aerobic and anaerobic/capnophilic quantified culture or ATP bioluminescence.

The final aspect of the investigation is the provision of a recommended list of changes to current calf management protocols, preferably in the form of a written, prioritised, 'to do' report.

Conclusion

Given the multifactorial nature of abomasal disorders in calves, a systematic calf management audit involving an investigative questionnaire and targeted sampling protocol is recommended. Critical to this audit is a holistic investigation of all aspects of calf management, not just focusing on the bugs or the milk/MR.

Effect of type of housing on prevalence of calf pneumonia on Irish dairy farms nationally

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Summary

- There were five predominant calf housing designs on Irish dairy farms with the most common being duo pitch (44% of farms)
- On average, 10% of examined calves had pneumonia; this varied from 0–80% across farms
- Round roof sheds with additional lean-to roof(s) had a significantly higher prevalence of calf pneumonia than other shed designs.

Introduction

Pre-weaning calf pneumonia represents a significant challenge for Irish dairy farmers; it is second only to scour as a cause of mortality in calves between one and three months of age. There has been no recent research on the relative importance of causative factors in the occurrence of calf pneumonia on Irish dairy farms. Hence, a collaborative Teagasc/UCD nationwide study was conducted. Preliminary results on some aspects of calf housing are presented here.

Materials and methods

During the spring of 2020 and 2021, 64 dairy farms from all provinces were visited twice (Figure 1). A survey was conducted on the calf housing design and whether calves were in a common airspace with older cattle. Ultrasound was used to examine 20 calves in each herd between four and six weeks of age for pneumonic lung lesions.

Results and discussion

The most common calf housing types were duo-pitch (44%) or round roof and lean-to (19%) (Table 1). On average, 10% of the calves examined had lung lesions indicative of pneumonia. Preliminary analyses suggest that, on average, pneumonia prevalence did not differ between shed types except for round roof and lean-to, which had a significantly higher prevalence of calf pneumonia. However, there was wide variation in pneumonia prevalence within all shed types. The higher prevalence of calf pneumonia in round roof sheds with additional lean to roof(s) may be a result of the comparatively large shed width and a design that results in under-ventilated microenvironments.

There was no significant difference in the prevalence of calf pneumonia between housing that shared calf airspace with adults and those that did not (Table 2).

Table 1. Effect of calf housing type on percentage of calves with pneumonia

Shed Type	Sheds (no.)	Mean	Median	Max	Min
Duo pitch	28	9.46	5	45	0
Lean-to	5	4.00	0	15	0
Mono pitch	10	11.00	7.5	30	0
Round roof	9	3.89	0	10	0
Round roof with additional lean-to	12	18.67	15	80	0

Table 2. Effect of calves sharing airspace with adult animals in housing on percentage of calves with pneumonia					
Shared airspace with adult animals	Sheds (no.)	Mean	Median	Max	Min
No	50	10.5	5	80	0
Yes	14	9.3	7.5	30	0

The lack of significant differences between most housing designs highlights the multifactorial nature of pneumonia. This research did not identify a 'best design of calf shed'. This suggests management is likely to have an equal, if not more important, effect than shed design, per se. Given how common round roof sheds with additional lean-to roof(s) are and the associated higher prevalence of calf pneumonia, farmers need to be conscious of this risk factor. Where calf pneumonia is a problem in such sheds one might consider moving calves to an alternate shed or modifying the existing shed. Merely increasing vaccination/treatment rates in the same shed may not be a sustainable long-term option given current pressure on antimicrobial use (AMU) and resistance (AMR).

It was perhaps surprising that housing calves in the same airspace as older cattle was not associated with a higher prevalence of calf pneumonia in this study. However, the wide variation in pneumonia prevalence within both shared (0–30%) and non-shared airspace housing (0–80%) made it very difficult to detect differences. In principle, calves should not share airspace with older cattle.

Conclusion

Most of the calf housing designs present on Irish dairy farms were not associated with increased prevalence of calf pneumonia apart from round roof sheds with additional lean-to roof(s). The wide variation in calf pneumonia detected between farms in this study could not be solely attributed to the design aspects of calf housing investigated above.

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Risk factors and causes of abortion in Irish dairy herds

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Summary

- The majority of abortions are concentrated just prior to the calving peak
- Approximately 30% and 20% of abortions are due to infectious (primarily sporadic) and non-infectious causes, respectively, and some 50% have no diagnosis
- In 30% of abortions the foetus is assisted at birth; a zoonotic risk.

Introduction

Since the commencement of BVD eradication in 2013, herd expansion following 2015, increased use of vaccines and improved herd fertility, the profile of abortion may have changed. Given these changes, the objective of this longitudinal study was to monitor both the risk factors for, and the causes of, abortions in Irish dairy herds since 2015.

Materials and methods

A whole herd, prospective, active surveillance model was used to investigate all recorded abortions (<260 days) in 40 Munster dairy herds over seven years. A text-and-collect service was provided. In total 210 foetuses (and 29 placentas) were examined.

Results

Characteristics of abortion

Abortions occurred between September and May with a peak in January. This profile corresponded to abortions from the fifth to ninth month of gestation, with a peak in the ninth month. These foetuses varied in weight from less than 1 kg to 34 kg, averaging 17 kg. While the majority of abortions occurred in cows, some 33% were in first calvers. Most cows were mated to dairy sires with 30% to beef sires. The majority of affected cows were bred by AI, with 25% served by natural service bulls. The majority of cows were in good body condition (3–3.5), with some 10% <3 and 5% >3.5. There were more female (55%) than male foetuses (45%) with a high proportion of multiple foetuses (nearly 20%). The majority (~66%) of foetuses were moderately or badly decomposed. In 95% of cases, the foetus was reported as dead at birth or found dead (though post-mortem examination showed some 15% of calves had breathed). Very few cows (~15%) were noticed with signs of abortion; restless, mounting other cows, bagging up, discharge on cow/in cubicles, passing the 'string/blister'). In some (~10%) cases, the foetus was mal-presented; 30% of abortions were assisted.

Causes of abortion

A diagnosis was made in half of all abortions using the clinical history, the post-mortem and the laboratory findings (Table 1). The two most important causes were infections (~30%) and lethal congenital defects (~10%). The most commonly detected primary pathogens were Trueperella pyogenes (11%), Leptospira spp. (5%), Listeria monocytogenes (4%), Neospora caninum (4%) and Bacillus licheniformis (3%). The majority of congenital defects affected multiple body systems, likely due to de novo mutations. In the majority (~60%) of cases of no diagnosis, the foetus was decomposed.

Table 1. Summary of diagnostic findings in 210 aborted foetuses			
Diagnostic group	Subcategory (No.)	No.	%
Infection[a]	Single (52), coinfection (4), dam (4)	60	28.6
Congenital defect	Individual (9), multiple (8)	17	8.1
Other COD[b]	Maternal stress/trauma, twin-twin syndrome	17	8.1
Multiple COD	Infectious and non-infectious	13	6.2
Diagnosis not reached	Fresh/mild (42), moderate/marked (61) foetal decomposition	103	49.0
Total		**210**	**100**

[a]*Includes primary pathogens only (secondary pathogens were detected in 32 other foetuses); [b]COD = cause of death*

Discussion

As expected, the majority of reported abortions occurred in the last trimester (larger foetus and housed cows, so easier to observe) but the peak in January (>40% of which were after Jan 15th, so probably during the calving season) is perhaps surprising. Abortions tend to be associated with the autumn in spring-calving herds. This novel finding and the high assistance rate at abortion (30%) indicates that farmers need to take personal and herd health biosecurity precautions, even during the calving season. This is particularly relevant, as imminent signs of abortion were not observed in most (85%) cases. Most diagnosed abortions were due to sporadic pathogens carried by cows or in their environment. Key preventive measures include maintenance of herd immunity through nutrition (sporadic infections), good herd hygiene (sporadic infections), effective prevention and therapy of metritis/endometritis/mastitis (T. pyogenes), feeding well-preserved silage (L. monocytogenes, B. licheniformis, fungi), preventing canid access to placentae/dead calves (Neospora) and vaccination (Leptospira, *Salmonella*, BVD, IBR). Surprisingly, salmonellae were not detected; this may reflect high vaccination rates and the success of the BVD eradication programme. The low placental submission rate (~15%) needs to be improved to increase diagnosis.

Conclusion

It is concluded from this new research that with widespread vaccination and the success of the national BVD programme, most abortions are now caused by sporadic, rather than endemic infections.

The National Farm Survey — biosecurity adoption decisions and dairy farm economic performance

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Summary

- Biocontainment practices (preventing disease spread within farm) were more commonly adopted than bioexclusion practices (preventing disease spread into a farm) on Irish dairy farms
- Vaccination was the most common and testing bought-in cattle the least common biosecurity practice adopted
- Vaccination can have a positive impact on economic performance of Irish dairy farms.

Introduction

One of the barriers to farmer adoption of biosecurity practices is the lack of economic data underpinning their cost-effectiveness. This research explored Irish dairy farmers' adoption of biosecurity practices and compared economic outcomes of adopters and non-adopters.

Materials and methods

The data came from 267 dairy farmers in the 2019 Teagasc National Farm Survey (NFS). The data included information on farm characteristics such as farm size, input costs and output, and data from questions on biosecurity in the supplementary survey. We explored adoption of biosecurity measures, and then compared economic outcomes for farmers who used more than three vaccines (the median) to farmers who used less. We focused on vaccination; this was the most commonly adopted biosecurity practice.

Results and discussion

The adoption rates for biosecurity practices varied widely (Table 1).

Table 1. Distribution of biosecurity practices adopted by dairy farmers

Biosecurity practices	%
Vaccinate cattle	86.1
Get bulk tank milk (BTM) tested for diseases	64.6
Carry out other biosecurity measures	55.5
Do not pool colostrum from more than one animal	45.0
Maintain a closed herd	35.6
Quarantine bought-in cattle[1]	30.2
Test bought-in cattle for diseases[1]	13.4

[1]percentage refers to farmers who buy in stock

Biocontainment practices were adopted more commonly than bioexclusion practices. Cattle vaccination is a legacy practice on most dairy farms while testing of bulk tank milk is a relatively recent practice promoted by the agri-industry. Despite the national concern about Johne's disease, the majority of dairy farmers still pool colostrum. The relatively low proportion of farmers reporting a closed herd reflects the current expansionary era. Neither quarantining nor post-purchase testing were widely adopted despite being low cost practices. Very few farmers (4.5%) sent their heifers out to be contract-reared. Dairy farmers were more likely to vaccinate against cow diseases than calf diseases (Figure 1). The high vaccination rates against leptospirosis and IBR reflect legacy practice and the recent AHI-IBR programme, respectively.

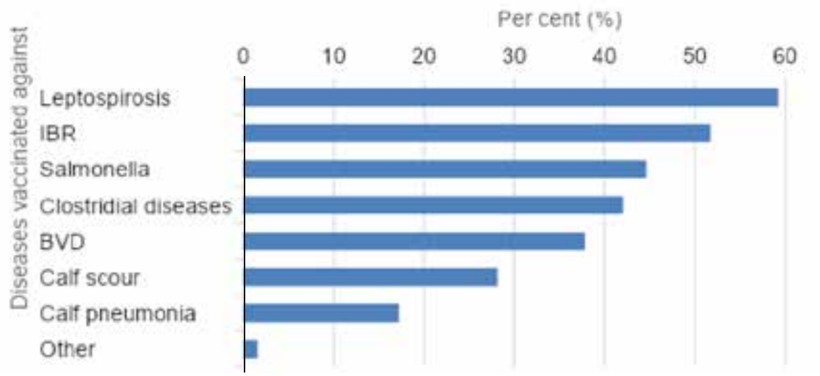

Figure 1. *Diseases dairy farmers (n=229) vaccinated against*

On average, farmers who vaccinated their cattle against three or more diseases achieved €475 higher gross margin/hectare (GM/ha) when compared to dairy farmers who vaccinated against fewer diseases (Table 2). However, this comparison does not account for farm management practices/other characteristics that may influence GM/ha, hence not all economic gains can be attributed directly to vaccination. Moreover, our data also show that farmers who vaccinated against three or more diseases had significantly larger dairy herds, higher stocking densities, produced more milk per cow, but also fed more concentrates.

Table 2. Mean farm characteristics, production and economic performance of farmers who used three or more vaccines vs. two or less

Variables	>3 vaccines (n=154)	<2 vaccines (n=113)
Gross margin/ha (€)	2,733.82	2,258.84
Dairy herd size (cows)	105.75	69.79
Stocking rate (LU/ha)	2.18	1.99
Milk yield/cow (litres)	5,956.46	5,266.62
Concentrates fed/cow (kg)	1,208.35	1,060.45

LU — Dairy livestock units

Conclusion

The most commonly adopted biosecurity measure on Irish dairy farms, vaccination, appears to be a cost-effective practice.

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Bovine TB in dairy herds: taking action to reduce the risk of a breakdown

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Summary

- Levels of bovine TB have been increasing since 2016
- Dairy herds accounted for 31% of all TB breakdowns in 2020
- There are several practical actions that dairy farmers can take to reduce the likelihood of a TB breakdown
- Stakeholders working together through the TB Forum can help to reduce disease levels through new policies.

Introduction

Levels of bovine TB (bTB) have been rising since 2016. Dairy herds accounted for 31% of breakdowns in 2020. In 2020, 55% of reactors were in dairy herds. In July 2021, 4.2% of herds had a breakdown in the preceding 12 months, with 21,546 reactors in that period. These figures highlight the need for urgent action by all stakeholders.

Actions that can reduce the risk of TB in dairy herds

Individual dairy farmers can protect their cattle from TB by taking steps to address the risk factors for a breakdown. These include:

- Consider culling older animals that were alive during a previous breakdown. The risk is that some may have undetected TB infections which can re-start a breakdown
- Source cattle from herds which have not had a TB breakdown in recent years and buy cattle with a recent test date. Cattle exposed to TB recently may have undetected infections and bring the disease into your herd. Maintain a closed herd if possible
- Animals that previously tested inconclusive and subsequently tested clear are at a higher risk of being infected with TB and spreading disease within your herd. These cattle should be culled no later than the end of their current production cycle
- Look for badger setts and activity on your farm. Notify the Department of any setts you find. Take steps to reduce badger to cattle contact on your farm by securing sheds/feed stores, raising troughs and fencing off setts and latrines. Do not feed concentrates on the ground as badgers can spread saliva in that area while finishing any leftovers, exposing cattle to risk if they then feed off that area again
- When selecting bulls for breeding choose ones that are genetically more resistant to TB by using the ICBF traffic light system. If your herd does subsequently experience a TB breakdown, this can reduce the number of exposed cattle which become infected
- Ensure good quality testing facilities are available and provide the vet with any assistance required. Each animal must be identified and have its skin thickness measured on both days of the test. If TB is present but is missed, it will spread further within your herd
- Cleanse and disinfect shared machinery and areas where bTB infected cattle were kept, as the TB bacteria can survive in the environment and cause new infections
- Ensure boundary fences are well maintained and avoid mixing groups of cattle which are normally managed separately

- If you engage in contract rearing, ask the rearer to take steps to reduce TB risk and have a contingency plan for a TB breakdown in either herd.

Consultation

Earlier this year a new Bovine TB Eradication Strategy 2021–2030 was launched, based on recommendations from the Bovine TB Stakeholder Forum. Membership of the Forum and its working groups are drawn from stakeholders across the agricultural industry including the farm organisations and the Department. One of the policies introduced as part of the strategy is the blood testing of inconclusive reactors. To-date circa 70% of the animals blood tested have tested positive. The removal of these infected animals prevents them spreading disease further and shows the value of the collaborative approach taken as part of the TB Forum.

Challenge

Being free of bTB remains critical, from a farm family profitability and sustainability perspective, and from a trade perspective. Every bTB restriction represents a significant emotional and financial challenge to the farm family concerned. Working together, we can reduce TB levels, protect cattle from infection, prevent the stress caused by TB on farm families, and mitigate the threat TB poses to our exports.

See www.bovinetb.ie for videos, advice leaflets, maps and information on how to protect your herd from TB.

BREEDING AND REPRODUCTION

Breeding for a lower environmental hoofprint

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Summary

- Improvements in herd-average EBI are associated with a reduction in carbon footprint per kg milk produced
- Significant variability exists in the methane emissions of cattle
- Low-cost tools that are already routinely available are being explored as mechanisms to support breeding for reduced methane emissions by dairy cows.

Introduction

The Economic Breeding Index (EBI) aims to improve cow lifetime milk solids yield without any associated increase in cow size; this happens to also be a good strategy for identifying more environmentally efficient cows. Nonetheless, the potential for further reductions in carbon emissions by dairy cows, independent of EBI, merits further investigation. The same is true for their beef progeny using the Dairy Beef Index (DBI), which is important given the growing use of beef-on-dairy matings.

Herd EBI and carbon footprint

The carbon footprint per unit milk yield of Irish dairy herds is routinely estimated using lifecycle assessment methodology from data collected in herds participating in the Bord Bia Sustainable Dairy Assurance Scheme (SDAS). This data from 6,764 spring calving dairy herds was examined, and corrected to remove the effect of stocking rate, herd size, the days spent at grass, and county. Herd-average EBI was also available. As shown in Figure 1, herds in the top 20% for herd EBI produced milk with a 0.08 kg lower milk carbon footprint than herds in the bottom 20%, and every €10 increase in herd-average EBI was associated with a 0.0074 kg decrease in milk carbon footprint.

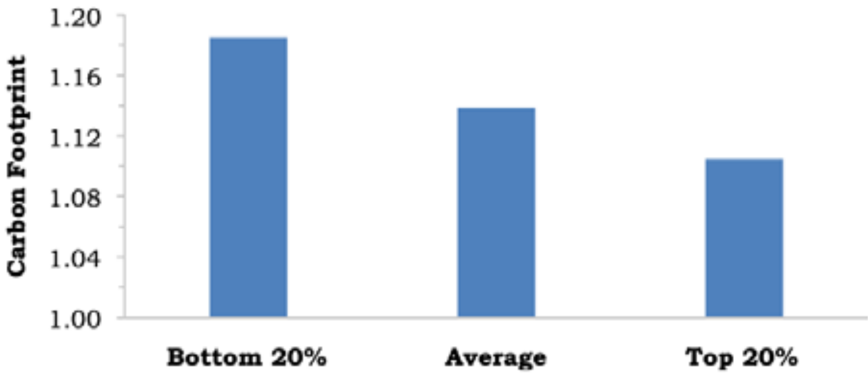

Figure 1. *Carbon footprint (kg CO_2e/kg fat and protein equivalent milk yield) for herds in the bottom 20%, average, and top 20% for herd-average EBI*

A higher milk solids yield combined with superior reproductive performance and cows surviving longer reduces the number of replacements required which contributes to the lower carbon footprint of high EBI herds. Research within the Teagasc '*Next Generation Herd*' has also shown that cows in the Elite group (high EBI) have a lower milk carbon footprint in comparison to cows of national average EBI (page 218 of booklet).

Genetic differences in methane emissions

Information on feed intake and methane emissions is now collected on dairy-beef cattle fed indoors at the Irish Cattle Breeding Federation Tully Progeny Test Centre in Kildare. In recent work, dairy-beef steers with an average age of 23 months consumed 13.3 kg DM/day of a total mixed ration and produced 273 g methane/day during the 90 day finishing period. The difference in average daily emissions between the high (top 25%) and low (bottom 25%) emitters was 112 g/day. Even within animals with the same growth rate and liveweight, the difference in daily methane emissions between the high and low emitters was 65 g/day. Preliminary analyses has revealed that approximately 25% of the variation (differences) in daily methane emissions observed is due to genetics. Similarly, international research in dairy cows fed indoors suggests that up to 30% of the variability in daily methane emissions is also due to genetics. For grazing Irish dairy cows, however, more measurements of methane emissions are required to quantify the contribution of genetics, as well as establish the rate of genetic gain possible in reducing methane emissions without sacrificing much in the rate of genetic gain for other important traits such as intake potential and production.

Potential breeding strategies for lower environmental hoofprint

Direct selection for lower methane emissions in dairy and dairy-beef cattle may be possible but the measurement of such emissions in grazing cattle is resource intensive, thus limiting the ability to achieve accurate genetic evaluations. All milk samples taken in Ireland, either on individual cows or bulk tank samples, are subjected to a technology called infrared spectroscopy. Moorepark has demonstrated that this technology can be used to estimate feed intake and energy balance (Page page 210 of booklet). International research suggests that it may also be possible to predict cow methane emissions from milk samples using the same methodology. Research is ongoing at Moorepark to evaluate if this holds true in grazing Irish cows.

Conclusions

Current research illustrates that variation exists in the methane emissions between animals, and the possibility of using data from milk samples in a breeding program aimed at reducing emissions is being investigated. Nonetheless, breeding for more environmentally efficient cows is complex due to the need to actually measure methane emissions, as well as the potentially unfavourable associations of methane with intake potential, milk production, and energy balance.

The environmental impact of selecting cows using the economic breeding index

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Summary

- The EBI in its current form is selecting for improved environmental efficiency
- Each €10 increase in EBI leads to a 1% reduction in GHG emissions per unit of milk solids
- Selection for lower methan emissions in absolute terms may slow down or erode the rate of gain in other economically important traits.

Introduction

The economic breeding index (EBI) was developed to breed cows that increase profitability in grass-based dairy systems. Recent environmental pressures facing the dairy industry, however, also require milk to be produced in a sustainable manner. The contribution of genetics should be considered when evaluating strategies to improve sustainability as breeding is cumulative and permanent; meaning any positive or negative effects of genetic selection will be compounded with successive generations.

How does the EBI impact the environment?

Greenhouse gas (GHG) emissions of both high and average EBI animals were recently modelled through a full lifecycle assessment analysis using biological data from the high EBI (Elite) and national average (Nat Av) genetic groups within the '*Next Generation Herd*'. The analysis was based on a 40-ha dairy farm carrying 110 cows. The results are presented in Table 1. The Elite cows were more productive (milk solids (fat and protein) yield) compared to the Nat Av cows but produced more methane per cow. However, because of their greater fertility performance, the Elite cows had lower GHG emissions from rearing fewer replacement heifers compared with the Nat Av cows and resulted in no overall difference in GHG emissions between the two groups. The net effect was 11% less GHG emissions per kg of milk solids. Each €10 increase in EBI between the Nat Av and Elite cows resulted in a 1% reduction in GHG emissions per kg of milk solids. A nitrogen (N) balance model was also developed integrating data from the *Next Generation Herd*. The model included all N inputs in fertiliser, herd replacements and feed as well as outputs in milk, calves and cull cows. This demonstrated the Elite cows to have a slightly greater N use efficiency (N output / N input) and lower N surplus (N input–N output) compared to the Nat Av cows due to their increased N output in milk protein (Table 1).

Table 1. Environmental impact of the Elite and National Average dairy cows

	Elite[1]	Nat Av[2]
Milk solids (kg/cow)	484	434
Greenhouse gas emissions (tonne/ha)	16.3	16.2
Greenhouse gas emissions per unit milk solids (kg/kg)	12.2	13.7
Nitrogen surplus (kg N/ha)	206	212
Nitrogen use efficiency (%)	0.332	0.315

[1]*EBI = €181;* [2]*EBI = €82*

Direct measurements of methane

The previous analysis was based on a computer modelling exercise. In 2021, direct measurement of methane emissions from grazing dairy cows is underway in the *Next Generation Herd*. This data will be used to investigate the impact of the EBI on direct measurements of methane. Relationships between methane emissions and economically important traits will also be assessed. This will be an important exercise as direct selection for environmental traits within the EBI will likely be considered in the future. Initial results suggest the EBI impact is in line with that modelled previously. Additionally, there is a similar level of variation between cows for methane emissions as there is for milk solids yield. This indicates it may be possible to select for lower methane emitting cows. However, as milk solids production increases, so does methane production; meaning selection for reduced methane emissions per cow may slow down the rate of gain for milk solids production. The results also show that cows producing more milk solids per unit of feed eaten (more feed efficient) produce more methane per kilogram of feed eaten. This indicates that selection for economically important traits such as feed efficiency and methane production may not go hand in hand.

Conclusion

The EBI in its current form is selecting for more environmentally efficient animals, with each €10 increase in the EBI resulting in a 1% reduction in GHG emissions per unit of milk solids. Selection for increased EBI, however, will not reduce emissions in absolute terms or on an area basis. Further work is being conducted on direct measurements of environmental traits with high and low EBI animals, while also assessing relationships between environmentally and economically important traits.

Benefits and uses of mid-infrared milk spectroscopy

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Summary

- Our national dairy breeding goal, the EBI, is reliant on the routine collection of accurate, unbiased data of its goal traits, or of correlated traits
- Mid-infrared spectroscopy offers vast potential to collect data on cows and milk through the existing pipelines of milk recording and milk testing
- Traits such as intake, fertility, and emissions could be predicted for individual cows from routine milk recording providing additional information for genetic evaluations and making the inclusion of new traits such as emissions and efficiency in the breeding goal feasible.

What is mid-infrared spectroscopy?

Mid-infrared spectroscopy (MIRS) is a technique routinely used to quantify milk composition, both of bulk tank and individual cow milk recorded samples. During MIRS analysis, light is shone through the milk sample at 1,060 wavelengths, and the absorbance of light through the milk at each wavelength is recorded; the associations between the absorbance values is used to predict the milk constituents.

Over the past decade, the potential of MIRS to tell us more than just the macro constituents of fat and protein has been explored; traits such as individual milk fatty acids, individual proteins and processing traits such as milk pH, heat stability and cheese-making characteristics can all be predicted using MIRS analysis of the milk sample.

Using milk to inform on cow traits

Milk, like any biological sample, can provide a lot of information about the status of the producing animal. Milk fat comprises hundreds of individual fatty acids which arrive in milk from different pathways: 1) synthesised in the mammary gland, 2) directly from the diet, or 3) mobilisation of body reserves when the animals' dietary energy does not meet supply requirements. Therefore, knowing the ratio of these fats in milk can inform of the dietary energy consumed by the cow, whether she is losing or gaining body condition (which is linked to fertility) and even the methane emissions of the cow. Since we can accurately predict the individual fatty acids in milk using MIRS, can we go one step further and predict dietary energy intake and mobilisation of body reserves? If successful, data on these traditionally difficult to capture traits would be routinely available on over half a million dairy cows several times across lactation, which would be useful to develop and enhance national genetic evaluations.

Machine learning algorithms to develop prediction equations

Quantifying associations between milk MIRS data and cow traits is complicated by the highly dimensional and correlated structure of spectral data. Recently this research team investigated the application of nine modern machine learning approaches to more appropriately handle MIRS data to predict milk traits. The alternative approaches tested used different methods to draw associations between the MIRS data and milk traits by reducing the dimensionality of the spectral data. Neural networks was the most successful single approach in that study to predict milk traits. Neural networks process data similar to how our brains do by passing the input data (i.e. the MIRS spectrum) through a series of layers of neurons, with each layer passing information to the next until an output is generated.

Predicting dietary intake

A database of 6,315 individual dietary intake records obtained from four Teagasc research herds, representing different breeds and experimental diets over the past decade combined with their corresponding MIRS data was compiled. Previous Teagasc research indicated the potential of MIRS to predict dietary intake; the purpose of this larger database was to build a more robust equation using more extensive data to better represent the national herd. A neural network algorithm was generated using 75% of the database to predict dietary energy using only the MIRS spectrum and milk yield. The remaining 25% of the database (different animals to those used to calibrate the equation) was used to validate the prediction equation. In the validation set of animals, the correlation between true energy intake and that predicted from just MIRS data and milk yield was 0.73. While an accuracy of 1 would show perfect prediction of intake, it is not expected; the correlation of 0.73 indicates a strong relationship and is similar to the genetic correlation between SCC and mastitis.

As further validation, the equation was redeveloped leaving out one herd at a time. The correlation between true and predicted values of energy intake ranged from 0.47–0.65 across the four validated herds.

Predicting body condition score change

Body condition score (BCS) is a useful predictor of fertility and is measured every three weeks on cows in Teagasc herds. The change in BCS from one day to the next was estimated and a database of 40,916 BCS change scores with milk spectral data compiled. The correlation between true BCS change and that predicted from the milk spectra was 0.81.

The next steps

Methane emissions data obtained from the GreenBreed machines at Moorepark (page 206) will be collated with their corresponding MIRS data and equations to predict methane emissions will be tested. Initial indications are that MIRS data is useful to accurately predict emissions.

Conclusion

Lack of data from commercial animals is the reason for the exclusion of some traits of importance from our breeding goal. Infrared spectroscopy has the potential to plug that gap by generating vast amounts of data on difficult to measure traits in a rapid, inexpensive and unbiased manner.

Exploitation of genetic differences in lactation yields and somatic cell count with each progressing parity

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Summary

- Genetic differences exist among breeds, but also among sires within breeds, in rate of maturity and in the rate of decline in lactation yield once maximum yield is achieved
- Selecting sires whose daughters maintain high lactation yield and low somatic cell count for longer in life is possible.

Introduction

The reproductive performance of Irish dairy cows has improved year-on-year for the past two decades. Cow longevity is also increasing in Ireland. Lactation yield is, however, expected to reduce once cows reach a certain age; somatic cell count is also expected to increase with cow age. Similar to the known inter-animal differences in milk and somatic cell count profiles within a lactation, of interest was whether the profile of total lactation yield or lactation average somatic cell count differed as cows aged, especially once maturity was reached.

Differences in rate of maturity between cows

Data from 196,775 lactations on 68,323 Irish cows of multiple breeds revealed that 79.7% of cows reached maximum milk production in fifth parity while 13.5% and 6.1% of cows reached maximum production in fourth and sixth parity, respectively. Somatic cell count increased consistently with parity up to ninth parity.

The heritability of a trait is the proportion of the observed difference between individuals that is attributable to genetics. The heritability of milk (fat and protein) yield and milk composition per parity varied from 0.17 (parity 7) to 0.39 (parity 1) and from 0.26 (parity 10) to 0.64 (parity 4), respectively. The range in heritability per parity for somatic cell count varied from 0.11 (parity 3) to 0.38 (parity 10). Importantly differences among sire families were evident in the trajectory of milk yield, composition, and somatic cell count across parities. Such differences are illustrated in Figure 1 for milk yield and somatic cell count, where differences in both the height and shape of the profiles for milk production and somatic cell count were evident for daughters of different sires. These differences demonstrate the potential to select sires whose daughters maintain their mature milk production and low somatic cell count for longer. The approach used here creates estimates of genetic merit for milk (fat and protein) yield, composition, and somatic cell count for every sire for each parity. In fact, there was a strong association between the genetic merit for third parity milk production and the milk production values from the national genetic evaluation for sires generated by the Irish Cattle Breeding Federation.

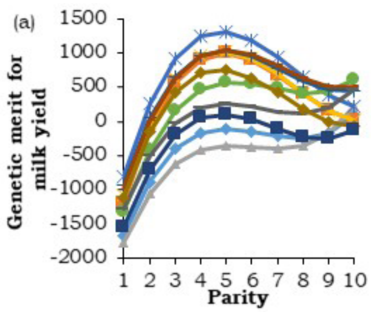

Figure 1. *Genetic merit of individual sires (each colour represents a different sire) for (a) daughter milk yield (kg) and (b) somatic cell count (log10 unit)*

Breed differences in rate of maturity

Obvious breed differences in the trajectory of milk yield, composition, and somatic cell count were also evident (Figure 2; breed trajectories were estimated from the genetic merit of individual sires). Relative to Friesian and Jersey sires, Holstein sires had higher average genetic merit for milk yield across all parities. On average, the decline in the genetic merit for milk yield with each progressive parity after maximum production was larger for Holstein sires than for Friesian and Jersey sires. While the average genetic merit for somatic cell count increased for all breeds between third and ninth parity, both Holstein and Friesian sires reached their highest average somatic cell count in ninth parity, whereas the genetic merit for somatic cell score of Jersey sires continued to increase with each progressing parity.

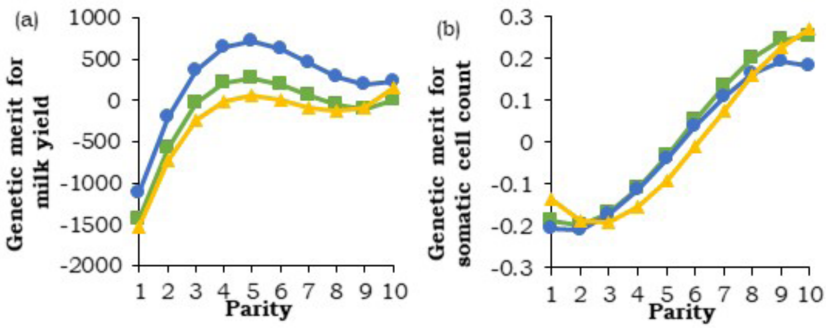

Figure 2. *Average genetic merit for (a) daughter milk yield (kg) and (b) somatic cell count (log10 unit) for Friesian sires (green square), Holstein sires (blue circle), and Jersey sires (yellow triangle)*

Conclusions

Genetic differences exist both within and between breeds for the rate of production maturity and the trajectory of milk production related traits across parities. These genetic differences in profiles could be exploited to select for sires whose daughters maintain a high lactation yield and low somatic cell count for longer, which may be beneficial to producers aiming to improve dairy cow longevity.

Benefits of genomics

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Summary

- Genomic evaluations enable farmers to more accurately identify genetically superior replacements
- Genomic information can also be used for DNA-based calf registrations and the monitoring of inbreeding and genetic defects.

Introduction

DNA information is currently available for 2.3 million Irish cattle. The study of DNA information, also known as genomics, provides an array of on-farm benefits. These benefits primarily relate to generating more accurate estimates of genetic merit for individuals; accuracy is a function of the quantity and quality of the data used in the prediction model. The benefits of genomics also include DNA-based calf registrations as well as the monitoring of inbreeding and genetic defects.

Advances in genomic selection

Genomic selection refers to the incorporation of DNA information into genetic evaluations. This process firstly involves the establishment of a reference population comprising thousands of genotyped animals with accurate performance information. From the reference population, the association between the animals' DNA and performance is quantified. Knowledge of such associations are then used to make genetic predictions, even for genotyped animals not in the reference population. The expansion in the numbers of both genotyped sires and cows in the reference population over time has translated into more accurate genetic predictions. Increased accuracy, or reliability as it is known, of genetic predictions means there is greater confidence that an animal's estimated breeding value reflects its true genetic merit (Figure 1).

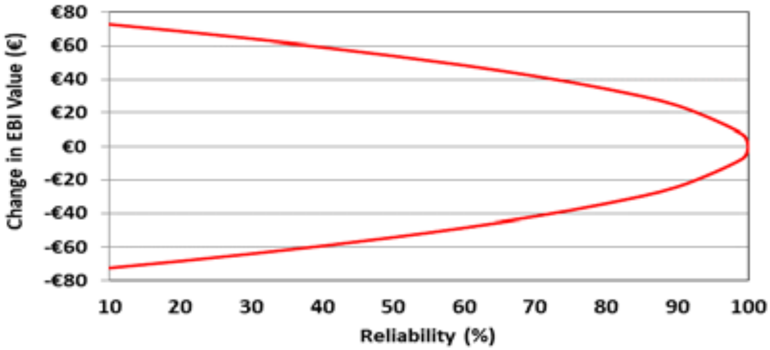

Figure 1. *Potential change in EBI at different reliabilities*

Genomic evaluations are more reliable than evaluations based on parental averages. The reliability increases further when both cows and bulls are included in the reference population (Table 1). To ensure the most accurate genomic predictions are available for breeding decisions, it is therefore necessary for farmers to genotype their replacements at a cost of €22 per heifer. Nonetheless, the benefits of genotyping outweigh the cost. For example, previous research found that for a herd with a replacement rate of 21% that retains 80% of heifers bred genotyping all heifer calves translates to a net gain of €33 per heifer retained. These net gains are derived from the use of the animals' DNA information to more accurately identify the most genetically superior replacements.

Verifying parentage & breed composition

Approximately 8% of dairy calves born annually have a parentage error. The correction of such errors improves the quality of available data and, in turn, the accuracy of the national genetic evaluations. One solution to correct these errors is DNA-based calf registrations. A pilot scheme for DNA-based calf registrations for dairy herds was launched in 2018. Through the scheme, farmers were required to send away a skin sample (obtained from the ear tag) for each calf. This skin sample was used to obtain the calf's DNA information, which was subsequently used to determine the calf's parents; thus, the calves were registered without the need for paperwork on the farmer's behalf. Such information can also be used to determine the breed composition of the calf, which is beneficial for exploiting hybrid vigour (i.e. where the crossbred progeny of two purebred parents outperform their parents); it is not possible to know a calf's true breed composition without genotyping the calf.

Table 1. Reliability (%) of genetic predictions based on parental average and based on a reference population including just sires or including sires and cows

Trait	Parental average (%)	Reference population	
		Sires only (%)	Sires & cows (%)
Milk	61	68	73
Fat	43	56	62
Protein	51	64	68
Calving interval	37	40	43

Genomic inbreeding and genetic defects

Inbreeding arises from the mating of two related animals and, in general, results in poorer progeny performance. Using pedigree information, an individual's level of inbreeding is calculated as half the relationship between their parents. DNA information enables the relationship between potential sires and dams to be exactly quantified, which can be used to ensure that the level of inbreeding, as well as its effect on performance, are minimised in the resulting progeny. DNA information can also be used to monitor the incidence of genetic defects. An example of a genetic defect is Turner syndrome, which results in infertility in females. In the absence of DNA information, heifers with Turner syndrome are indistinguishable from those without. Therefore, unless heifers are genotyped early in life, this inability to go in-calf goes unnoticed until breeding, resulting in a large opportunity cost.

Conclusion

Numerous benefits of genomics exist, including more accurate genetic predictions and the monitoring of inbreeding and genetic defects. To fully reap the benefits, genotyping all replacement heifers is necessary.

Breeding for healthier calves

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Summary

- Considerable exploitable genetic variation exists for health traits such as calf pneumonia and scour highlighting the potential to breed for calves that are less susceptible to disease
- Selecting sires with greater genetic merit for disease resistance will enhance herd health, reduce costs, and increase profit.

Introduction

Calf health has a major impact on the economic viability of cattle operations. In addition to greater treatment and labour costs associated with sick calves, economic losses may also arise due to morbidity, mortality and reduced growth rate. Calf health is no different to any other performance trait in that it is influenced by many factors such as pathogen load, ventilation, nutrition, etc. In addition, like many other traits, there is likely to be a genetic component to differences in calf health. Financial incentives as part of the Beef Data and Genomics Programme (BDGP) were offered to Irish beef farmers to record different measures of calf health. Access to such data enables the estimation of the contribution of genetic differences to beef calf health; the impact is the potential for national genetic evaluations for calf health. Given the increasing use of beef bull semen in dairy cows, improving beef calf health (and dairy calf health if the data were available) is important.

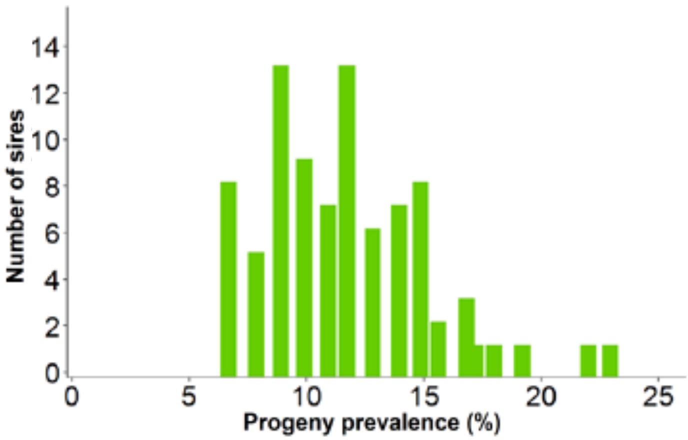

Figure 1. *Prevalence of calf pneumonia in the progeny of beef sires with ≥ 100 calves born in ≥ 5,108 beef herds*

Potential of breeding for calf health

Analysis of data from the Beef Data and Genomics Program (BDGP) from Irish beef herds revealed that 14.7% of calves were recorded as having had scour during the first five months of life, whereas 6.4% of calves were recorded as having had pneumonia within the first five months of life. The research revealed large variability among sires in the occurrence of calf pneumonia in their progeny. For instance, only 6% of calves bred from one particular sire had pneumonia (Figure 1). Whereas, the progeny of another sire had a 23% prevalence of pneumonia (Figure 1). The genetics of the calf (i.e. the heritability) for calf vigour, scour and pneumonia was 12%, 2% and 8%, respectively. Therefore, potential exists to breed for healthier and more vigorous calves as the heritability is greater than zero and even higher than traits Irish farmers have made much genetic progress on (e.g. fertility, calving difficulty). The research also identified the risk factors associated with calf health and vitality (Figure 2), which will not only assist in informing breeding and management decisions, but also ensure that calf well-being is maintained to the utmost standard.

Females (relative to males) were:

- More vigourous
- Less susceptible to scour
- Less susceptible topneumonia

Twins (relative to singletons) were:

- Less vigourous
- More susceptible to scour
- More susceptible topneumonia

Difficult births were associated with:

- Less vigorous calves
- Calves that were more susceptible to scour
- Calves that were more susceptible to pneumonia

When the calf was born:

- Calves born later in the calving season were more susceptible to scour than those born earlier

Figure 2. *Non-genetic factors associated with calf health and vitality traits*

Conclusion

Breeding for healthier and more vigorous calves is a useful addition to current herd health management strategies. Given that breeding is both a cumulative and permanent strategy, it will reduce the need for antibiotics in the future and ensure the utmost calf welfare standards are being maintained. Similar genetic progress in dairy calves could be achieved provided appropriate data is recorded by dairy producers.

Teagasc's Next Generation Herd — an update

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Summary

- The *Next Generation Herd* represents a futuristic national herd, and is a strategically important resource, providing a "forward view" of the performance of high EBI herds under varying grazing strategies
- Results continue to highlight productivity, fertility and efficiency benefits that Irish farmers can avail of via improvements in EBI
- Results also highlight the contrasting yet complimentary attributes of high EBI Holstein-Friesian and high EBI Jerseys.

Introduction

Based at our Dairygold Research Farm, Teagasc's *Next Generation Herd* was established in 2012. It represents a futuristic national herd deemed strategically important to provide a "forward view" of the performance of high Economic Breeding Index (EBI) herds under varying grazing strategies. Lessons learned from the past suggest that periodic re-evaluation of breeding goals is prudent. In the case of our national breeding strategy and EBI, it is important to ensure the compatibility of resultant genetics with our seasonal pasture-based production system. The study herd originally comprised 90 Elite (Top 5% based on EBI) and 45 National Average (NA) Holstein-Friesian cows. From 2018–2020, the study design comprised 72 Elite Holstein-Friesians, 36 NA Holstein-Friesian and 72 purebred Jersey cows. Table 1 shows the latest EBI values. While controversial, the complimentary attributes of the Jersey compared to Holstein-Friesian leads many to continue to crossbreed with Jersey to avail of these perceived complementarity traits and to capitalise on hybrid vigour or heterosis. Jersey cows were added to the *Next Generation Herd* to provide a comparison of modern Jersey genetics with our Elite Holstein-Friesian and to develop a nucleus of high EBI Jersey genetics. The Jersey cows introduced to the study represented genetics originating from both pasture-based (New Zealand; NZJ) and high-input indoor systems (Danish; DKJ). The Holstein-Friesian cows were stocked at 2.75 cows/ha while the Jersey were stocked at 3.0 cows/ha.

Table 1. EBI and sub-index values for Holstein-Friesian and Jersey cows within the Next Generation Herd

	Elite	NA	NZJ	DKJ
EBI	184	125	156	75
Milk	58	43	62	18
Fertility	82	50	42	43
Calving	35	26	38	-5
Beef	-14	-11	-55	-55
Maintenance	16	13	57	63
Health	5	2	3	5
Management	3	1	8	5

Results

Results from the last three years (2018–2020) are presented in Table 2. In line with previously published results, the NA Holstein-Friesian had higher milk yields compared to the Elite Holstein-Friesian cows but the Elite cows did produce milk of significantly higher milk fat and protein content and consequently produced higher annual milk solids yields (Table 2). Superior efficiency and productivity per ha were also evident with the Elite cows. The Elite cows continued to maintain higher body condition score and express superior fertility performance (three week submission rate, six week pregnancy rate and 12 week pregnancy rate) when compared to the NA cows. There was no difference in mean live weight between the two Holstein-Friesian groups.

The NZJ were superior in all aspects of milk production compared to the DKJ. The NZJ produced more milk, of higher fat and protein yield, resulting in considerably more milk solids (+41 kg) over lactation compared with the DKJ. The productivity of the NZJ was such that, despite a substantial difference in milk volume compared to the Holstein-Friesian cows, the NZJ only produced 7 kg less milk solids/cow when compared to the NA cows. The advantage of the Jersey is especially apparent when milk solids production is expressed per ha and per kg of bodyweight. The NZJ achieved milk solids yields of 110% of mean body weight over lactation. This is due to the Jersey's smaller size and higher intake capacity. Interestingly, the NZJ and ELITE cows had similar body condition score (2.96 and 2.93, respectively), as did the DKJ and NA cows (2.79 and 2.78, respectively).

Table 2. Cow strain on lactation performance

	ELITE	NA	DKJ	NZJ
Milk Yield (kg/cow)	5,645	5,706	4,412	4,574
Fat (%)	4.71	4.48	5.45	5.81
Fat (kg)	265	254	241	263
Protein (%)	3.73	3.64	3.91	4.21
Protein (kg)	211	207	172	191
Average body condition score (1–5)	2.93	2.78	2.79	2.96
Average weight (kg)	532	532	399	411
Three week submission rate (%)	95	88	79	94
Six week in-calf rate (%)	82	65	65	70
Twelve week in-calf rate (%)	92	88	90	92
Milk solids yield (kg/kg bodyweight)	0.90	0.87	1.03	1.10
Milk solids yield (kg/ha)	1,310	1,270	1,240	1,356

Conclusions

The results continue to provide confidence in the EBI and its ability to identify more productive and profitable cows for our seasonal pasture-based system of milk production. The results also concur with previous research highlighting the contrasting yet complimentary attributes of high EBI Holstein-Friesian and high EBI Jerseys originating from pasture-based production.

Prevalence of endometritis and effects on fertility in dairy herds

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Summary

- Uterine infection reduces cow fertility
- Awareness of risk factors can identify susceptible cows
- Good herd management is essential to reduce fertility loss.

Introduction

Cows with endometritis have poorer submission rates, six-week in-calf rates and final pregnancy rates. This negative impact on fertility reduces farm profitability through increased breeding costs and longer calving to conception intervals. Including endometritis screening as part of pre-breeding reproductive management provides an opportunity to identify and treat affected cows.

Endometritis diagnosis

Clinical endometritis is identified by examining vaginal discharge using the metricheck device, which can be scored using a simple scale based on the absence or presence of purulent vaginal discharge (Figure 1). The metricheck device can be used 21 or more days after calving, ideally 3–5 weeks before the start of the breeding season to allow time to treat and resolve infection.

Figure 1. *Vaginal discharge scoring scale. Score 0 = no discharge; Score 1 = clear mucus only; Score 2 = mostly clear mucus with small flecks of pus; Score 3 = mucus containing <50% pus; Score 4 = mucus containing ≥50% pus; Score 5 = mucus containing ≥50% pus and odour*

A large scale study of five commercial dairy herds in Munster was completed in 2020. In total, 1,706 cows were examined for clinical endometritis using the metricheck device. In each herd, cows were examined on a single date 31 days before the planned mating start date (range 20–36). Of the cows examined, 478 (28%) presented signs of infection (i.e. vaginal discharge score ≥2). The breakdown of the percentage of cows with different scores is summarized in Figure 2.

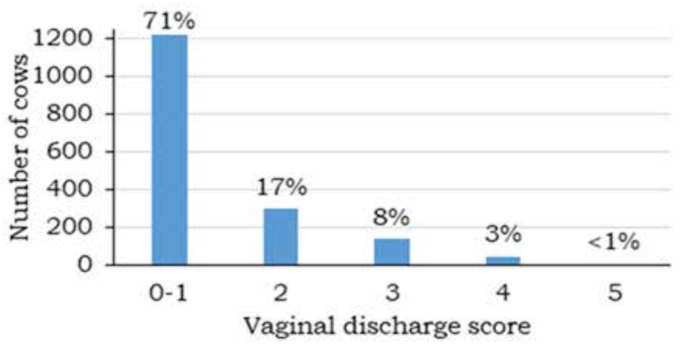

Figure 2. *Distribution of vaginal discharge scores from 1,706 dairy cows in five herds*

Discussion

Parity, breed (Holstein-Friesian vs Jersey crossbred) or EBI were not associated with risk of uterine disease, but there was a large variation in the incidence of uterine disease between herds. This indicates that herd management has an important effect on incidence of uterine disease. Good herd health regimes, maintaining clean calving facilities, and timely interventions when problems do arise will help reduce the incidence of uterine disease. The farms involved in the trial had low levels of calving difficulty and small incidence of twins, which are usual risk factors for uterine disease.

This study observed that cows with clinical uterine disease (score ≥3) had poorer 21 day submission rate, poorer pregnancy rate to first artificial insemination (AI) and reduced pregnancy rates at 21, 42 and 84 days after mating start date compared with healthy cows, as summarized in Table 1.

Table 1. Reproductive performance of healthy cows with no endometritis vs. cows with clinical endometritis

	SR-21[a] %	PregAI-1[b] %	PR-21[c] %	PR-42[d] %	PR-84[e] %
Healthy	92.8	60.3	55.6	81.5	95.1
Clinical endometritis	87.8	53.2	48.3	75.7	87.6

[a]*SR-21 = 21 day submission rate;* [b]*PregAI-1 = pregnancy rate to first AI;* [c]*PR-21 = pregnancy rate at 21 days after mating start date;* [d]*PR-42 = pregnancy rate at 42 days after mating start date;* [e]*PR-84 = pregnancy rate at 84 days after mating start date*

Conclusion

Careful herd management will reduce endometritis incidence and subsequent fertility loss.

Evaluation of the fertility of in vitro produced embryos in dairy herds

Alan Crowe[1,2], Pat Lonergan[2] and Stephen Butler[1]

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Summary

- *In vitro* embryo production can accelerate genetic gain by facilitating multiple matings between elite dams and sires
- *In vitro* produced embryos generated using slaughterhouse ovaries from beef dams as the source of oocytes could improve the beef merit and economic value of non-replacement calves.

Introduction

In most dairy herds ≥60% of the calves born are destined for beef production. Many of these are male offspring of dairy sires and have low economic value. Many dairy producers are increasingly using sexed dairy semen to generate replacements, and mating dairy dams not required to generate replacements to beef sires. 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 allowing an increased number of offspring to be produced from genetically elite dams. Using ovaries collected from beef dams post-slaughter to produce IVP beef embryos, it is also possible to transfer beef embryos into dairy cows that are not required to generate replacements, resulting in calves with 75–100% beef genetics coming from the dairy herd.

IVF-ET trial Moorepark

In spring 2021, a large field trial was undertaken to evaluate the production and use of fresh and frozen IVP embryos and ET in a pasture-based, seasonal calving dairy system. Specifically, the trial used commercial IVP practices to produce embryos with the following objectives:

- Evaluate the potential to accelerate genetic gain in dairy cattle (Economic Breeding Index; EBI) using live elite dairy dams as oocyte donors
- Evaluate the potential to accelerate genetic gain in a beef breed suitable for crossing on the dairy herd (Dairy Beef Index; DBI) using live elite beef dams as oocyte donors
- Evaluate the potential to impregnate dams that are not suitable for generating replacements with beef embryos (commercial beef).

The elite dairy and elite beef embryos were produced after collecting oocytes from 40 elite dairy dams (weekly for eight weeks) and 21 elite beef dams (weekly for eight weeks) using a technique called ultrasound-guided transvaginal ovum pick-up. To produce commercial beef embryos, ovaries were collected from 119 beef heifers post-slaughter (once), and oocytes were harvested. All oocytes were fertilised *in vitro* with sperm from high EBI bulls for the elite dairy embryos and with sperm from high DBI bulls for both the elite beef and commercial beef embryos. After fertilization, the developing embryos were cultured in a lab incubator for seven days and either frozen or transferred fresh. 1,200 lactating dairy cows in nine herds were synchronized using a standard 10-day Progesterone-Ovsynch protocol. On the day of synchronised estrus, 20% of the cows were bred to AI (as normal). The remaining 80% of the cows were not bred, and instead assigned to receive embryo transfer seven days later. In seven of the herds, 40% of the cows were assigned to receive an elite dairy embryo (of which 50% were fresh and 50% were frozen) and 40% were assigned to receive an elite beef embryo (of which 50% were fresh and 50% were frozen). In the remaining two herds, 80% of the cows were assigned to receive a commercial beef embryo (of which 50% were fresh and 50% were frozen). Immediately before ET, cows were examined by ultrasound to determine suitability, after which 9.5% of cows were deemed unsuitable for ET. Pregnancy rates were determined on day 32 after synchronised estrus.

Results

The provisional pregnancy rate results are presented in Table 1.

Table 1. Pregnancy rates determined on day 32 after synchronised estrus for cows bred using AI or ET

	AI	ET–Dairy		ET–Beef	
		Fresh	Frozen	Fresh	Frozen
% Preg., All cows	47.7	61.1	40.1	51.7	41.2
% Preg., Elite embryos	43.8	61.1	40.1	49.1	43.5
% Preg., Commercial beef	54.2	-	-	55.8	35.0

Overall, there were no differences in pregnancy rate between cows bred using AI and ET, nor were there differences between dairy ET and beef ET. Of note, the pregnancy rate for fresh ET was better than frozen ET. The difference between fresh ET and frozen ET was more pronounced for dairy embryos than for beef embryos. Note that the values in Table 1 are only for cows bred, and does not adjust for cows that were synchronised but deemed unsuitable for ET.

Conclusions

The IVP method of producing embryos allows for oocytes to be collected multiple times between calving and the beginning of the breeding season and as such, fits well with a seasonal-calving, pasture-based production system. The results indicate that fresh embryos had better pregnancy rates than frozen, and achieved pregnancy rates comparable to AI. The calves will be monitored after birth to evaluate the rate of genetic gain and added value from elite dairy, beef and commercial beef embryos.

Sexed semen use on maiden heifers

Stephen Moore and Stephen Butler
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Summary

- Genetic gain is maximised by breeding heifers with sexed semen
- Timed AI protocols allow for two inseminations within 24 days
- Delaying timing of AI improved pregnancy rates.

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. Targeting sexed semen use on heifers allows faster genetic gain, reduces calving difficulty, increases the proportion of replacement heifers born at the start of the calving period, and facilitates greater beef AI use on dairy cows. Despite these advantages, breeding heifers is very time consuming because they are often on an outside block or far away from the farmyard. To overcome this challenge, synchronisation protocols have been developed to maximise the submission rate. There are two categories of synchronisation available:

- Heifers are bred as normal for the first week, and a prostaglandin (PG) injection is administered to heifers that have not yet been inseminated on day seven after mating start date. The PG protocol requires heat detection, is effective only in heifers that are cycling, and 90–100% of heifers can be submitted within 10 days of mating start date
- A timed AI (TAI) protocol is implemented over an 8-day period facilitating AI of all heifers on a single day. The TAI protocol does not require heat detection, is effective in heifers that are cycling or not cycling, and submitting 100% of heifers on mating start date allows the breeding of the main dairy herd to be prioritised thereafter.

Timed AI sexed semen study 2021

Sexed semen has a shorter duration of viability in the female reproductive tract (12–16 hours) compared with conventional semen (>24 hours), which is largely attributed to damage sustained during the sorting process. Recent studies have indicated greater reproductive performance when AI of synchronised heifers with sexed semen is delayed so as to occur closer to the time of ovulation.

In spring 2021, a sexed semen trial was conducted with 271 heifers on four farms to compare the reproductive performance of altering the timing of AI in heifers exposed to the same TAI synchronisation protocol. All 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_48). For the other half of the heifers, the hormone treatments were identical and the only change was that AI was delayed until eight hours after the injection of GnRH, which was 56 h after the second PG injection and progesterone device removal (TAI_56). Heifers were inseminated by AI technicians for the first AI. Heifers observed in oestrus 17–24 days after the first AI were also inseminated by an AI technician except on farm four, which used stock bulls. Pregnancy diagnosis was performed at 32–43 days and confirmed 54–67 days after mating to determine the pregnancy rate to first service (PRFS) and within 24 days of mating start date (PR24).

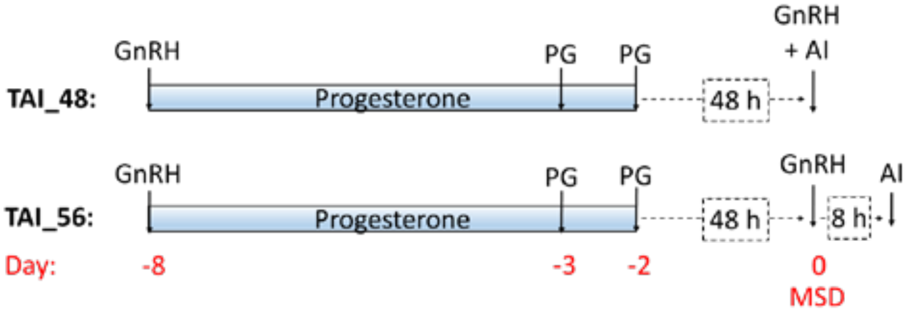

Figure 1. *Synchronisation protocols for TAI of heifers with sexed semen*

The mean PRFS (and range) was 45% (40–64%) and 53% (47–66%) for TAI_48 and TAI_56 heifers, respectively (Figure 2). The industry target PRFS of >60% was achieved on only one of the four farms. For comparison, during the 2020 breeding season heifers (n=230) on three of the four farms were inseminated with sexed semen following observed oestrus and achieved a mean PRFS of 57%. Despite the disappointingly low PRFS following TAI, combined pregnancy rates of 75% and 80% were achieved when heifers repeated and were bred within 24 days (PR24) of mating start date in the TAI_48 and TAI_56 treatments, respectively.

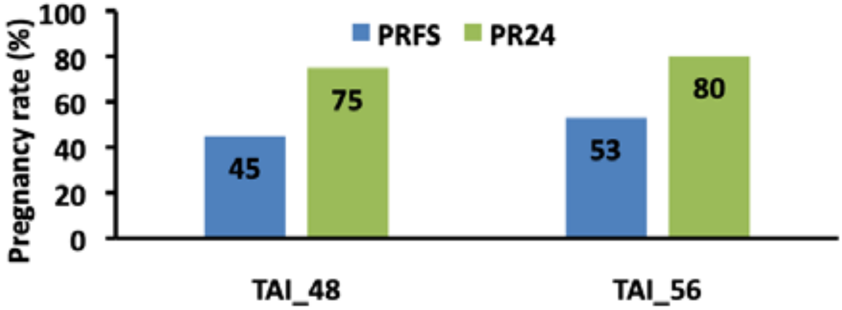

Figure 2. *Pregnancy rate to first service (PRFS) and within 24 days of mating start date (PR24) for heifers inseminated with sexed semen*

Conclusions

The study indicated a modest benefit of delaying TAI by 8 h after the final GnRH (8% increase in PRFS). Even though the PRFS was less than the industry target of >60%, TAI of heifers at mating start date meant that the majority of the repeat heats occurred three weeks later, resulting in ≥75% of heifers pregnant by day 24. Generating more replacements from maiden heifers accelerates genetic gain and facilitates greater beef AI use on dairy cows. More research is needed to optimise TAI protocols for use with sexed semen.

Teagasc dairy breeding survey 2021

Stephen Moore[1], George Ramsbottom[2] and Stephen Butler[1]

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Summary

- 80% of herds use timed AI, once-a-day milking or preferential feeding to maximise in-calf rates of thin or non-cycling cows
- 95% of herds use manual or automatic heat detection aids but only 55% of herds detect heats at least three times per day
- 57% of herds use sexed semen to generate high EBI heifers
- 94% of herds use/will use beef AI to maximise dairy-beef quality.

Introduction

A survey was distributed electronically to Teagasc dairy discussion groups to benchmark breeding management practices. The objective was to gain insights in management practices related to problem cows, AI practices, and usage of both sexed dairy semen and beef semen.

Results

In total, 457 farmers responded to the survey. Average herd size was 147 (range 28–800). The management practices implemented to improve the fertility performance of problem cows are summarized in (Figure 1) with ~80% of farmers using one or all management practices.

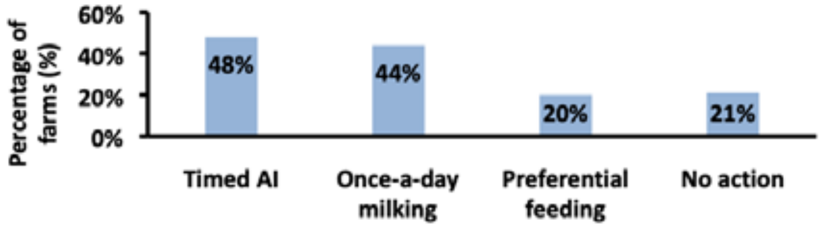

Figure 1. *Management practices used by surveyed dairy herds to improve the in-calf rates of cows in poor body condition or not cycling*

Heat detection is performed with a manual heat detection aid (e.g. tail paint) on 77% of farms, with an automated heat detection system on 18% of farms, and without any heat detection aid on 5% of farms. Heat detection is performed at milking only on 45% of farms and additional observation occurs once, twice, or three times daily on 4%, 22%, and 29% of farms, respectively. Of farms that do not have an automated heat detection system, 18% plan to invest in a system within five years, 38% do not plan to invest, and 44% are considering it.

Heifers are bred using a combination of AI and stock bull(s) on 70% of farms, whereas 19% of farms breed their heifers by AI only, and 11% use a stock bull only. On farms where AI is used to breed heifers, the following practices were reported:

- 37% use AI for seven days, and then administer prostaglandin to non-bred heifers
- 25% use a timed AI protocol to breed heifers
- 5% administer prostaglandin 11 days apart and AI after observed heats
- 33% use AI without synchronisation.

Cows are bred using a combination of AI and stock bull(s) on 75% of farms. On 50% of the farms, most cows receive AI following observed heats, and a timed AI protocol is used on late-calving or non-cycling cows. On 48% of farms, cows are inseminated without the use of any synchronisation protocols, and on 2%, all cows are bred using a timed AI protocol.

Current and planned usage of sexed dairy semen and beef semen is summarized in Figure 2. Currently, 43% of farms are using sexed semen, and a similar number reported plans to use it in the future. Similarly, the vast majority of farmers are using beef semen and plan to maintain or increase use.

Herds identified the percentage of beef cross calves born in 2021 as being 0–20%, 21–40%, 41–60%, 61–80% or 81–100% of the total calf crop, and the percentage of herds that fell into these categories was 31%, 36%, 24%, 8% and 2%, respectively.

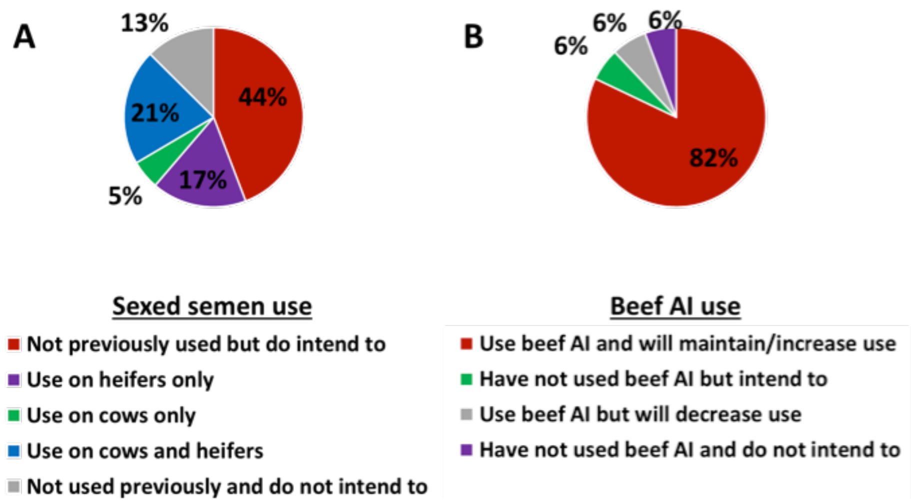

Figure 2. *Sexed semen and beef AI use on dairy herds surveyed*

Conclusions

In an effort to overcome the negative effects of poor body condition score and non-cyclicity on in-calf rates, ~80% of herds implement timed AI, once-a-day milking, or preferential feeding. Heat detection was performed only at milking times on 45% of farms, which limits submission rates as research has indicated that 55% of cows display heat for eight hours or less. Sexed semen and beef AI are important components of breeding decisions on most dairy farms to generate high EBI heifer replacements and to maximise the beef quality of the bull calf crop.

Improving beef from the dairy herd using the Dairy Beef Index (DBI)

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Summary

- The dairy beef index (DBI) ranks beef bulls for use on dairy females based on their genetic potential to produce high quality profitable cattle, with minimal impact on dairy cow performance
- Traits currently included in the DBI relate to calving performance, carcass traits, feed intake and docility
- Research is on-going on the inclusion of additional traits such as calf health, age at slaughter, meat quality and environmental traits into the index.

Introduction

The expansion of the dairy herd, along with improved cow fertility, will result in a greater quantity of Irish beef originating from dairy herds. The Dairy Beef Index (DBI) is a tool that ranks beef bulls based on their suitability for use on dairy females and to improve the beef quality of calves produced from the dairy herd.

Composition of DBI

The traits included in the DBI, along with their relative emphasis, are shown in Figure 1. For a trait to be included in the DBI it must be under genetic control and of importance to either the dairy or beef farmer. Traits currently included in the DBI relate to calving performance, carcass traits, feed intake and docility.

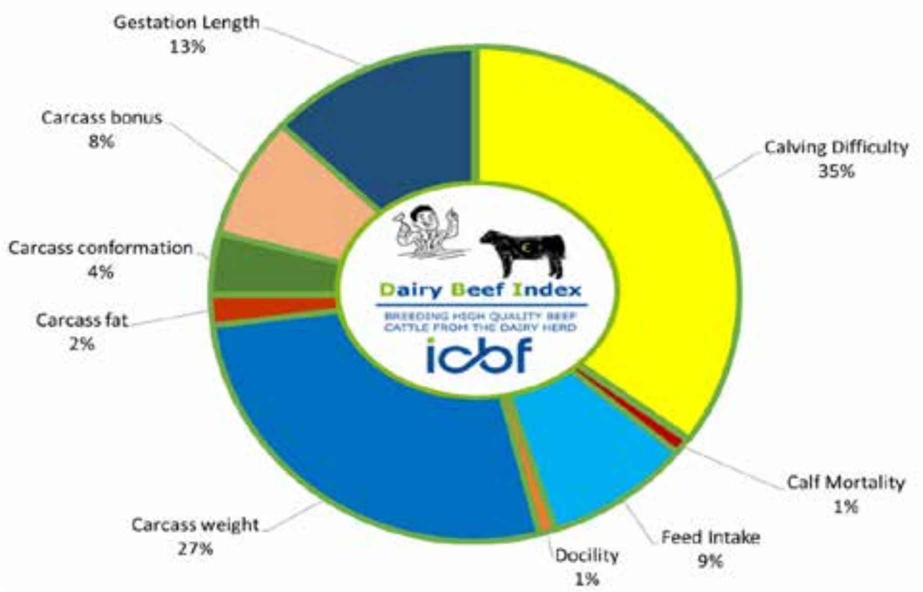

Figure 1. *Traits and their relative emphasis included in the DBI*

The relative emphasis of each trait included in the DBI is determined based on the costs and prices experienced by the dairy and beef farmer. Traits including calf health, age at slaughter and methane emissions are under investigation and may be included in the DBI in the future.

DBI versus EBI

The predicted transmitting ability (PTA) or the breeding values of the top 20 beef bulls ranked on the DBI was compared to the top 20 dairy bulls ranked on the Economic Breeding Index (EBI; Table 1). Results showed that beef bulls ranked based on the DBI would, on average, be slightly harder calved on dairy cows (1.73 percentage units harder) and heifers (3.19 percentage units harder) and result in a slightly longer gestation length (+3.22 days) compared to dairy bulls ranked on the EBI. Beef bulls selected on DBI would, on average, produce superior progeny with a heavier (+25.35 kg) and more conformed (+2.55 units) carcass relative to the progeny from dairy bulls ranked on the EBI.

Table 1. The average predicted transmitting ability (PTA) for calving and carcass traits of the top 20 beef bulls ranked on DBI versus the top 20 dairy bulls ranked on the EBI

Benefit	Trait	Top DBI Bulls	Top EBI Bulls
Dairy	Gestation length (days)	-0.87	-4.09
	Calving Diff. heifers (%)	8.62	5.43
	Calving Diff. cows (%)	4.01	2.28
	Calf mortality (%)	-0.45	-0.39
Finisher	Carcass weight (kg)	19.95	-5.40
	Carcass conf. (1–15)	1.82	-0.73
	Carcass fat (1–15)	-0.17	-0.22

Benefits of using the DBI

To highlight the benefit of the DBI index to both dairy and beef farmers, the performance of progeny from beef bulls ranked on the DBI was compared to beef bulls ranked based only on their calving sub-index in the DBI. The results showed that ranking beef bulls based on either the DBI or their calving sub-index made no difference to the calving performance of dairy cows or to gestation length, but beef bulls ranked on the DBI were slightly harder calved on dairy heifers (2 percentage units harder). However, ranking beef bulls on the DBI resulted in a heavier (+8.58 kg) and more conformed (increase from O= to O+) carcass relative to the progeny from bulls ranked on their calving sub-index. This shows that more balanced progeny will be produced based on selecting beef bulls using the DBI, helping meet the requirements of the dairy farmer but also generate additional profit for the beef finisher.

Conclusion

The DBI is a selection tool available to all dairy farmers to rank beef bulls for use on dairy females. Using top DBI beef bulls, on average, will result in heavier and more conformed progeny with minimal repercussions on dairy cow performance therefore addressing the needs of both the dairy and beef farmer.

Breeding for younger animals at slaughter

Alan Twomey[1] and Ross Evans[2]

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Summary

- Significant differences exist in the genetic potential to reduce age at slaughter
- Breeding for age at slaughter is a sustainable strategy that can reduce economic and environmental costs on beef farms.

Importance of age at slaughter

One of the most effective ways to reduce costs and improve the environmental sustainability of beef farms is to reduce the age at slaughter. Nationally, the average age of steers slaughtered is 28 months. Data from the ICBF's database suggest that the carcasses of steers slaughtered at 20–24 months are only 25 kg lighter than a steer slaughtered at 28 months of age. Younger animals at slaughter require less feed, labour and capital over their lifetime.

Breeding for age at slaughter

Although on-farm decisions play a large role in age at slaughter, recent research shows that 35% of the inter-animal variability in age at slaughter is under genetic control. Breeding decisions in dairy herds create the genetic product, which will consequentially affect the economic and environmental viability of beef herds that finish dairy bred animals. Until now, no breeding value existed for age at slaughter, although the current Dairy-Beef index (DBI) has been shown to have a favourable association with age at slaughter. The first age at slaughter evaluations have been developed at Teagasc Moorepark. As expected, early maturing breeds are younger at slaughter. Based on breeding values for age at slaughter, Hereford sired progeny will be slaughtered four days younger than Angus sired progeny while Holstein-Friesian, Belgian Blue and Limousin sired progeny will be 36, 35 and 23 days older, respectively, than Angus. Nevertheless, there is large variation within breed.

Can genetics actually improve age at slaughter?

Validation of the age at slaughter evaluation shows a positive association between breeding values for age at slaughter and performance on farm. The average superiority of progeny slaughtered in 2020 from AI sires ranked in the top 20% versus in the bottom 20% for age of slaughter were 36 days younger at slaughter, with no difference in carcass weight (Table 1). Selecting sires based on age at slaughter breeding values will also have a favourable impact on age at slaughter within breeds. Progeny of Holstein-Friesian sires ranked in the top 20% for age at slaughter were six days younger and carcasses were 7 kg heavier at slaughter than Holstein-Friesian sires ranked in the bottom 20% (Table 1). Similarly, within Angus and Hereford sires, progeny were eight days younger and carcasses were 10 kg heavier from sires in the top 20% compared to the bottom 20% (Table 1).

Table 1. The average age and carcass weight (Cwt) of steers at slaughter from sires ranked based on breeding values for age at slaughter across breed, within Holstein-Friesians and within Angus and Hereford sires

		Top 20%		Average		Bottom 20%	
Sire breed	Number of sires	Age (days)	Cwt (kg)	Age (days)	Cwt (kg)	Age (days)	Cwt (kg)
Across breed	388	802	336	832	336	838	336
Holstein-Friesian	231	832	341	835	334	838	334
Angus & Hereford	65	792	340	795	338	800	330

Breeding for both carcass weight and age at slaughter

A potential concern with breeding for animals that are younger at slaughter is the possible reduction in carcass weight. However, there is a very weak relationship between age at slaughter and carcass weight. This weak association means that both traits can be selected for independently of each other. A selection index was developed using economic values for both age at slaughter and carcass weight. Across breed, animals from sires ranked in the top 20% for a selection index including age at slaughter and carcass weight were 42 days younger and 12 kg heavier at slaughter compared to sires ranked in the bottom 20% (Table 2).

Table 2. The average age and carcass weight (Cwt) of steers at slaughter from sires ranked based on a breeding index including age and carcass weight across breed, within Holstein-Friesians and within Angus and Hereford sires

		Top 20%		Average		Bottom 20%	
Sire breed	Number of sires	Age (day)	Cwt (kg)	Age (day)	Cwt (kg)	Age (day)	Cwt (kg)
Across breed	388	795	340	832	340	837	328
Holstein-Friesian	231	834	343	832	338	838	330
Angus & Hereford	65	793	344	793	336	803	328

Conclusion

With increasing economic and environmental challenges impacting beef herds, age at slaughter will become even more important to ensure the sustainability of beef herds. It is envisaged that age at slaughter will be incorporated into the DBI in the near future.

Grange Dairy Calf-to-Beef system evaluation

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[1]*Teagasc, Animal & Grassland Research and Innovation Centre, Grange, Dunsany, Co. Meath;* [2]*Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork*

Summary

- High merit beef sires can improve production efficiencies and economic performance of dairy-beef systems
- Age at slaughter can be reduced while maintaining carcass specification
- Grass-based dairy-beef systems can be high output and profitable.

Introduction

Dairy bred progeny account for 57% of the cattle processed in Irish meat plants. While the numbers of dairy-beef animals has grown in recent years due to the expansion of the dairy herd, there has been a decrease in carcass conformation score and weight. The selection criteria (calving ease, gestation and breed) for beef sires used on the dairy herd has not had enough emphasis on carcass merit to counteract the poor terminal performance of dairy genetics.

Poor terminal performance of dairy bred animals limits economic and environmental performance of beef producers, reduces demand for calves placing increased pressure on labour and housing, and weakens our credentials as a producer of high quality meat and milk products. Improved reproductive efficiency of the dairy herd creates an opportunity to increase the use of high beef merit sires on the dairy herd, improving the economic, environmental and social sustainability for all.

Grange Dairy Calf-to-Beef system evaluation

The objective of this study was to compare the physical and financial performance of three dairy-beef genetic groups. They consisted of male Holstein-Friesian (HF) and two Angus (AAX) groups, representing the main calf breeds coming from the dairy herd. The HF group were the progeny of the top four EBI sires on the active bull list. The two AAX groups were the progeny of AA sires that were ranked high (HIGH AAX) or low (LOW AAX) for carcass weight and conformation, but both had similar breeding values for calving traits. All progeny were from HF dams and were born in spring 2018 and 2019.

Male calves were purchased from 33 dairy farms throughout Ireland and arrived on farm between 14 and 30 days of age. The effect of calf nutrition on lifetime performance was evaluated, with half of each genetic group reared on either 4 or 8 L of milk replacer per head per day. At pasture each group of animals received 48-hour grass allocations, grazing to a post-grazing sward height of 4 cm. Over the finishing period, steers were offered ad-lib silage and 5 kg per head per day of concentrates.

Preliminary results

There were no differences in lifetime growth or carcass performance of calves reared on 4 or 8 L of milk. Despite the 4 L treatment consuming 25 kg more concentrate, there was a saving of €33 per head over the calf rearing phase. Each group achieved major reductions in their age at slaughter compared to the national dairy-beef herd. Angus groups had the same slaughter age and finishing period (63 days), which was one month shorter than HF steers. HIGH AAX steers had slightly higher carcass weight and conformation than LOW AAX steers, but both AAX groups had superior carcass performance to HF steers resulting in higher carcass value. Overall, the HIGH AAX animals produced a higher proportion of high value cuts, leading to an increased retail value over LOW AAX and HF steers.

The level of forage in the diet of each group was high, with both AAX groups achieving 87% of their lifetime feed requirement on a DM basis from grazed and conserved forage, compared to HF at 85%, meaning that AAX groups consumed a total of 549 kg of concentrate compared to HF steers consuming 695 kg.

HIGH AAX steers achieved the highest net margin (Table 1), due to their improved carcass weight and conformation, maximising the value of each carcass kg, and both AAX groups performed better than HF steers due to higher carcass performance and reduced finishing costs.

Table 1. The effect of sire carcass merit on slaughter and system performance of dairy-beef cattle

	HF	HIGH AAX	LOW AAX
Carcass/slaughter performance			
Age at slaughter (days)	686 (22.8 month)	656 (21.8 month)	657 (21.8 month)
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+)
Carcass value[1]	€1,065	€1,156	€1,123
System performance			
Carcass output/ha (kg)	960	976	960
Net margin (€/ha)[2]	502	720	602

[1]Base price of €3.70/kg on the QPS grid; €0.20/kg QA payment and €0.10/kg breed bonus; [2]Net margin excludes land & labour charge and assumes a calf purchase price of €60 and €160 per head for HF and AAX sired bull calves.

Conclusion

All groups achieved similar carcass weight, but AAX groups produced a carcass of higher value through improved conformation. In addition, the AAX groups had a younger age at slaughter and so fewer lifetime inputs compared to HF. The use of beef genetics on the dairy herd will play an important role in improving the sustainability of both the dairy and beef sectors, but large scope exists to improve the carcass characteristics of beef sires used commercially on the dairy herd.

Lessons learned from the Teagasc Green Acres Calf-to-Beef programme

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Summary

- Profitability on Teagasc Green Acres Calf-to-Beef Programme farms increased from a net margin of €56/ha to €455/ha over the first two years of the project
- Increased liveweight output per livestock unit and per hectare were achieved
- Grass production increased from 8.6 t DM/ha to 10.3 t DM/ha over the first two years
- Silage quality improvements lead to increased first winter performance and reduced finishing time and cost
- Reduced herds of origin and the implementation of a vaccination protocol led to a higher health status of calves.

Introduction

Phase II of the Teagasc Green Acres Calf-to-Beef Programme commenced in 2019. Twelve commercial demonstration farms, located nationwide, have benefited from advice from dedicated programme advisors. Robust farm plans have been developed focusing on improving soil fertility, grassland management, animal health and animal performance in order to improve overall farm profitability.

Key factors in ensuring calf-to-beef success

Liveweight output

Maximising liveweight (LW) output on both an individual animal (per livestock unit) and a per hectare basis are key contributing factors to profitable calf-to-beef production systems. Marked improvements in output have been realised on programme farms increasing from 1,020 kg LW/ha in 2019 to 1,286 kg LW/ha in 2020.

Grassland management and silage quality

A central focus of the Teagasc Green Acres Calf-to-Beef Programme is maximising animal performance from grass — both grazed and ensiled as a winter feed. Through the use of PastureBase Ireland, the participating farmers have become proficient grassland managers. As a result of soil fertility improvements, implementing paddock rotational grazing, and grassland measuring and budgeting, the quantity of grass grown has increased from 8.6 t DM/ha to 10.3 t DM/ha. Notable improvements in silage quality have also been achieved, increasing from an average of 69.5 DMD to 73 DMD between 2019 and 2020 due to implementation of appropriate fertiliser programmes and targeted cutting dates. This improvement has resulted in increased LW gain over the winter months, with the average daily gain (ADG) target of 0.6 kg being largely achieved. The quantity of concentrates required for weanling and finishing stock has been reduced due to higher quality silage.

Calf health

An increased focus has been placed on purchasing healthy calves by programme farmers. Research shows that purchasing calves from a higher number of sources increases the risk of calf health problems. Over the duration of the Teagasc Green Acres Calf-to-Beef Programme, farmers purchasing calves have reduced the number of source herds. At the commencement of the programme, each farmer purchased an average of 94 calves from

10 different herds by each farmer. In 2021, on average, 110 calves were purchased from six herds. In addition, vaccination programmes for respiratory diseases have also been introduced, which is contributing to reduced morbidity, antibiotic use and mortality at farm level.

Genetics

The genetic make-up of the calf influences how they will perform in a calf-to-beef setting and is determined by the breeding decisions made in the dairy herd. A concerted effort is made by programme farmers to source calves sired by bulls of high merit for carcass weight and conformation. Although small, improvements have been observed in the early-maturing and continental calf classes.

Table 1: Carcass merit (kg) of Teagasc Green Acres programme calves

	2020 carcass merit (kg)	2021 carcass merit (kg)
HO/FR	-3.8	-4.1
Angus	-0.7	-0.4
Hereford	-1.6	0.03
Continental	7.1	8.8

Conclusion

The efficiency changes implemented on Green Acres farms in grassland management, animal health and genetics have resulted in improved levels of output and profitability. Farmers are achieving increased levels of liveweight output per hectare derived from a lower cost base than the farms had achieved previously. While the improvements implemented on farm have shown a significant level of increased profit, there is scope to improve this further over the next number of years.

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Contract rearing of dairy-beef calves

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Summary

- Contract rearing agreements provide an excellent opportunity for both dairy and dry stock farmers
- The preliminary results indicate the potential of high quality grassland management on commercial farms to deliver excellent animal performance in dairy-beef systems.

Introduction

Increased cow numbers on dairy farms, coupled with improved six week calving rates have resulted in large numbers of poor beef merit male calves being born over a compact period each spring. In managing this peak calving period, dairy farmers face many challenges such as, sourcing skilled labour, the lack of available lands to lease/purchase and access to adequate calf rearing facilities. As a result, more dairy farmers are looking to outsource the rearing of male calves. Teagasc has recently developed an ongoing project looking at the performance of male dairy and beef × dairy calves on commercial rearing farms in addition to new contract rearing template agreements.

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 rearing farmers. In the programme, Teagasc and 10 dry stock farmers have entered a collaborative arrangement where the dry stock farmers will contract rear approximately 400 male progeny from Teagasc dairy farms. The calves are contract reared from three weeks to 14 months of age (mid-April of the subsequent year) or 330 kg liveweight (LW). Thereafter, the animals will be moved to a grazier and finishing units for slaughter at 22 months. All animals are weighed every six weeks by Teagasc during the programme to monitor animal performance. The project is anticipated to run for three years (2020–2022 inclusive). A complete financial analysis will be undertaken and published at the end of the rearing period to evaluate the potential of the project to increase the value of male progeny from the dairy herd.

The mean birth weight of the calves during 2020 was 37 kg and these were moved on average at 24 days of age (52 kg 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 gained 0.85 kg LW per day during the 2020-grazing season on a predominantly grass only diet. During the winter period up to mid-February, average daily LW gain was 0.7 kg, resulting in a mean LW of 343 kg by April 15th 2021 at the end of the study period. On average over the entire measurement period from birth to 14 months of age, the entire group achieved an average daily LW gain of 0.75 kg, exceeding the targets for the group. The preliminary results are indicative of the potential of high quality grassland management on commercial farms to deliver excellent animal performance in dairy calf-to-beef systems.

Contract calf rearing agreements

Contract calf rearing involves the movement of male calves from the owner's farm to another farm for rearing on a contract agreement. The animals remain in the ownership of the dairy farmer and an agreed fee per head per day is paid for the duration of the agreement. The key areas in the formation of these agreements are:

- *Outline* — animal owner and contract rearer's details
- *Duration* — identify the start and end date of the agreement
- *Payment* — agreed payment rate per head per day
- *Terms and conditions* — establish a management protocol.

What are the benefits for dairy farmers?

Additional land, labour and facilities provided

As the contract rearer is completing all works associated with the management and rearing of these calves, they are in effect providing:

- *Labour* — very difficult to source reliable, skilled workers
- *Facilities* — reduced need for capital expenditure for calf housing, feeding systems and feed storage
- *Land* — removes the exposure to high rental/purchase costs.

Ease of management

Reduced numbers and groups of animals on the farm allows for increased efficiency, improved management and reduces the disease pressure on the remaining heifer calves in the calf housing area.

Increased milk production and profitability

Additional lands are now available for grazing or fodder production allowing increased milk output or reducing the need to purchase forage, thereby increasing farm profitability if completed in an efficient manner.

Conclusion

Contract rearing provides an opportunity for non-dairy farmers to devise an alternative system, in the knowledge that in return for good performance, they will be rewarded for their land, labour and management through a pre agreed monetary rate. For the dairy farmer, removing animals at an early age, reducing the need for additional facilities, labour etc. and the opportunity to allocate more time and resources to the main cow herd can be very beneficial.

The Teagasc Contract Rearing agreements can be found at https://www.teagasc.ie/rural-economy/farm-management/collaborative-farming/

CREATING GREAT DAIRY FARM WORKPLACES

Developments from the People in Dairy Action Plan

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Summary

- The People in Dairy Action Plan outlines action areas that aim to enhance the 'people side' of dairying
- Numerous initiatives will be implemented in collaboration with industry partners to deliver the Action Plan.

Introduction

Irish dairy farms have undergone significant changes since the abolition of EU milk quotas in 2015. According to the Teagasc National Farm Survey milk production has increased by over 1,500 litres per hectare, on average, from 2010–2019. Production efficiency in terms of milk yield per cow has improved as well, but significantly, over that same period, average herd size has expanded from 64–80 cows per farm. This expansion is expected to continue as total livestock units have also risen, signalling more calves are being retained for herd replacements.

In conjunction with herd size expansion and larger farm sizes (over 40% of farms are now between 50–100 ha), labour input requirements are increasing. Farmers and family members contributing labour into operations face longer working hours, increased workloads, and strain on work-life balance. Simultaneously, there has been an increase in demand for hired labour on farms. Employing and managing staff members, however, relies on a different set of skills than what farmers need to effectively manage cows and grass. Thus, for the future sustainability of Irish farms, a key area in need of more research, awareness-raising and support is the 'people side' of dairying, or more aptly, the people behind the operations.

Development of the people in dairy action plan

In recognition of the structural changes and emerging challenges within the Irish dairy industry, Teagasc initiated a multi-stakeholder consultation in 2018 to develop the People in Dairy Action Plan. It sets out seven action areas:

- Action Area 1 — Enhance the supply of skilled farm operatives to meet seasonal and year-round demand
- Action Area 2 — Improve labour efficiency on dairy farms
- Action Area 3 — Increase farmers' effective use of human resource management practices
- Action Area 4 — Develop and deliver excellent formal and informal training and continuing professional development
- Action Area 5 — Highlight multiple different progression pathways to becoming a dairy farmer and support "Stepping up" and "Stepping back" processes
- Action Area 6 — Promote dairy farming as an attractive career
- Action Area 7 — Effectively implement the Action Plan.

As suggested under Action Area 7, a Programme Manager (Beth Dooley) was hired in 2020 to drive forward the wider implementation of the action areas and coordinate with industry players. Since, internal collaboration and deliberation within Teagasc has aimed to map the existing activities, resources and priorities for implementation across advisory, education and research. Outreach and brainstorming with dairy industry partners is ongoing, with initiatives being developed in the following areas:

Labour recruitment/retention: Farms across Ireland have different labour profiles that require different types of communication skills and management approaches. Strategies to attract highly skilled employees are important, but maintaining positive, mutually beneficial relationships with all labour contributing to the business (relief milkers, contractors, unpaid family members, full- or part-time employees) is also crucial. The Great Farm Workplaces project is being developed to explore these issues on-farm to try to understand how different strategies may be carried out and achieve positive outcomes.

Training and development: Continuing professional development, or lifelong learning and upskilling, is a way for people in all roles across the dairy industry to gain new information, build on existing practices and learn additional skills. Different methods of engagement and learning will be trialled to allow users to access helpful resources, trainings and courses in various flexible and convenient formats.

New entrants: A steady stream of highly skilled people are needed to fill the different roles available for employees as well as entrepreneurs to undertake collaborative arrangements (e.g. share milking, long-term leases, partnerships, contract rearing, etc.) and 'step up' as successors when existing farmers want to 'step back'. The dairy industry must attract people both from farming and non-farming backgrounds as well as support and recognise the transferable skills offered by those seeking to change careers. Accordingly, Teagasc will work with industry partners, e.g. Macra and FRS, on promotion and outreach.

Progression and succession: The dairy industry offers many opportunities for career progression for people who want to advance to roles with more responsibility and decision-making, such as from farm operative/technician to herd manager, or entrepreneurs interested in taking on risk. Additionally, succession is an element of long-term strategic planning that every business should start early and methodically review, revise and implement to ensure the operation can sustainably continue beyond the tenure of the current owner/operator. Workshops with the Land Mobility Service on capacity building for joint ventures and the role those may play in easing the transition process are just one form of activity under development in this area.

Conclusion

The People in Dairy Action Plan is a long-term vision for the future of Irish dairy that is fundamentally based on developing and building on the expertise, performance, wellbeing and quality of the people working in the industry. Working together, we can ensure there are myriad opportunities for people to thrive in dairying.

What will dairy farm workplaces look like in 2030?

Abigail Ryan
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Summary

- There will be a high requirement for weekend staff and more weekly planning of the workload to achieve the desired time off. Over 70% of respondents would like 2–3 weekends off per month and finish working by 6 pm daily. Up to 32% want to work 40 hours per week and 40% want to work 50 hours per week on average
- Overall, the dairy farm working week in 2030 will have to be more flexible. Contract work designs and more training is required to help farmers design this so that dairy farms are competitive, enjoyable and safe places to work
- Additional technologies to improve animal breeding are required for the future dairy farm workplace according to the 122 farmers and students surveyed.

Introduction

Students and graduates of agricultural degrees, the Professional Diploma in Dairy Farm Management programme, and recently expanded dairy farmers were invited to complete an online survey in June 2021. The survey objective was to find out what will make future dairy farm workplaces more competitive and attractive for farmers and their teams. 122 people responded indicating they want to be farm owners (63%), in partnership (23%), share farming (3%) or working on farms (11%) in 2030.

Main findings

Throughout the survey, it was apparent that the main issue on dairy farms was time management. When asked what areas they would change on the farm to make it more enjoyable, the majority of those surveyed said they would like a more organised and flexible time schedule or roster, with a designated start and finish time, followed by improved facilities and improved salary. When asked about their current holiday schedule, 30% said they take one full week's holidays whereas 50% take individual days off during the year. Of those surveyed, 25% expect to be working in excess of 60 hours per week, on average, in 2030, while a further 25% thought that the average hours worked per week should be 40 hours. Respondents indicated the spring would require longer working hours because of calving etc. Most expect to finish their daily work by 6 pm (outside the busy season). The number of weekends off per month was important to respondents, and up to 80% expect to have two or three weekends off per month. Of those surveyed, 63% would consider once-a-day milking to improve their time management schedule if they were unable to source relief milkers.

Respondents recognised farm safety as another important area for improvement. Creating more awareness around health and safety and implementing correct procedures to reduce accidents were suggested. Some recommended using 100% AI in 2030 to reduce the danger posed by bulls. Respondents want more training on machinery operation and/or outsourcing of machinery work. Many improvements recommended in this area would be easy to implement; for example, not using a mobile phone while operating machinery. Better maintenance of facilities and additional staff facilities were also considered important, such as a canteen, bathroom, shower and sleeping area (separate from the farm family house) if required in spring.

The area of training and extra skills required was important to the group surveyed. All felt that 3–4 years of college or university and practical experience were important. Respondents were highly interested in short courses on the latest technologies. Areas they require training include computer skills and Department of Agriculture, Food and the Marine online services. Respondents would like technologies for heat detection, drafting and continued improvements in stock health in the 2030 dairy farm.

What do the results indicate?

The farm workplace of 2030 will be an efficient, simple farm system similar to today's farm workplace according to the respondents. However, it is very clear that the future workplace will have to be more organised with designated rosters, more flexible working times and roles designated for specific tasks. There will be more part-time workers required for weekends or for specific tasks. This gap will have to be filled by people suited to roles with flexible time commitments. The participants pointed out it was currently a challenge to source weekend staff, yet they plan to take more weekends off per month in 2030, putting further pressure on staff recruitment. Training and technology will be required to upskill farmers for this change in work organisation.

Conclusion

The farm workplace will not look much different in 2030 but work patterns will. Respondents expect to work fewer hours, have better working facilities and to be paid fairly for their labour. Technological tools and training in strategic management and work organisation will be required. In addition, there will be more demand for flexible staff as well as full-time staff, requiring clear communication, strong teamwork and effective leadership. More efficient use of time and work organisation will be components of future dairy farmer success.

Labour self-sufficiency on family dairy farms: is it possible?

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Summary

- A family farm with a herd size of approximately 117 cows with efficient facilities and practices can be operated effectively with 3,000 hours/year and 1,500 hours between mid-January and June
- Annual average number of hours worked by the farmer per week was 47 hours, but 53 hours per week between mid-January and June, i.e. 79% and 88% of total labour, respectively
- Good and efficient facilities and practices are key to alleviate the 'spring-time peak'; in this study, labour requirement during 42% of the year (23 weeks; mid-January to June) was just 50% of annual demand.

Introduction

A core strength of the Irish dairy industry is the role of the family in the operation of the dairy farm. The success of family farms is highly dependent on the efficient use of labour input. However, recent trends have indicated a decreasing family workforce and an increasing reliance on hired workers. The availability of skilled workers has declined due to the perception of long working hours, precarious working conditions, and low wages. Therefore, it is important to identify a strategy that would allow a family farm to be largely self-sufficient in labour while at the same time achieving a good work-life balance. Such a strategy would help maintain the viability of the family farm unit.

The study

This study focused on farmers who had the ability to manage their dairy herd with minimal external labour input, while still achieving a good work-life balance and good output performance. Four spring calving farms were selected based on data from previous labour studies on Irish dairy farms. Two farms met the pre-defined selection criteria of: (a) farmer working hours equal to or less than 50 hours/week for the overall year; (b) family and hired workers contributing 500 hours or less, and (c) total annual hours less than 3,860 hours (farmer hours (2,860 hours) + family and part-time hours (500 hours) + contractor hours (500 hours)). Two further farms were selected based on data from a spring-time labour study. These farms met the selection criteria of (a) farmer working hours equal to or less than 60 hours /week; (b) family and hired workers contributing 500 hours or less, and (c) total hours for the 23-week period (mid-January to June) less than 1,900 hours.

Results and discussion

The herd size and total labour input for each of the four farms are shown in Table 1.

Table 1. Average herd size and overall labour input for the four case study farms based on time-use data collected for either one year (Farm 1 and Farm 2) or between mid-January and June (Farm 3 and Farm 4)

	Farm 1	Farm 2	Farm 3	Farm 4
Herd size	136	102	118	117
Total labour input	2,969	3,002	1,427	1,574
Farmer (hours)	2,182	2,446	1,029	1,377
Family (hours)	0	5	273	96
Hired worker (hours)	119	339	0	80
Contractor (hours)	668	213	124	22

A total labour input of approximately 3,000 hours was observed on Farms 1 and 2 with an average cow number of 119. Farms 3 and 4 required approximately 1,500 hours between mid-January and June. This indicates that the farmer, with little input from family, hired workers and contractors, can manage a herd size of 119. This was enabled by good facilities and efficient practices, as observed on these farms. The spring-time peak labour requirement of Farms 3 and 4, during 42% of the year (23 weeks) in this study, was 50% of the annual demand of Farms 1 and 2. Farmers generally describe the spring-time as a busy period, and this study indicates that the ‘spring-time peak’ can be alleviated by good and efficient facilities and practices. All four farms were operating to a very high standard in terms of physical performance indicators for pasture-based seasonal calving farms. These farms also had significantly lower labour requirements when compared to some corresponding farms in the studies from which they were selected. These results emphasise the importance of managing the farm facilities and operations in an efficient manner, particularly those associated with the most time consuming tasks such as milking, cow care, calf care and grassland management.

The average length of the working day for the farmer (excluding breaks and other enterprise tasks) was 7.5 hours/day. Average hours worked per week annually for Farmers 1 and 2 was 47 hours, while Farmers 3 and 4 worked 53 hours/week, on average, between mid-January and June. The labour contributed by the farmer represented 79% of total labour requirement over the full year and 88% of labour requirement between mid-January and June. Contractors, hired workers or family members (Table 1) contributed the remaining labour input. Labour efficient farms require low levels of labour input (minimal input from hired workers or contractors) to complete the remaining work after the farmers’ input is accounted for. Therefore, the cost of either hired labour or contractors is low. This emphasises the importance of managing the farm facilities and operations in an efficient manner.

Conclusion

Excellent and efficient facilities, practices and organisation can complement good labour management, resulting in high output performance, and can safeguard the family farm into the next generation.

Working efficiently

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Summary

- Considerable variation in labour efficiency exists across farms of similar herd size
- Milking and calf care are the two most time consuming tasks between mid-January and June, and therefore are key tasks to focus on for increased labour efficiency
- There are a variety of work practices/technologies that can increase labour efficiency and are widely available to farmers.

Introduction

Expansion in the Irish dairy industry in recent years has resulted, in many cases, in increased herd sizes and additional labour requirements. Furthermore, labour input on Irish farms is distinctly seasonal, with 57% of annual labour input occurring in the spring and summer seasons. These factors, together with difficulties associated with the attraction and retention of farm workers have increased the necessity for improved labour efficiency/productivity associated with the management of dairy herds. Consequently, a study was designed to quantify labour efficiency, and identify key labour efficient work practices and technologies on Irish spring-calving dairy farms, in the spring and summer seasons.

Time-use study

A labour time-use study was completed between 22nd January and 30th June 2019. Farmers and farm workers recorded their labour input on a smartphone app on one alternating day each week. Other farm workers as well as contractor hours were recorded through an online survey. Seventy-two farms were included in the study. Farms were divided into four herd size categories (HSC) for analysis (HSC 1: 50–90 cows; HSC 2: 91–139 cows; HSC 3: 140–239 cows; and HSC 4: ≥240 cows). Herd sizes ranged from 50–394 with an average herd size of 137 cows. Average labour efficiency was 19.2 hours/cow (h/cow) for the study period and is presented in Table 1 for each HSC.

Daily labour input peaked at 16.5 h/day and 16.9 h/day in the months of February and March, respectively. Daily labour input for April, May and June were 14.7 h/day, 15.6 h/day, and 14.3 h/day, respectively. Milking was the most time-consuming task, accounting for 30% of all labour input. The remaining tasks (proportion of labour input) were calf care (13%), grassland management (12%), cow care (11%) repairs & maintenance (10%), administration/business (8%), feeding (cows & heifers) (4%), heifer care (3%), other enterprises (3%) and contractors (6%).

Work practices and technology survey

A survey was completed with each farmer to determine work practice and technology implementation. There were 112 questions related to work practice/technology implementation included in the survey. Each work practice/technology was classified according to its associated farm task and statistically tested; 63 were found to have a relationship with task labour efficiency. A score was given to each farm depending on how many of the 63 work practices/technologies they implemented; a farm received one point for each work practice/technology that was implemented.

Table 1. Labour efficiency (h/cow) and work practice/ technology implementation score for 72 farms involved in the study from mid-January to June				
Herd size category	1 (50–90 cows)	2 (91–139 cows)	3 (140–239 cows)	4 (≥240 cows)
Average herd size (no. cows)	72	115	185	285
Labour efficiency (h/cow)	27.5	18.7	14.7	11.6
Labour efficiency range (h/cow)	12.0–50.6	12.1–32.2	8.7–19.6	7.6–13.2
Average (score) number of work practices/ technologies implemented	27.1	31.5	35.5	40.1

On average, farms implemented 32 labour efficient work practices/technologies (range 10–46). The number of work practices/technologies implemented increased as herd size increased. The milking (19 work practices/technologies) task had the most labour efficient work practices/technologies available, followed by cow care (13), calf care (9), administration/business (6), grassland management (5), feeding (cows & heifers) (4), heifer care (3) and general (3). Many of the work practices required minimal capital expenditure and focused on improved work organisation. The work practices and technologies with the greatest association with milking and calf care labour efficiency are presented in Table 2.

Table 2. Work practices/technologies with the greatest relationship with milking and calf care labour efficiency	
Milking	Calf care
Automatic cluster removers	Bull calves not reared on farm
Drafting facilities	Contract heifer rearing pre-weaning
Milker not leaving the milking pit to herd cows into the parlour	Group feeders used to train calves (days 1–4)
Ability to operate cow exit gates from any point in the pit	Automatic calf feeders used once calves were trained and grouped

Conclusion

Considerable variation in labour efficiency was observed across and within HSCs. This highlights opportunities for improvements and the potential for farms within all HSCs to achieve high levels of labour efficiency. This study demonstrates that there are a wide variety of work practices/technologies that can increase labour efficiency available to farmers. Milking and calf care were identified as the two most time consuming tasks between mid-January and June; thus, labour saving techniques associated with these tasks should be the first to be considered to improve labour efficiency.

Application of Lean principles to dairy farming

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Summary

- Application of Lean principles on-farm can reduce working hours and physical workload.

Introduction

There are two ways of increasing work efficiency: increasing output or removing waste and working smarter. Often, increasing output is associated with an increase in labour input and given that labour is limited on many farms, reducing the workload whilst maintaining or improving productivity is the preferred option. However, the challenge is to reduce labour input without negatively affecting productivity or product quality. Lean principles aim to ensure quality while minimising labour input, thereby increasing labour efficiency and maintaining or even improving farm performance.

Time-use study

For this analysis, a subset of 76 farmers and any farm staff who recorded their time on a smartphone app between 21st January and 31st March (11 recording days) were selected from a time-use study conducted in spring 2019. Farmers were categorised as 'Lean' (n=5) or 'not Lean' (n=71) based on information supplied. Average herd size for the 'Lean' farmers was 171 cows and 139 cows for the 'not Lean' farmers. 'Lean' farmers worked 7.6 hours/day on average compared with 9.7 hours/day for the 'not Lean' farmers. 'Lean' farmers spent significantly less time on 'milking', 'administration/business' and 'repairs and maintenance' compared with 'not Lean' farmers. 'Milking' included herding, milking and wash-up. Having adequate capacity in the collecting yard, a sufficient number of milking units and a good milking routine contributed to the 'Lean' farmers having an efficient milking process. Increasing efficiency in milking, the most time consuming area of the business, will positively affect overall business efficiency as seen in the time-use study.

Case study — the milking process

Aidan Ahearne is farming in partnership with his father Thomas and his wife Lisa in Co. Waterford. They are milking 207 spring-calving crossbred cows on 82 hectares with a 4 ha outside block. The herringbone parlour has 16 units (DeLaval) with automatic cluster removers. Cow exit gates can be operated from anywhere in the pit and there is a manual drafting system. With 13 rows, the milking process including herding can take three or four hours per day, which Aidan feels is unsustainable in the long term. The recommendations are for seven to eight rows of cows for one operator in the pit and a maximum of 1.5 hours milking. His goal is to maximise the efficiency of the current milking process using Lean practices before investing in extending his parlour at some stage in the future. Before any improvements could be made, the inefficiencies or 'wastes' needed to be identified by observing and timing the different steps in the milking process. This baseline data was collected while Aidan completed a morning milking in October before any cows were dried off. Aidan left the parlour pit 14 times during the milking process, mostly to bring cows into the parlour, which was due to poor cow flow into the parlour. Another issue was slower milking cows. The rows with slower milkers had longer row times, which affected the subsequent rows' times.

From the data and observing the milking process, it was clear that Aidan had a very good milking routine from the outset. In a short time, Aidan implemented the following recommendations:

- Reduced the number of times the operator exits the parlour pit by improving cow flow, helped by removing the blind ‘corner’ in the collecting yard by covering a gate with stock board
- Marked slow milkers to ensure they are attached as soon as they enter the parlour, stripping cows to stimulate milk let down
- Visual management: added yellow tape to every fourth cluster as a visual aid to help with spraying
- Created a place for everything and ensured that everything is in its place (5S board) in the parlour pit for tape, cow markers, CMT paddle, gloves, tail paint, etc.
- Implemented 5S in the plant room
- Completed cleaning and washing down of yards immediately after milking
- Created a standardised operating procedure for the milking process.

Ten days after the initial visit and discussions with Aidan, the milking process was observed and timed again to determine if the recommendations saved time. Aidan saved 20 minutes per milking, equating to 40 minutes per day. The key is to measure — certain tasks may take more or less time than perceived by the operator. Aidan reduced the number of times he exited the pit by eight, saving time and also reducing the effort required. As Aidan had an excellent milking process to begin with, the savings made here could be much greater on other farms. The Lean management process was reviewed recently with Aidan. The process is working well for him and he continues to focus on minimising the number of times he exits the pit. He regularly reviews and updates the 5S process in the dairy and plant room. For example, he has since installed additional whiteboards and refreshed the labelling of key items in the dairy and plant room. As a consequence of engaging with Lean management, Aidan is starting to adapt Lean practices in other areas of the farm, such as using whiteboards in the calf shed.

Conclusion

With on-farm workload increasing, it is necessary to manage the farm’s processes more efficiently. The application of Lean principles on-farm can reduce working hours and physical workload as well as deliver improvements in safety while having a significant positive impact on farmers’ quality of life and mental wellbeing.

Transitioning into people management

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Summary

- Respondents to a survey use a variety of people management practices on their farms, the most common are payment of overtime to workers and rosters
- Respondents with more employees have a better understanding of their role as an employer and a more positive attitude toward employees.

Introduction

Following the removal of milk quotas, many farmers have capitalised on the opportunity to expand their dairy enterprises. With this expansion, the role of the dairy farmer has changed as many farmers are employing people for the first time. Management in agriculture has traditionally been associated with farm operations and livestock. As well as managing the technical aspects of the farm, farmers employing workers are also people managers responsible for their employees' development.

The survey

Three hundred and fifteen dairy farmers (representative of location and herd size) were surveyed regarding people management practices. Farmers were asked for their experiences and opinions regarding farm practices, farm safety, labour or human resource practices within the Irish dairy industry.

Results

The surveyed farmers used a variety of people management practices as outlined in Table 1. The practices reported in this study are a guideline to the best approach that farm employers should take when employing people. The most prevalent people management practices used on the surveyed farms were: rosters (27%), regular staff meetings (26%) and payment of overtime (27%). Farmers employing three or more people typically implemented more people management practices compared with farmers employing one or two people.

Table 1. People management practices implemented by the survey respondents who were employing staff

	FE 1[1] (n=117)	FE 2[2] (n=53)	FE 3[3] (n=33)
	Responses (n) (Percentage)	Responses (n) (Percentage)	Responses (n) (Percentage)
Induction program for new employees	8 (6.8)	5 (9.4)	10 (30.3)
Probationary period for new employees	4 (3.4)	8 (15.1)	10 (30.3)
Performance review/appraisal	6 (5.1)	5 (9.4)	5 (15.2)
Rosters	21 (17.9)	15 (28.3)	18 (54.5)
Regular staff meetings	22 (18.8)	13 (24.5)	18 (54.5)
Training plans	2 (1.7)	3 (5.7)	5 (15.2)
Career plans	1 (0.9)	3 (5.7)	3 (9.1)
Paid sick leave provided to employees	23 (19.7)	12 (22.6)	12 (36.4)
Overtime paid to employees	29 (24.8)	17 (32.1)	9 (27.3)

[1]FE 1 = Farmers employing one person. [2]FE 2 = Farmers employing two people. [3]FE 3 = Farmers employing three or more people

An open-ended question allowed respondents make any further comments regarding the content of the survey if they wished. There were 194 responses and when the responses were analysed the topics that emerged were: Labour and Employment (n=55), Health and Safety (n=33), Management and Communication (n=30), Training (n=26), Social and Economic Sustainability (n=22), Other (n=17), Pay (n=11).

As the number of people working on farms increased, there was a gradual change in farmers' attitudes towards employees. Farmers with no employees had the most negative experiences with employees, as typified in the quote: "*I had labour in the past and I got sick of excuses, not turning up, having to leave early or turning up late, damage to machinery, grassland and fencing. I still ended up working weekends*". Respondents with one employee also had some negative experiences with employees, but acknowledged the value of employees: "*A good man in the yard is worth a lot of money.*" Respondents with two or more employees had a good understanding of their requirements as employers and provided advice to help farmers transition into their role as people mangers: "*have the people before the cows",* and "*involve and empower employees to make changes.*" Another suggestion was to show respect and appreciation to employees: "*Farmers do not, in my experience, show appreciation to their employees. Simple things like thanking them at the end of the day for their help are not done.*"

Conclusion

Farmers employing people or transitioning into employment must implement suitable people management practices. Good people management creates a happy work environment, increases employee motivation and commitment to their employer.

The benefits of collaborative learning

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Summary

- Collaborative learning offers different perspectives on how and why certain practices may be done
- Peer-to-peer learning may result in multiple different economic, social and environmental benefits
- To maximise the benefits from peer-to-peer learning, participants should be open and willing to share as well as challenge their own and others' way of thinking.

Introduction

Learning in group formats has a long history within Irish dairy. A vast network of farmer discussion groups has been operating across the country since 1993. Other forms of collaborative learning are available as well (e.g. demonstration events, monitor farm open days). Collaborative learning offers participants the chance to share experiences and knowledge with their peers. Numerous benefits may result from engaging in this type of learning, both for the attendees and their operations. This paper aims to explore why you might consider engaging in these types of learning opportunities, and how can you maximise your participation?

Benefits of learning with peers

Collaborative learning in farmer discussion groups and monitor farms has been shown to result in sustainability (economic, social and environmental) benefits for participants. Economic benefits that many farmers have experienced are increased profitability, efficiency, lower costs, etc. Participants can view how a process or practice on farm may be implemented differently, easier, quicker, or with less labour input. This offers the learner a direct example of how something may be done in practice rather than just a description. As every farm is different, the next step is to assess whether that practice makes sense to apply on your farm.

Social benefits have also been found to result from participating in collaborative learning opportunities. Farming can be isolating if you are the sole operator and work alone most of the time, even more so during the COVID-19 restrictions when in-person contact on-farm with advisors, vets, and others became even less frequent. Despite the never-ending tasks on dairy farms, numerous farmer discussion group participants have spoken about the importance of getting off-farm and investing in learning for yourself and your business. Collaborative learning events allow you to build peer-to-peer relationships and networks for practical support in finding ways to solve problems or change practices on-farm, but also emotional support that is important to everyone's health and wellbeing.

Collaborative learning may also present a way to navigate new challenges and harvest environmental benefits. National and EU policies have set the stage for high-level targets and on-the-ground actions that contribute to reducing the climate crisis, benefiting biodiversity, protecting water quality, etc. These results-focused objectives present challenges but also potential opportunities for farmers to learn from each other alongside formal research outputs. Participants could trial new practices together and/or debate how they could be tailored to each individual farm and different ecological contexts. For current practices, simply seeing, hearing and talking about how they could be made more environmentally friendly while maintaining profitability is another way collaborative learning could help build the confidence needed to make changes on-farm.

Engaging critically

Collaborative learning allows people to gain different perspectives from their peers' examples, experience and knowledge. This may then be used to reflect on your own practices and challenge whether things could be done better, more efficiently, cheaper, etc. This process of careful consideration should avoid jumping to conclusions that just because your system is different, the practice is irrelevant. Can it be modified to suit your farm setup? Could the practice help with modifying your setup to improve efficiency? Learning about how someone else does something and then reflecting on how and why you do it a certain way on your farm can be very valuable. If the reason is 'because we've always done it that way', is that a good enough reason to justify continuing it? Especially if another way may have lower costs, less labour input, or is more time-efficient or profitable?

Engaging critically through collaborative learning does not just happen through reflection and self-assessment. Social interaction is critical to the learning process. Particularly, discussion about a topic where the participants disagree and (respectfully) debate has been found to result in deeper learning than when people either 'passively' agree or disagree but do not say anything. Thus, to gain the most out of collaborative learning opportunities, participants should be open to challenging each other and being challenged about their ideas, processes and practices. This may prevent 'groupthink', which is a possible negative result of collaborative learning where everyone becomes firmly attached to one way of thinking and discourages different points of view.

Conclusions

Learning with your peers offers the possibility to not only see different things being done in practice, but to question how and why certain decisions were made. Collaborative learning offers a space to debate the benefits or drawbacks of practices, challenging assumptions about the reasons behind different approaches. This requires an open mind-set about revealing challenges and struggles to your peers. That way, everyone learns and can benefit from avoiding wasted time, money and effort. Many farmers are adamant that 'you get out what you put in', so a willingness to share and critically discuss failures as well as successes is essential to gain the maximum benefit from collaborative learning.

Farmers' experiences of working with others during COVID-19

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Summary

- Two farmers from the midlands were interviewed about how they have changed the way they work with others because of COVID-19
- Positive changes included: using a whiteboard to communicate, entrusting people with specific jobs and greater availability of workers
- The two farmers interviewed missed the social interaction with other farmers at discussion group meetings
- Working outdoors meant that the farmers were able to provide safe working conditions for their workers.

Introduction

Every farm involves people. Regardless of farm size, it takes a combination of people to get the work done — owner, family, part-time or full-time workers, contractors or relief workers. COVID-19 has changed how we live, but has it changed how farmers work with others? Two farmers were interviewed to find out about their experiences of working with others during the pandemic.

What worked well?

Good communication is essential to the success of any farm and is critical to creating strong working relationships. Due to COVID-19 restrictions, however, farmers faced new communication challenges with people working on the farm. Using a whiteboard worked well to reduce face-to-face communication for the farmers interviewed. Key information, such as vet visits, sick animals, grazing plans, etc. was updated on the whiteboard daily. One farmer created a WhatsApp group for everyone (family and workers) working on the farm so they could set weekly targets and report on performance measures remotely. This sharing of information helped motivate his workers. Motivated workers feel they have a stake in their jobs and have greater confidence and want to be involved in decision making. Motivation can also have a very positive effect on retention of workers, and many farm employers are concerned about retention issues.

Many workers are motivated by responsibility. COVID-19 provided an opportunity for one farmer with multiple workers to give them more responsibility. To avoid unnecessary interaction on farm, he delegated specific tasks to workers, for example, one was in charge of feeding, another looked after calf rearing. For milking, a combination of milking alone and a split roster was used depending on parlour size. This ensured that interactions on farm were limited. The workers on the two farms studied, valued the increased responsibility of being in charge of a specific task and this motivated them to complete the job successfully. However, not all workers find extra responsibility motivating, so employers should aim to understand what workers' value by talking to them.

Worker availability was a positive outcome that arose from COVID-19 for the farmers. One of the farms gained two highly skilled workers who had planned to travel but were unable to due to the global pandemic restrictions. The other noted that his regular workers were happy to work extra hours if required allowing the farmer to have a manageable workload during the spring. Another positive was that family members who would have otherwise been working off-farm or studying away from home were available to work as needed. As society begins to open up again, the question arises whether fewer prospective workers or family labour will be available and what challenges the industry faces.

Challenges

A challenge faced by both farmers was isolation. Both farmers missed the social interaction they normally had at sales and discussion group meetings. Discussion groups provide a great opportunity to meet other farmers, see their farms, learn from each other and socialise. The farmers interviewed highlighted missing the group meetings after the calving season, which is a busy period with long hours, stressful situations and minimal interaction with other farmers. This isolation impacts on wellbeing and provides insights into the (perhaps under-valued) importance of social interaction and connection with peers to farmers' professional identities.

Positive working environment

Finally, the farmers discussed feeling proud that their working environment was 'COVID-friendly'. Working outdoors in open spaces and fresh air meant that it was easy to practice social distancing on their farms. For breaks, the farmers provided a separate area for the workers to have their meals. They were able to provide safe working conditions as well as steady employment for their workers, while other industries were closed for months due to the restrictions.

Conclusion

Overall, COVID-19 presented more opportunities than challenges for these two farmers in terms of working arrangements. Nevertheless, they modified working practices to cope with the challenges and found some benefits from the changes for themselves and the people working on their farms. As the pandemic restrictions thankfully start to lift, there is an opportunity to assess if certain work processes on your farm should be altered or delegated to be more efficient.

Find more information on managing workers here: https://www.teagasc.ie/publications/2017/teagasc-farm-labour-manual.php

The success and future of dairy start-up farmers

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Summary

- Just over 1,000 people started dairy farming between 2015 and 2020. In addition, approximately 400 commenced dairy farming between 2011 and 2014 from quota granted by the Department of Agriculture just before quota abolition in 2015
- The percentage increase in the overall milk pool from Dairy Start-Ups (2015–2020) is 7% of the overall milk production in 2020 or 22% of the increased milk supply since quotas were abolished
- Teagasc have run dairy start up courses each year since 2015. The participants joined an Academy for one year as part of the course which consisted of up to 11 meetings on a hub farm.

Introduction

Dairy start-up farmers have been a very successful cohort of farmers within the industry. Dairy farming has allowed many farm families to return to economic viability. The decision to change the home farm business is a life changing decision and a lot of planning is required. A very high level of skills is required to become a dairy farmer. Many of the people that became dairy farmers are highly educated, but do not necessarily have a main degree in Agriculture. The age range of dairy start-up farmers varied from early 20's to people in their 60's.

Dairy start-up academy key learnings

One of the dairy start-up Academies (23 participants) started milking between 2015 and 2021 with an average of 100 cows and have increased cow numbers to an average of 200 in 2021. Depending on the levels of individual borrowings, on average cash flow (excluding the single farm payment) became positive after year three. Some sold stock from other enterprises which required less borrowings and resulted in an earlier positive cash flow. As the herd matured and management improved, the cash flow became positive. All farmers in the Academy required planning permission, everyone emphasised the requirement to allow 1–2 years to acquire full planning. This means that planning must be applied for at the beginning of the conversion/start-up time line and to work with a draughtsman/architect who has a proven record. Most of the group prepared budgets at a milk price of 28 c/l litre but actual milk price was higher resulting in better cash flow than was budgeted for. The group say that having an income every month compared to sporadic income from animal sales was a positive change. Most would suggest borrowing enough from the start instead of looking for additional borrowings or funding capital jobs from cash flow. The group purchased high EBI genetics, and most purchased in-calf heifers initially. They would also prefer to start with the full numbers from year one as it is the same work load but more production and better cash flow. However, this may not suit everyone, and should be whatever the farmer is comfortable with. Another key message is to learn what stocking rate suits your own farm, above or below the ideal stocking rate reduces cash flow. Weekly grass measuring and grass management skills empowered the group to make this decision.

Case study

A recent dairy start-up supplying Lakeland co-op established a 200 cow dairy farm on owned land. It cost €1,000,000 or €5,000/cow for stock, roofless cubicles, slurry storage for 300 cows, new 20 unit herringbone parlour with room to add eight more units, drafting facilities, second-hand bulk tank and grazing infrastructure. Existing sheds were modified for calving and calf rearing. The farm is set up to milk 300 cows, except to build additional cubicles and add units to the milking parlour. The project was financed by selling the beef herd and borrowing €600,000 over a 15-year lending period. The average EBI of the herd is €164. High EBI genetic crossbred calves were purchased in 2019, and calved in 2021. The farmer credits the other participants of the Academy for the majority of the technical knowledge he has gained. One of the biggest challenges was managing cash flow during the set up. This case study farmer emphasised how important it is to put together a strong technical support team that are fully aware of every aspect of a conversion, because if there is any delay then this puts financial pressure on the entire process.

Teagasc dairy start-up course and academy

Since 2015, Teagasc have run annual dairy start-up courses including one year Academies for people thinking of becoming dairy farmers. The local dairy advisor in the region where the course is taking place manages the course and the Academy. Each participant is likely to be spending a minimum of €500,000 in order to milk 100 cows. Access to this money can be a challenge and knowing the key areas to invest in for optimum return is very important. Teagasc will be offering dairy start-up courses in conjunction with your local milk processor. Contact your milk adviser for details of courses for 2021/2022.

Conclusion

When starting a dairy farm, the main areas to focus on are stock, grazing infrastructure, milking parlour, cow flow/drafting, calf rearing, wintering and compliance. Start with cow numbers that you are comfortable with. Plan the whole business at the start so that you can expand to extra numbers easily.

Farm succession and inheritance planning

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Summary

- Farm Succession and Inheritance are subjects for every farm family
- Planning for succession is one of the most important aspects in the life of the farm business
- Planning for and carrying out succession can be a complex process. It needs to be given time at an early stage in the business cycle to ensure that the process is successful
- Open communication within the family is one of the most important factors contributing to a successful succession and inheritance process
- Use all the available supports.

Introduction

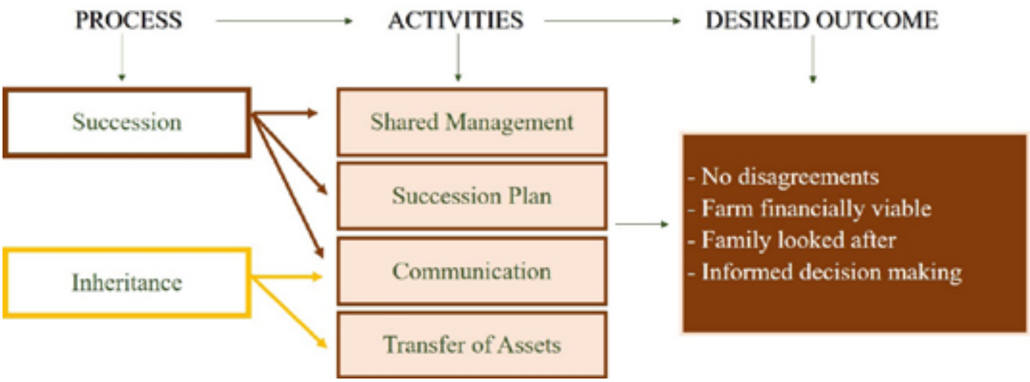
The subject "Transferring the family farm" is one that every farm family should plan for during the life of the farm. People in general do not like to talk about succession and inheritance. It is a sensitive subject as farmers may feel it marks the end of their farming career. If the goal is for the farm business to continue functioning (well) beyond the tenure of the current owner/operator, then talking about and planning for succession is vitally important to ensure a smooth transition and viable future. It is important to understand that within farm transfer, there are two processes: succession and inheritance.

- Succession is defined as the gradual transfer of management of the farm from one generation to the next
- Inheritance is defined as the legal transfer of the farm assets from one generation to the next.

Planning for both these processes in an open, collaborative way is critical to avoid extreme conflict and breakdown within the family unit.

Succession planning

Succession is very important for the farm business, but it can be difficult and complex. The farmer and spouse are faced with trying to maintain a viable farm business for the next generation, treat all of their children fairly (not necessarily equally) and provide financial security for their own retirement. Fortunately, succession also incentivises the next generation to expand or change the farm in order to generate sufficient income for additional family members, and it provides the necessary resources, labour and skills to carry the plan through. It is important to note that succession is not a single event but a process that occurs over time. Planning early for succession allows for a lot of the main issues to be addressed and resolved before transition starts. The goal in involving all family members in planning is to build consensus over the plan and proposed outcomes for the farm. A key starting point to this is establishing the needs, expectations and fears of all family members with regard to the farm business.



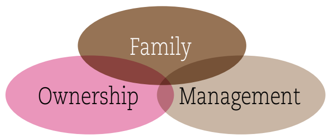
Communication

Effective communication is the key ingredient to successful succession planning. It allows for family members to share concerns, decide on options available and what actions to take. It also allows for effective planning and helps prevent disputes, misunderstandings and unnecessary anger.

Typically, when it comes to discussions around succession and inheritance, farmers tend to be "passive" communicators. This means that there are a lot of assumptions around who is getting the farm and the plans for the future, but these are not always explicitly communicated to the people involved.

When communicating on succession and inheritance, it is important to discuss and clarify the three key aspects of how family, ownership and management will play out, overlap and change over time/at different points in the future. When planning any discussion on succession, the following should be considered:

- Who should be involved in the discussion?
- What needs to be discussed?
- When and where to meet?
- What life stage are the children at?



Conclusions

Communication is the key to effective succession planning. It is important to have the discussion early and with all family members. This should help prevent disagreements and ensure that all family members have had the opportunity to discuss their needs, fears and requirements as to how the farm business will continue. For further information, log onto the farm succession page on www.teagasc.ie at the following link https://www.teagasc.ie/rural-economy/farm-management/succession--inheritance/ or open the camera on your smartphone and scan the QR code.

Equipping yourself for a successful dairy career — education options

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Summary

- There is a variety of employment opportunities on dairy farms, including farm operations and management as well as relief (part-time) staff. Additional progression opportunities exist through leasing, share farming and partnership arrangements
- Greater technical performance and profitability have been linked to farmers with formal agricultural education
- The Teagasc Level 6 Advanced Certificate in Dairy Herd Management and the Level 7 Professional Diploma in Dairy Farm Management (PDDFM) support the next generation of dairy farmers in the development of their skills and technical knowledge
- The continued growth and sustainability of the Irish dairy sector is reliant on highly skilled and technically excellent dairy farmers.

Introduction

The dairy industry is continuing to grow, albeit at a slower pace than observed in the last decade. The availability of skilled labour continues to be one of the dominant challenges facing the industry. Furthermore, due to the rapid and significant change occurring within the industry, farmers need to keep up-to-date with skills and knowledge, adopting new technologies and methods relevant to their farming system. The sustainability of the Irish dairy industry is reliant on skilled farmers who have the ability to cope with such change as well as managing financials, people and day-to-day farm tasks. This paper introduces two education and training options available to people interested in pursuing a career in dairying.

Advanced Certificate in Dairy Herd Management

The Level 6 programme provides graduates with the knowledge and technical skills required to operate dairy herds. Having completed 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 (grassland management, breeding, nutrition and health) and farm business planning modules.

Students who successfully complete the Level 6 programme have the skills and competencies to join the dairy industry as a skilled dairy operative. Progression from the Level 6 programme includes the Teagasc PDDFM programme or agricultural degree courses in the Institutes of Technologies. Course fees are currently €990 per annum.

Professional Diploma in Dairy Farm Management

The Level 7 specific purpose programme is the gold standard for farm management and farm ownership training in Ireland. The programme aims to equip trainee dairy farmers with best practice management and cutting edge research to successfully run dairy enterprises.

The main component of the programme is two years of professional work experience where students are based on high performing dairy farms in Ireland, with an option to complete a 6-month placement abroad. During this time there is approximately 20 days course work, where students further develop a broad range of skills in technical farming as well as a greater understanding of financial skills and people management. Course days are typically delivered at Teagasc Moorepark or Kildalton College. Course days incorporate both formal (lectures) and informal (discussion groups and skills practicals) training, delivered by an integrated team of highly specialised Teagasc staff, including Moorepark researchers, college teachers and dairy specialists. Guest lectures are invited from key industry stakeholders and highly successful commercial dairy farmers. Students who successfully complete the PDDFM have the skills and competencies to successfully manage dairy farms to a high level.

Applicants to the PDDFM programme must possess a Level 6 Advanced Certificate in Agriculture or an equivalent agricultural award. Course fees are currently €990 per annum. Students are paid at least minimum wage by host farms; currently €10.20 per hour worked.

Conclusion

The next generation of farm owners and managers should avail of every training opportunity available to them in order to acquire the knowledge, skills and experience to secure the long-term future of their dairy business. Work experience with high quality dairy farmers not only reinforces learning experiences, but it offers a network of people and mentors that can make a significant positive contribution throughout future farmers' careers.

NEWBIE and NEFERTITI, sustaining a cohort of new entrants

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Summary

- New entrants bring innovation, entrepreneurship, practical skills and positivity to the dairy industry
- Current dairy farmers play an important role in encouraging young people into the industry
- On-farm demonstration and social media have an important role to play in promoting the industry and attracting new entrants.

Introduction

In 2016, the Central Statistics Office showed that there were 137,500 farms in Ireland, with an average farm size of 32.4 hectares. That same year, 30% of farmers were aged over 65 years while only 5% were aged under 35 years, which broadly reflects the situation today. The People in Dairy Action Plan, published by Teagasc in 2018, reported that 6,000 people need to enter the dairy industry by 2025. These statistics highlight the importance of new entrants for the sustainability of Irish dairy farming over time. New entrants bring innovation, entrepreneurship and practical skills that are essential to maintain viability and deal with challenges facing the industry.

New entrants face considerable challenges in entering the sector. The NEWBIE new entrant network aims to address the challenges faced by new entrants when establishing a farm business. The NEFERTITI project's Network 10 - Farm Attractiveness aims to promote careers in dairy farming among younger people through on-farm demonstration.

Lessons learnt from new entrant farmers

New entrants face quite a number of barriers, with the most common hurdles including access to land, access to capital, access to labour and access to markets. Case studies identifying factors that may lead to new entrants' successful entry into farming have been compiled. Some of the success factors for recent new entrants included:

- Collaborative farming models, e.g. partnerships, which enable access to land, knowledge and skills as two generations worked together
- Funding supports and taxation incentives for new entrants, such as the young farmer capital investment scheme, young farmers scheme, national reserve, collaborative farming grants, succession farm partnership scheme, and LEADER funding
- Access to knowledge: Seeking advice from a farm advisor, participating in courses, gaining additional qualifications and being a member of a discussion group have been beneficial to new entrants.

Key aspects for farmers to promote careers in farming

Dairy farmers are essential to the process of promoting careers in dairy farming to younger generations. Each individual dairy farmer has a role to play and there a number of possible actions he or she could take.

- Open their farm to demonstration events to promote dairy farming and engage with students from the local area
- Create a positive image of the industry for their families and the community through the way they speak about dairying and how they work

- Host secondary school and college students for work placement and ensure that they have an enjoyable experience
- Share their story on how they became a dairy farmer by hosting events, school visits or social media
- Give employment and upskilling opportunities to young people locally.

Conclusions

Sustaining a cohort of new entrants is crucial for the agricultural sector. While there are many challenges facing new entrants, especially when starting farm businesses, there are many examples of these challenges being overcome in innovative ways. Dairy farming must be portrayed as a positive career with multiple career opportunities to encourage new entrants/successors to enter the industry.

Acknowledgment

NEWBIE is an EU Horizon 2020 project aiming to create a network of new entrants that offers guidance on overcoming challenges for new entrant farmers. Register on http://www.newbie-academy.eu/ to join the NEWBIE network, keep up-to-date with the project and to see new entrant examples from Ireland and across Europe. NEFERTITI is an EU Horizon 2020 project aiming to network European demonstration farms to enhance cross fertilisation and innovation uptake through demonstration. Register on https://nefertiti-h2020.eu/ to keep up-to-date with the project and future demonstration events. The 2019 demonstration campaign factsheet can be viewed at https://nefertiti-h2020.eu/fact-sheets-and-reports/.

MODERN FARM INFRASTRUCTURE

Design and performance of land drainage systems

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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 4–7 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 water table and/or reduce the period of waterlogging. This lengthens the grass growing season, the grazing season, increases the utilisation of available grass by livestock and increases the 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. Therefore, peat soils should not be drained. 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 4–7 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 its 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, www.teagasc.ie/publications.

Evaluation of land drainage system materials

Ian Byrne[1], Patrick Tuohy[1], Mark Healy[2] and Owen Fenton[3]

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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 single sized aggregate in the 10–20 mm range 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 supports increased production and, together with other technologies and optimised soil fertility, 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, and 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. 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.

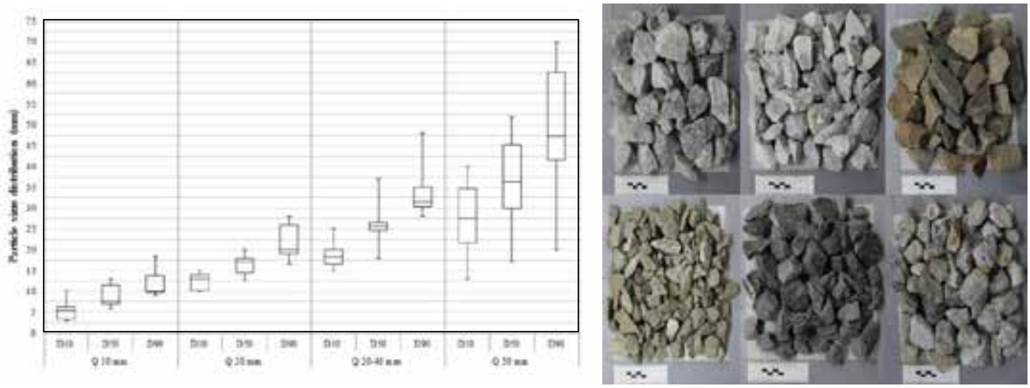

Figure 1. *Estimated ten, fifty, and ninety percent passing (D10, D50 and D90) figures from the most popular sizes indicated by quarries throughout Ireland (left) and a selection of Q 50 mm aggregates (right)*

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 10–40 mm grading range currently recommended and an effort should be made to select a more suitable 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, specifications call for an aggregate size much smaller than what is currently in use in Ireland. Initial analysis has shown that clean aggregate in the 10–40 mm range should be used, with further benefits evident for smaller (10–20 mm) material. Work is currently ongoing to test a range of aggregate sizes in a laboratory environment to determine a suitable aggregate size that will be suitable for heavy soil textures in Ireland.

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. Further research is needed on the efficacy of materials currently in use in Irish drainage systems and to identify suitably sized aggregates for Irish mineral soils.

Planning for good grazing infrastructure

Tom Fallon[1], Pat Tuohy[2] and Paul Maher[2]

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Summary

- Ensure farm roadway network is appropriate for herd size and soil type
- Paddocks of the correct size with good fencing will facilitate the management of grassland
- Upgrade water supply to paddocks. Achieve a good flow rate to troughs with large pipe bores and "full flow" type ballcocks.

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 the 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. Between mid-April to August, three grazings is preferred as this maximises pasture intake and milk production. The guideline paddock area is 1.2 ha per 100 cows for two grazings and 1.8 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 in medium land and 170–250 metres on light land. The upper limits are more applicable to larger herds. Use multiple gateways especially on heavy land and during wet weather.

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 system to aid grassland management. It should be easy to quickly set up access to paddocks between grazings. Good maintenance is essential.

Roadways

Design, construction and maintenance of farm roadways have a big impact on cow flow, walking speed and lameness incidence. 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, a smooth surface, adequate crossfall, raised above the grazing area and sweeping bends at corners and junctions. The main roadway should be wide enough for good cow flow (e.g. 100 cows four metres wide; 200 cows five metres wide). New farm roadways must be laid in good weather with dry soil conditions. Construction costs will be up to €30 per metre length, depending on the cost of materials, the width, depth of material and the construction method. Cow tracks are a cost effective way (€8–€11 per metre) to improve access, particularly on heavy land and to the furthest point of 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.

All farm roadways need to be assessed in the light of new regulations that oblige all farmers to take appropriate measures to prevent water runoff from roadways to water bodies. For more information contact your local adviser/consultant or the ASSAP adviser covering your area. DAFM Specification S199 outlines construction details and measures farmers can undertake to prevent runoff from roadways.

Water system

Ask the following questions when assessing your current water supply to 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 lift 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 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 10% of the herd to drink at once. Assess costs in advance; costs can amount to €275 per hectare for new installations.

Table 1. Water pipe sizes

	Internal bore width (mm)
<80 dairy cows & drystock	20
80–150 cows	25
150–300 cows	32-40
>300 cows	40

Pipe size will also depend on the distance and the height the water has to be pumped and whether a looped system will be used + appetite for expansion.

Assessing the condition of grazing infrastructure on Irish dairy farms

Paul Maher[1], Pat Tuohy[1], Michael Egan[1] and Michael Murphy[2]

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Summary

- Just 20% of paddocks on study farms were deemed to be adequate size for a 36 hour allocation
- 43% of paddocks on farms with more than 150 cows are only adequate for 12 hour allocations
- The median sized 150 cow herd walked 533 km on average on farm roadways in 2020.

Introduction

Grass utilisation on farms is a key driver of net profit. Effective grassland management relies on robust grazing infrastructure. This should consist of appropriately sized paddocks, adequate entry points served by a quality road network and a good drinking water supply. Without this, grass cannot be optimally utilised. Every extra day at grass in the spring is worth €2.70 per cow, and €1.80 per cow per day in the autumn. Increases in herd size over-time has placed additional pressure on existing grazing infrastructure on farm, which can have a negative impact on grass utilisation, dry matter intake and subsequent cow performance. On many farms grazing infrastructure has remained unchanged for many years and can easily be overlooked when farm performance is being evaluated.

Paddock size

Paddock size should be based on having as many paddocks as possible suitable for 24 or 36 hour allocations for the number of cows in the herd. The impact of a sub-optimal grazing allocation can be significant in terms of grass utilisation & milk production. Grazing smaller paddocks, relative to herd size, results in higher inter-cow competition for grass, reducing animal intake and greater labour demands. Reducing the stocking density through the use of 24 and 36 hour allocations can alleviate this undue strain on the herd (in particular first lactation animals).

A recent study undertaken at Teagasc Moorepark during February and March 2021 assessed the size of paddocks on commercial dairy farms located throughout Ireland. The objective of the study was to quantify paddock size on each farm relative to herd size. In total 138 farms were assessed with 3,760 paddocks reviewed. Paddocks were categorised into 12, 24, 36, 48 and >48 hour allocations. Pre-grazing herbage was assumed to be 1,400 kg/DM/Ha, and a demand per cow of 17 kg/DM/LU, across all farms. As herd size increased paddock size did not increase, with 43.2% of paddocks only suited for 12 hour grazings in herds greater than 150 cows, and 16.6% of paddocks in herds of less than 150 cows. Farms with less than 150 cows, typically had a larger proportion (72%) of the farm in 24 and 36 hour allocations compared to farms with larger (≥150 cow) herds (54%) (Figure 1).

Roadway usage on commercial dairy farms

The total distance walked on farm roadways by cows for the year 2020 was calculated. The study included 138 farms. The median herd size was 150 cows. As expected herd size had a large impact on the distance cows walked. Farm layout also played a significant role. The median distance walked was 533 km on farm roadways, ranging from 190–1,032 km per year across the study farms.

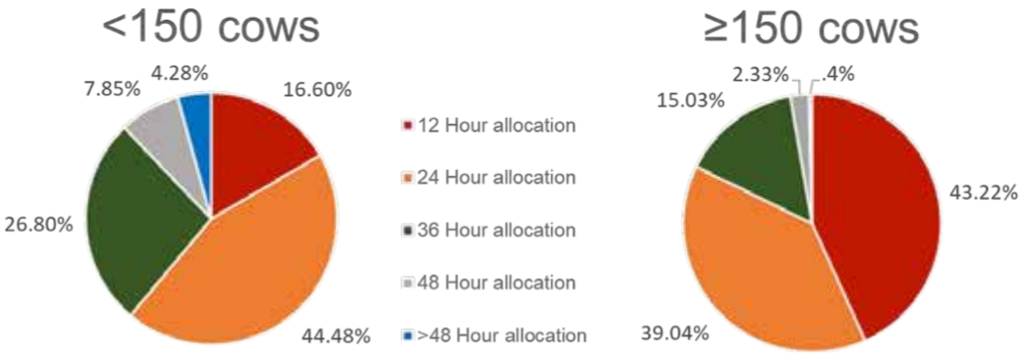

Figure 1. *Paddock sizes relative to herd size for <150 cow herds and ≥150 cow herds*

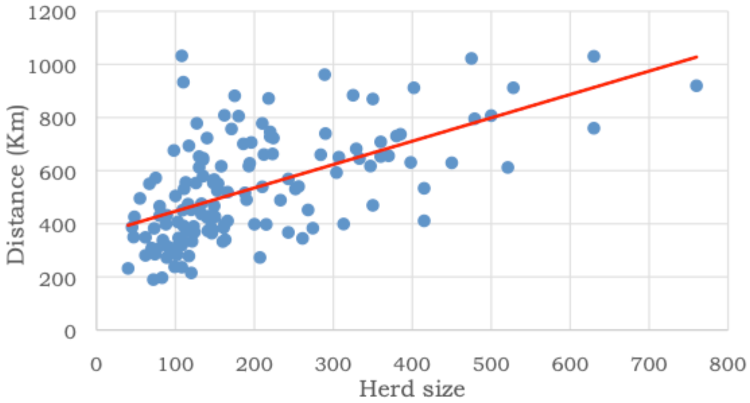

Figure 2. *Distance walked in 2020 relative to herd size on 138 farms.*

An additional on-farm study assessing the roadway network and access points to paddocks across 55 farms is on-going. Areas being assessed include roadway surface condition, water run-off, roadway width and congestion points amongst other factors.

Optimising the management of poorly drained soils: Lessons learned from the Heavy Soils programme

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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 65% (850–1,405 kg/Ha) since the start of the programme.

Introduction

The initial development of the Heavy Soils Programme was encouraged by 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. Generally profitability on such soils is closely related to weather and as such can be extremely volatile. 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. It was decided in 2011 to establish the Heavy Soils Programme to develop a network of farms on poorly drained soils to acts 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. Over time 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 32% from the 2011 level, with a corresponding increase in milking platform stocking rate from 2.12–2.82 cows/Ha. Output in terms of milk solids/Ha has increased by 65% (850–1,405 kg/Ha), (Table 1).

The natural variability of soils is apparent between different regions of the country, and indeed within farm boundaries (Figure 1). A campaign to classify, sample, measure and map soil type and characteristics at a paddock scale across the programme farms was undertaken as part of the Heavy Soils Programme. This survey produced high-resolution soils maps and detailed soil classifications of every soil subgroup on each farm.

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

Figure 1. *Soil profiles in heavy soils programme farms in Stradone and Kishkeam*

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.

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
- A cumulative 70–170 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 & 3 is 1 t DM/ha.

Introduction

Poor soil fertility is a major limiting factor to output potential on farms in Ireland, particularly farms dominated by fine particle size 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 2010 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 reduction 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 to have no negative effect on soil physical structure. Increasing soil pH by 1 pH unit increased herbage production by 1.3 T DM/Ha.

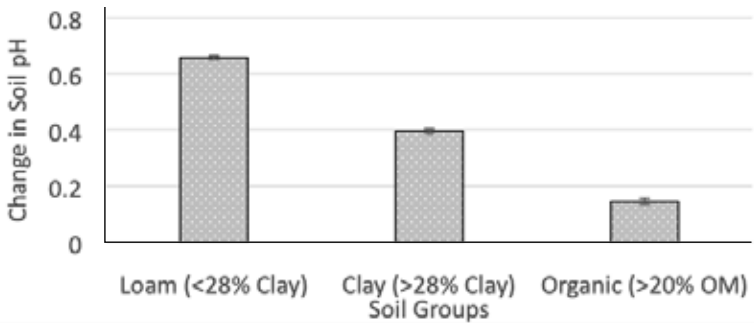

Figure 1. *Change in soil pH @ 5 tonne lime/Ha across soil groups*

Phosphorus

The effects of P application on the Heavy Soil Program 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).

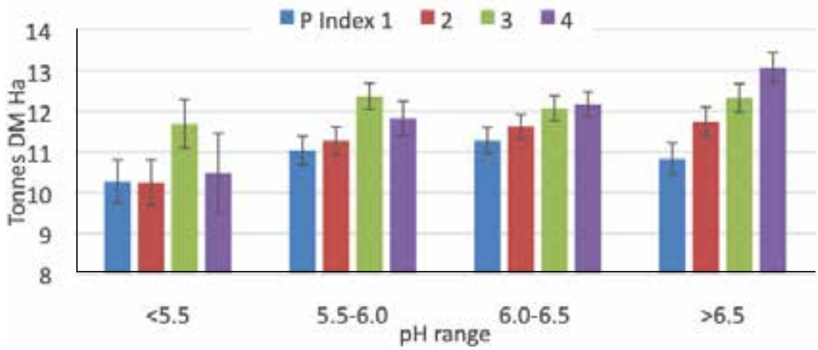

Figure 2. *Effect of soil pH range and soil P index on herbage production*

Conclusion

Currently in Ireland, standard P recommendation 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.

Assessing soil moisture status using satellite imagery

Rumia Basu[1,2], Patrick Tuohy[1], Eve Daly[2] and Colin Brown[2]

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Summary

- Soil moisture is an important variable affected by soil type and local weather
- It can vary widely within a farm and will dictate accessibility during wet weather and output during drought
- Remote sensing, using satellite images, offers a novel method for measuring soil moisture
- Such information could be used to assist in grazing management.

Introduction

Surface soil moisture is a key variable governing the management of agricultural soils. On poorly drained soils excess soil moisture will limit production and utilisation in wet weather. On the other hand, a low soil moisture content during drought will limit production potential. A full understanding of the variability of soil moisture across soil types and over time is required to help predict its impact on farm management. Changes in soil moisture itself are dictated by changes in precipitation, temperature, solar irradiation and humidity.

Soil moisture varies greatly in time and space due to variations in soil properties, land cover type, topography, rainfall and different rates of evapotranspiration. Soil moisture is typically estimated using conventional ground measurements such as using a Time Domain Reflectometer (TDR) or gravimetric techniques, which require in-situ point measurement and/or soil sampling which are time consuming and costly. While these can provide point based measures, they cover short periods of observation and cannot detect any changes in spatial distribution of soil moisture.

Remote sensing technology, which uses "Sentinel-2" satellite imagery, may provide a solution to such problems by allowing temporal and spatial coverage at high resolution. To test such technologies, we estimate surface soil moisture at Rossmore, one of the Teagasc Heavy Soils programme farms, using one of the most popularly used optical remote sensing techniques, known as OPTRAM (Optical Trapezoid Model) that makes use of Short Wave Infrared (SWIR) and Vegetation Indices (VI) to estimate surface soil moisture. Sentinel 2 data from 2015–2020 has been used in the model. The estimates made from remote observations are being compared with continuous measurement of soil moisture by moisture sensors located on the farm. We make modifications to the linear OPTRAM model by introducing non-linear relationships in the SWIR-VI space to show that in Ireland which is governed by wet conditions for large parts of the year, a non-linear approach to estimating soil moisture suits better. We use different vegetation indices such as the Normalised Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Modified Soil Adjusted Vegetation Index (MSAVI) and the Normalised Difference Red Edge Index (NDRE) for estimating surface soil moisture at the study farm.

Results

The normalised surface soil moisture maps for Rossmore (Figure 1) show clear variability across the farm and weather effects over time. These preliminary results are reliant on the collection of cloud-free "Sentinel-2" images from the site and as such can be difficult to collect. An alternative satellite, "Sentinel-1" offers much more frequent imagery and this will also be assessed for it potential to measure soil moisture in the future.

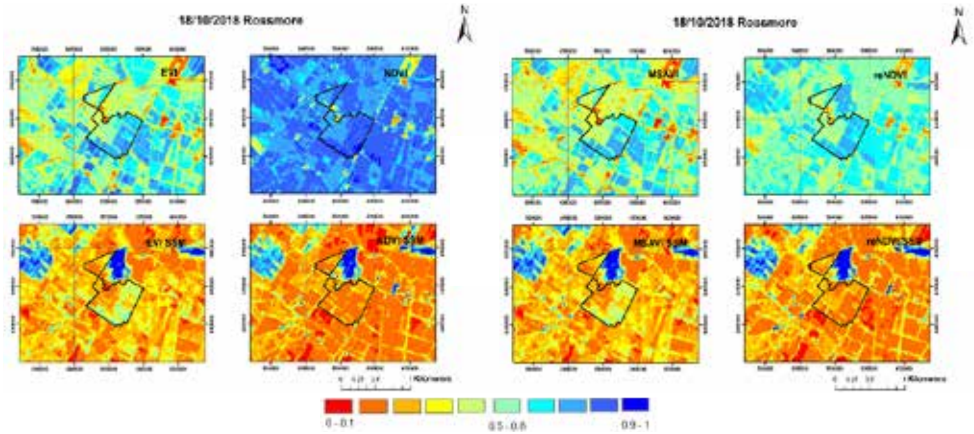

Figure 1. *Normalised surface soil moisture maps for Rossmore*

Conclusion

An assessment of preliminary results covering a period of 18 months has shown that for the study site tested, which is subject to wet conditions for large parts of the year and is dominated by poorly drained soils, the Sentinel-2 data is effective in identifying variability in surface soil moisture. The next steps will be to calibrate this information with ground based measurements on-site. Our study can then open up avenues for testing this approach at other sites. While we have shown the potential of Sentinel-2 in mapping surface soil moisture, even with sparsely available data, it would also be worthwhile to explore the use of Sentinel-1 data in mapping soil moisture. As this techniques is further refined and made ready for wider application, it will then be possible to assess soil moisture over wide geographical areas and help predict grass production and utilisation at field scale. Such information could refine production prediction models and allow for precision grazing management.

The farm roadway runoff visual assessment booklet

Owen Fenton[1], Karen Daly[1], Paul Rice[1]; Patrick Tuohy[2] and John Murnane[3]

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Summary

- Direct runoff of soiled water from farm roadways to waters is not allowed from 1st January 2021 (S.I. No. 605 of 2017). This is applicable to all farms
- Roadway runoff contains nutrients and *E. coli* from animal urinate and faeces and sediment
- The EPA/DAFM Co-Funded Roadrunner Project has produced a booklet to identify the extent of connectivity (direct or indirect) between roadway runoff and waters. This is of upmost importance as roadways near waters are potentially a high pollution risk and need to be identified and assessed as a priority
- The booklet also examines the structure and configuration of the entire roadway network and evaluates its pollution risk potential
- Booklet available on Teagasc website for free.

Introduction

On farms in Ireland, internal roadways come in many shapes and sizes, with a variety of hard surfaces. These farm roadways often facilitate surface water flow along them for short periods during and after rainfall; this is termed roadway runoff. Farm roadway runoff can also transport significant deposits of animal manure, urinate and machinery contamination and discharge them to adjacent waters such as streams and ditches. Such pollutant loads contain suspended sediment, dissolved nutrients (nitrogen (N) and phosphorus (P)) and bacteria such as *E. coli* and can result in significant deterioration of surface water quality. In rivers, N and P loss can result in excessive plant and algal growth. This reduces the amount of oxygen in the river and suffocates sensitive fauna. From a human health perspective, bacterial contamination of watercourses is a significant issue, particularly in the context of drinking water and bathing water quality. To safeguard water quality therefore, farm roadway runoff must be prevented from directly entering waters.

What are visual assessment indicators?

These are recognisable features that help identify connectivity between roadway runoff and waters. Additionally, visual assessment indicators identify sections of roadway that may need improvement. This will minimise the source of pollutants on these sections of roadway.

What is the first step?

This is a priority to protect water quality and should be carried out and acted upon on all farms in Ireland. This step identifies priority areas for runoff management away from waters. Firstly, print off a farm map (e.g. Land Parcel Identification System, LPIS), satellite image or sketch out your own map of the farm/farm roadway network. Secondly, walk the roadway network, find and note on your map where direct roadway runoff enters waters (as defined in SI No 605 of 2017). This exercise is best carried out during or immediately after a rainfall event, when farm roadway runoff is visible. Repeat over time.

What is the second step?

This step should be considered after the first step and will enable you to note sections of the roadway network that need attention and are problematic because of the structure or configuration of your roadway network. Using the map from the first step other visual indicators are noted for the roadway. Take a look at the condition of your farm roadways for defects that may be causing problems. These relate to roadway structural deficiencies, which lead to poor roadway integrity and loss of sediment. Roadway configuration deficiencies (e.g. road too narrow, sharp bends, obstructions such as drinking troughs and inappropriately located gates or gaps) may also be evident and these can reduce the speed of animal movement and increase the level of soiling (i.e. create nutrient and *E. coli* sources) on the roadway. When it rains, such deposits can become temporarily mobilised and enter waters where direct or indirect connectivity exists. The occupier of a holding with farm roadways must comply with the minimum specification for farm roadways (Current specification S199, July 2020).

Final Map Output

This final map gives you two things 1) the locations of where you need to invest in roadway runoff diversion measures and 2) where you need to invest in the structural or configuration of your roadway network. Both of these will minimise the source of pollutants on your roadway and when runoff occurs protect water quality.

ROADRUNNER

Adoption of precision livestock farming (PLF) technologies in Irish pasture-based dairy systems

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Summary

- Adoption rates of PLF technologies varied widely depending on the type of technology, ranging from 52% of dairy farms with automatic parlour feeders to 6% of dairy farms with electronic plate meters
- In general, Irish dairy farms with larger herd size, younger farmers and discussion group members are more likely to adopt reproductive- and grass-management technologies.

Introduction

Precision livestock farming (PLF), or the use of information and communication technologies (ICT) to monitor animals' behaviour, welfare and production, has been promoted as an important approach to comply with current market and regulatory challenges. This is because it is expected that PLF technologies will improve efficiency, quality, animal health and welfare, and reduce the environmental impacts of dairy farms. Despite its potential benefits, there is limited information regarding the uptake of these technologies, especially in pasture-based dairy systems. Therefore, the objectives of this research were to establish the level of PLF technology adoption in Irish pasture-based dairy farms and to determine the factors associated with PLF technology adoption.

PLF technologies uptake levels

Data from the 2018 National Farm Survey (NFS) was used to assess on-farm uptake levels of different PLF technologies. Specifically, we estimated uptake levels of individual cow activity sensors (e.g. Moo Monitor), plate meters, automatic milk washers, automatic cluster removers, automatic parlour feeders, milk meters, automatic drafting gates, automatic calf feeders and Pasture Base Ireland. Figure 1 shows that Irish dairy farmers most commonly adopted PLF technologies related to the milking process (automatic parlour feeders, milk meters, automatic milk washers and automatic cluster removers). Similar results are reported in other countries with pasture-based dairy systems, although with different adoption rates. This might be so because milking process is physically demanding and time-consuming.

Factors influencing PLF technologies adoption

We used farm socioeconomic data to conduct a statistical analysis that allowed us to identify the factors associated with the likelihood of adopting different groups of PLF technologies (reproductive management technologies and grass management technologies). Table 1 shows that farms with larger herd size, farmers with higher agricultural education, more household members and discussion group membership are more likely to adopt reproductive management technologies (individual cow activity sensors and automatic drafting gates). While older farmers are less likely to adopt reproductive management technologies. For grass management technologies (plate meters and PBI), we saw that farms with larger herd size, higher farm family income and higher proportion of hired labour are more likely to adopt these technologies. Younger farmers and members of discussion groups were also more likely to adopt grass management technologies.

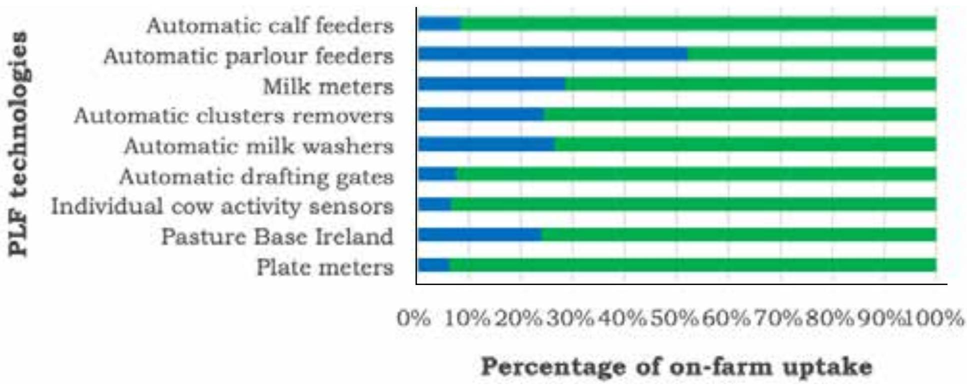

Figure 1. *Technology adoption levels*

Table 1. Factors associated with PLF technology adoption by group		
Variables	Reproductive management tech	Grass management tech
Herd size (№)	+	+
Farm family income (€/ha)		+
Hired labour (%)		+
Age (years)	-	-
Household members (№)	+	
Higher agricultural education	+	
Discussion group membership	+	+

(+) factor positively associated, (-) factor negatively associated

Conclusion

The results of the research show that the uptake of PLF technologies varied widely depending on the type of technology and they are mostly influenced by herd size, farmer age, and discussion group membership. The next part of the research will evaluate the economic benefits of investing in these technologies.

Milking efficiency of rotary and herringbone parlours

Ryan Prendergast[1,2], Fergal Buckley[1,2], Michael D. Murphy[2] and John Upton[1]

[1]*Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork;* [2]*Munster Technological University, Cork*

Summary

- Milking process efficiencies were documented on herringbone and rotary dairy farms through the use of video cameras and infrastructure surveys
- The average total milking process time for the herringbone group was 1 hr 45 mins and 2 hr 25 mins for the rotary group
- The average cow throughput was 105 cows/hour for the herringbone group and 155 cows/hour for the rotary group.

Introduction

Milking efficiency is often defined as the number of cows milked per hour, or cows milked per operator per hour. In order to achieve optimum milking efficiency, there must be successful engagement between factors that can have most impact on the milking process such as cows, equipment, and people. Milking is a significant task and accounts for approximately 30% of a dairy farmers daily workload. This paper will describe the milking processes times and milking efficiency of a subset of Irish dairy farms across both herringbone and rotary milking systems.

Materials and methods

Farmers were chosen for inclusion in this study based on their willingness to participate in data recording, share farm data and manage progressive dairy farms that are representative of future Irish dairy farms. Data were collected using both surveys and video cameras. The purpose of the survey was to generate a descriptive profile of all facilities as well as establish the presence of automation on the farms. The cameras were used to collect empirical data from the milking process. Recording of video data took place over a period of one week on each farm, with the recording period lasting from 28th July 2020 until 23rd October 2020.

The milking process was then divided into three distinct stages:

1) *Set-up Time* — First cow in holding yard until first cluster attached;

2) *Milk Time* — First cluster attached until last cow out of last row;

3) *Clean-up Time* — hanging up of first cluster until hosing of facilities complete.

Total process time was defined as the first cow in the holding yard until hosing of facilities was completed. The times presented here are an average of AM and PM milking's.

Results — Infrastructural survey

Herringbone: The Herringbone group consisted of a sample of seventeen farms. The average herd size for the herringbone group was 174 cows (range 70–336 cows). The average number of milking clusters was 18 units, (range 6–36 units). One farm had a double-up system as opposed to a swing-over system. Automatic cluster removers were installed on 88% of the farms, 41% had automatic feeders, 59% had automatic entry/exit gates, 24% had automatic backing gates and 12% had a rapid exit system installed.

Rotary: The Rotary group consisted of a sample of ten farms. The average herd size for the rotary sample group was 386 cows, (range 275–570 cows). The average rotary farm had 50 units (range 44–64 units). Automatic cluster removers were installed on all of the farms, 70% had automatic teat sprayers installed and 60% had automatic backing gates.

Results — Video recording

Herringbone: The average total process time for the Herringbone group was 1 hr 45 mins (range 1 hour 1 min to 2 hr 48 mins). Average Set-Up time was 6 mins (range 1 min to 21 mins). Average Milk time was 1 hr 23 mins, (range 53 mins to 2 hr 24 mins). Average Clean-Up time was 25 mins, (range 10 mins to 52 mins). Average number of operators present at milking was 1.5, with 42% of the sample having more than one person present at milking. Average number of rows recorded was 10 (range 6–20). The average milking efficiency was 105 cows per hour, (range 52–200).

Rotary: Average total process time for the Rotary group was 2 hr 25 mins, (range 1 hr 55 mins to 2 hr 59 mins). Average Set-Up process time was 17 mins, (range 6 mins to 33 mins). Average Milk time was 1 hr 40 mins, (range 1 hr 8 mins to 1 hr 58 mins). Average Clean-Up time was 34 mins, (range 25 mins to 44 mins). For 70% of rotary farms there was only one operator present at milking, however, 30% of the sample had two operators present at milking. The average milking efficiency was 155 cows per hour, (range 78–189).

A breakdown of the milking process times documented for both Herringbone and Rotary sample farms is presented in Figure 1.

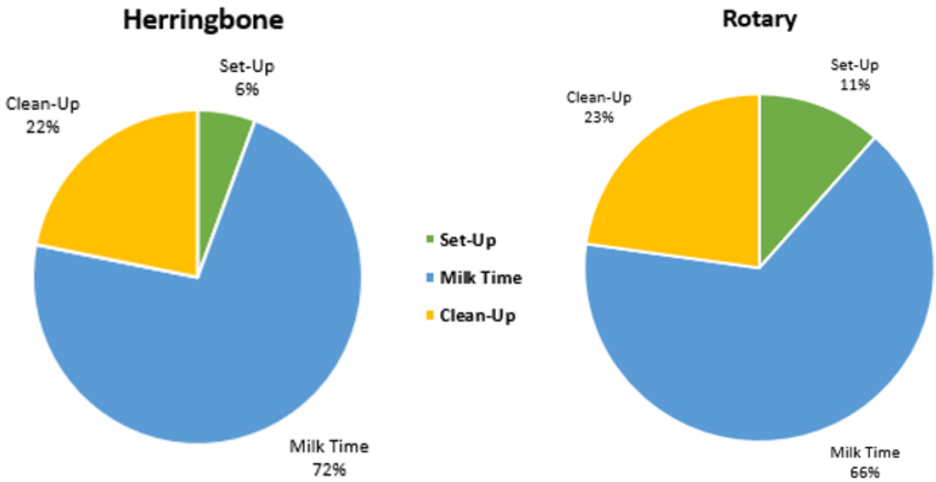

Figure 1. *Breakdown of milking process times for Herringbone and Rotary milking systems*

Conclusion

Rotary farms had longer milking process times and higher cow throughput compared to herringbone farms. The farm to farm variability between herringbone and rotary systems warrants further investigation in order to identify the factors that have the largest influence on milking efficiency. The future work of this research project will seek to determine where maximum reductions in milking process time can be achieved.

Energy efficiency of herringbone and rotary milking parlours

Fergal Buckley[1,2], Ryan Prendergast[1,2], Michael D. Murphy[2] and John Upton[1]

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Summary

- Energy consumption of herringbone and rotary milking parlours were documented through the use of energy meters and infrastructure surveys
- The average energy consumption per 1,000 litres of milk produced for herringbone parlours was 38.53 kWh and 44.23 kWh for the rotary parlours evaluated
- The average energy cost per 1,000 litres of milk was €6.69 for the herringbone and €6.96 for the rotary parlours.

Introduction

The amount of energy consumed per litre of milk produced (kWh/1,000 Lmilk) is often used as a method for assessing the energy efficiency of the milking process. Appropriate system sizing, operation and process management are all critical aspects to be considered to improve the energy efficiency of the milking process. This paper will describe the energy consumption and costs on a sample of Irish dairy farms across both herringbone and rotary milking systems.

Materials and methods

A total of 27 dairy farms were evaluated (17 herringbone, 10 rotary). Energy data was gathered using energy meters installed on each farm. Data on the main energy consuming plant on each farm was gathered via an infrastructure survey. The aggregate energy consumption and all main energy consuming processes associated with milking (vacuum pump, milk cooling, water heating, wash pump) were metered on all 17 herringbone farms and one rotary farm using permanently installed meters. Energy meters recording the aggregate energy consumption only were temporarily installed on the remaining nine rotary farms for a one week period per farm. This aggregate energy is equivalent to the aggregate energy which was metered on the farms with permanent meters. An analysis of the energy demand profile for the late lactation period of each farm was carried out and the main energy users were identified.

Results — Infrastructural survey

Herringbone: The average herd size for the herringbone group was 174 cows (range 70–336 cows). The average number of milking clusters was 18 units, (range 6–36 units). One farm had a double-up milking system. Of the Herringbone group studied, 82% used electricity to heat water for parlour washing while 18% used gas, 47% had variable speed drives installed on their vacuum pumps, 6% had an ice builder for cooling milk and 18% had solar photovoltaic panels installed.

Rotary: The average herd size for the Rotary group was 386 cows, (range 275–570 cows). The average rotary farm had 50 units (range 44–64 units). Of the Rotary group studied, 50% used electricity to heat water for parlour washing, 40% heated water using gas and 10% used oil, 100% had variable speed drives installed on their vacuum pumps, 20% had an ice builder for cooling milk. None of the rotary farms used solar photovoltaic panels. An analysis of the energy data recorded for the late lactation period of 2020 for all 27 participant farms is presented in Table 1.

Results — Energy metering

Table 1. Energy consumption and cost analysis for herringbone and rotary farms

Parlour Type	Variable	mean	range
Herringbone (Sept. 2020–Nov. 2020)	Milk yield (L)	177,936	69,99–349,055
	kWh	6,352	2,035–11,985
	kWh/cow milked	0.31	0.15–0.46
	kWh/1,000Lmilk	38.53	26.84–50.92
	€/1,000Lmilk	6.69	4.13–9.14
	€/cow milked	0.06	0.03–0.08
	Per cent night rate electricity	50	35–66
Rotary (first week Oct. 2020)	Milk yield (L)	28,937	18,379–49,268
	kWh	960	503–1,829
	kWh/cow milked	0.24	0.09–0.51
	kWh/1,000Lmilk	44.23	25.26–64.66
	€/1,000Lmilk	6.96	3.38–11.61
	€/cow milked	0.05	0.02–0.09
	Per cent night rate electricity	45	26–73

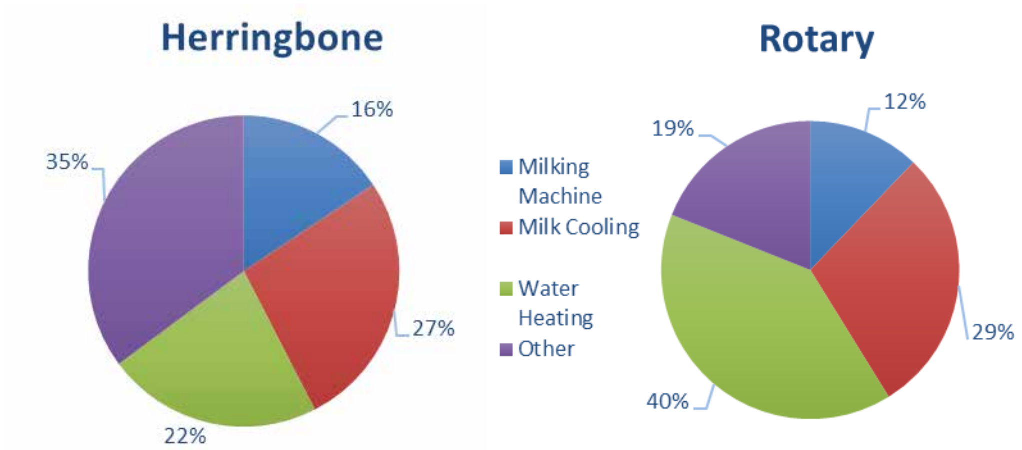

Figure 1. *Average % breakdown of energy consumption of all sub-metered herringbone and rotary farms in this study*

Conclusion

Rotary farms consumed more energy (44kWh/1,000 Lmilk) and had higher energy costs (€6.96/1,000 Lmilk) than herringbones (39kWh/1,000 Lmilk and €6.69/1,000 Lmilk). However, further investigation into the impact that milking infrastructure, energy saving technologies and managerial practices have on the energy efficiency of the milking process is required.

Quarter milking simulation to estimate quarter and cow milking duration and box time in AMS

Pablo Silva Boloña[1], John Upton[1], Victor Cabrera[2], Tedward Erker[2] and Douglas Reinemann[2]

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Summary

- We created a simulation of quarter milkings which were used to predict quarter and cow milking duration and box time in an Automatic Milking System (AMS)
- We applied different teatcup removal settings to these simulated milkings and found that quarter milking duration can be reduced by 19% and cow milking duration by 8% when increasing the flowrate for teatcup removal from 0.2 kg/min to 0.6 kg/min
- This model could be used to assess the impact of other milking management strategies on milking duration and AMS efficiency.

Introduction

The increasing adoption of automatic milking systems have put pressure on achieving high efficiency of these systems to increase their profitability. A simulation model is a simplified representation of a real system (e.g. cows milked in an AMS). They are useful to allow repeating the same conditions several times (which experiments do not), allow simulation of large numbers of cows and milkings and they help control for parameters that might be difficult to control in experimental settings (e.g. milking interval). The aims of this research were to: 1) create a model to simulate quarter milkings and use them to estimate quarter and udder milking duration and box time (time that the cows are inside the robot) for a herd of cows milked with an automatic milking system; 2) test how accurate this simulation was compared to real data and; 3) apply different teatcup removal settings to the quarter milking simulations to predict their impact on quarter and cow milking duration and box time in an AMS.

Development of the model and simulation

We simulated quarter milkings by using information from two commercial farms, one from an AMS farm with 32 robots milking over 1,500 cows and a second from an AMS farm with one robot milking 60 cows with more detailed quarter milking information. We simulated a herd of cows, each with their own days in milk, parity, milking interval and quarter milk production rate (kg of milk produced per hour). With this information, we simulated quarter milkings (the milk flowrate throughout the milking) for each quarter of each cow. Then, we calculated quarter milking duration as the total time that the flowrate was greater than 0.1 kg/min. We also simulated the time that it takes the robot to attach each teatcup and with that information calculated cow milking duration as the time from the first teatcup attached to the last teatcup detached. Finally, we simulated a preparation time for each cow, which is the time between the cow entering the robot until the first teatcup is attached and adding preparation time plus cow milking duration we calculated box time. We simulated more than 84,000 quarter milkings and to test how accurate the simulation was, we compared it to a portion of the actual data. Figure 1 shows the quarter milk flowrate for an entire milking of one simulated cow. We found that simulated quarter milking duration had an error of 7.5% when compared with actual data. Simulated cow milking duration had an error of 8% and box duration an error of 12%.

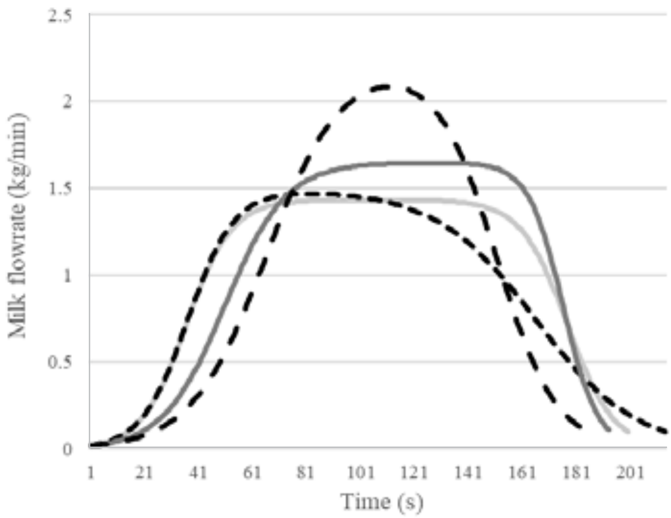

Figure 1. *Milk flowrate for the simulated quarter milkings. Each line represents a different quarter of the same cow.*

We applied different quarter teatcup removal settings on the simulated quarter milkings and tested their impact on quarter and cow milking duration. Teatcup removal was applied if quarter milk flowrate was less than 0.2 kg/min, 0.4 kg/min and 0.6 kg/min or at 20%, 30% and 50% of the quarter's 30 s rolling average milk flowrate. This showed that quarter milking duration could be reduced by 19% when increasing the flowrate for teatcup removal from 0.2 kg/min to 0.6 kg/min. By using a teatcup removal setting of 20% of the quarter's rolling average milk flowrate, quarter milking duration was 4% longer than using 30% of the rolling average flowrate.

Table 1. Effect of teatcup removal settings on several variables related to milking efficiency

	Percentage			Absolute (kg/min)		
Variable	20%	30%	50%	0.2	0.4	0.6
Quarter milking duration (s)	259	241	218	209	190	170
Cow milking duration (s)	498	480	450	419	403	387
Box duration (s)	590	573	543	512	495	479

Conclusion

This research showed it is possible to accurately simulate quarter milkings and use them to estimate quarter and cow milking duration and box time in cows milked in an AMS. By applying the different teatcup removal settings to the simulated data we showed that this model could be used to assess the impact of other milking management strategies on milking duration and AMS efficiency.

Testing the milking machine

Francis Quigley
Farm machinery & milking machine specialist, Teagasc, Kildalton, Piltown, Co. Kilkenny

Summary

- The milking machine should be tested by an MQI registered technician at least once per year
- Liner change should be done at 2,000 milkings
- Milking installations should be serviced twice a year.

Introduction

Milking machines that are not setup correctly and tested regularly can contribute to udder infections in the herd. The most common reason for problems with the milking machine is a lack of routine maintenance of the rubber ware and the mechanical components. Having your milking machine technician carry out a milking machine test, to the MQI standard, ideally twice a year, will ensure that the milking parlour is up to recommended ISO standard and performing optimally. Testing is typically done following a service, however, if there is a problem with mastitis or cell count it is recommended to test the milking machine before servicing followed by a second test after servicing. By comparing the two tests it can highlight problems which may have been causing issues and show that they have been fixed.

It is important to keep a copy of the test report on file, and discuss the results of the test with the technician. Milking machine testing should be done by an MQI registered milking machine technician. MQI (Milk Quality Ireland) (formerly known as IMQCS) oversees the training and registration of milking machine technicians and others involved in servicing, installing, testing and/or solving milk quality problems with milking machines. The full list of those currently on the register is on www.milkquality.ie

Vacuum and airflow tests

The milking technician uses an accurate test gauge to check the working vacuum of the milking machine at various test points. They also confirm that the vacuum gauge on the machine is reading correctly. The vacuum level should be set typically between 47 and 48.5 kPa for a midline plant. It is essential for the farmer to check the vacuum gauge at milking time to ensure correct vacuum level is being maintained. A red line on the gauge can be set at the desired vacuum level and the needle on the gauge lines up with the red line during milking, so you can see at a glance if something is wrong. Airflow is measured using an air flow meter and vacuum gauge. The unit is connected to the machine at the appropriate test point. Testing includes checking the pump capacity. This is measured in litres per minute (l/min) and is checked against the estimated pump capacity required for the type of machine being tested. Effective reserve is also tested, the required effective and cleaning reserve recommended for a modern machine can be found on www.milkquality.ie. The technician will also have these figures available in the test report booklet. Effective reserve is the ability of the vacuum pump to maintain vacuum when a cluster falls off or if excessive air is admitted while putting on a cluster.

Pulsation

Pulsation is checked using a specialist testing unit. It measures the vacuum changes over time in the pulsation chamber (i.e. the space between the liner and the shell). A pulsation cycle consists of four phases A, B, C and D. The A phase is the liner is opening phase, B is the liner open phase (when milk is flowing), C is the liner closing phase and D the liner is closed phase (when massage of the teat occurs). The ratio is the portion of the pulsation cycle taken up with the A and B phases and is typically between 60 and 70%. The pulsation results should be within the range recommended for your machine but also should be no more than 5% variation between any of the units.

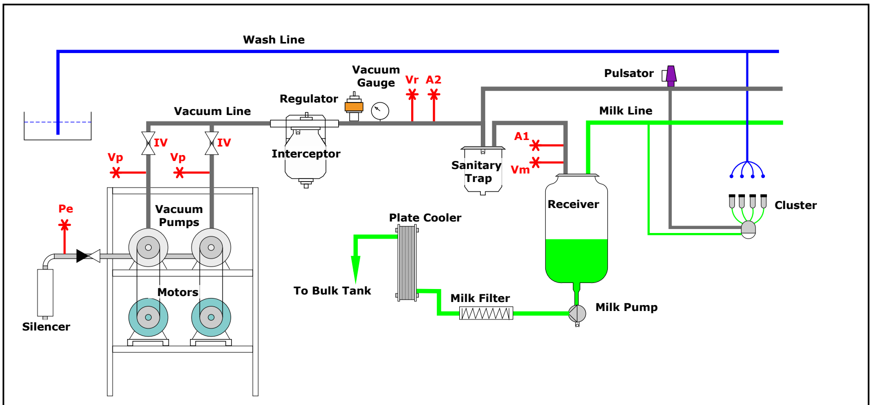

Figure 1: Location of test points in ISO standards (ISO 3918) tees + isollation valves (IV)

Vacuum Level -	**46-48.5 kPa** for modern midline plant with big pipelines
Pulsation rates -	**58-62 c/min** (varies between manufacturer)
Typical Pulsation values-	AB 64-68%, CD 32-36% A 13-17% B 45-55% C 8-13% D 20-26% (200-260ms)

Typical air usage per unit	Pulsator	30 L/min
	Claw	10 L/min (air bleed + lekage)
	ACR	10 L/min
		50 L/min per unit

Liner change interval = $\frac{2000 \times \text{number of units}}{\text{herd size} \times \text{milkings per day}}$

Changing liners

Liners should be changed every 2,000 cow milkings. If a farmer with a 12 unit machine is milking 96 cows twice a day the liners should be changed after about 125 days. Only liners suitable for the shells should be used. Old liners can cause longer milking times and are inclined to close off the teat at the base of the udder which can lead to under milking. When you are changing liners cut open a few to see what condition they are in. If they are long overdue like the liners in the photo you may find roughness and distortion where the teat contacts the liner.

Conclusion

The consistent performance of the milking machine over time is dependent on regular servicing and maintenance. A minimum of one machine test should be carried out per year to identify any issues. Changing liners at recommended time intervals is important to maintain milk-out and udder health.

Online tools to help increase energy efficiency

Philip Shine[1], Michael D. Murphy[1] and John Upton[2]

[1]Munster Technological University, Cork; [2]Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

Summary

- Teagasc has partnered with MTU and SEAI to develop the Dairy Energy Decision Support Tool to aide farmers in making decisions regarding energy efficiency and renewable energy investments
- This on-line tool can be used to obtain farm specific recommendations related to energy use, technology investments, CO_2 mitigation and renewable energy generation.

Introduction

The average cost of electricity on Irish dairy farms is €5 per 1,000 litres of milk produced. There is a large variation in that figure — from €2.50–€9.00 per 1,000 litres produced, or from €15–€50 per cow per year. The main drivers of electricity consumption on dairy farms are milk cooling (31%), the milking machine (20%) and water heating (23%). It is challenging to deliver a set of generalised recommendations to farmers to improve energy efficiency because every farm is different in some key areas. These include herd size, infrastructure specification, farmer age and eligibility for grant aid and availability of grant aid for specific technologies. Hence, it is necessary to evaluate the cost/benefit of key energy efficient and renewable technologies on a case by case basis on individual farms.

Dairy Energy Decision Support

Teagasc has partnered with Munster Technological University and the Sustainable Energy Authority of Ireland to deliver an on-line decision support tool to aid farmers making decisions regarding energy efficiency and technology investments. The tool, known as the Dairy Energy Decision Support Tool (DEDST) is available to use for free at: https://messo.cit.ie/agri-energy.

The DEDST can be used to obtain farm specific recommendations related to energy use, technology investments, CO_2 mitigation and renewable energy generation. It is an interactive and easy to use tool aimed at farmers, farm managers and farm advisors. It provides information to the user regarding key decisions that determine the energy efficiency and cost effectiveness of the milk production process, such as investment in certain technologies and changes in farm management practices. It can also be used to support government bodies in forming new policy relating to provision of grant aid for energy efficient and renewable energy technologies.

Description of the tool

The DEDST operates as a web based platform. The user enters details of a specific farm, including farm size, milking times, number of milking units, milk cooling system, water heating system and electricity tariff. Details of an alternative technology to be evaluated on that farm can then be entered. Possible alternative technologies include plate coolers, variable speed drives, heat recovery systems, solar photovoltaic systems, wind turbines and solar thermal water heating systems. The user may also enter economic details regarding potential future grant aid for specific technologies, as well as renewable energy feed-in tariffs and inflation. All energy and economic calculations are then computed, and the outputs are displayed on an easy to interpret output screen.

Example — Investment in a Solar Photovoltaic system

Solar Photovoltaic (PV) cells generate electricity using energy from the sun, which in turn can be used by the farm. These systems can be stand-alone (i.e. the generated electricity is only used by the farm) or grid connected (where surplus electricity is fed into the national electricity grid). Unfortunately, in Ireland there is no payment for export of electricity to the grid from small scale PV systems (though this may change in the future). Hence, the most logical solution for Irish farmers would be a stand-alone system, sized so that all electricity generated is consumed by the farm. For a 100 cow spring calving herd, the ideal PV system size falls at around 6 kWp of installed capacity, which would cost in the region of €7,500 (plus VAT). In the absence of a capital investment grant, this system would have a payback period of 10 years. If a 40% capital grant was utilised (PV systems up to 11 kWp are covered by TAMS), the payback period would fall to six years, while a 60% grant would make the payback period fall to four years. The inclusion of a 6 kWp PV system would result in 30% of the farm's electricity being provided by a renewable source and would offset more than 2.4 tonnes of CO_2 per year. PV systems qualify for accelerated capital allowances (i.e. the entire cost of the installation can be written off against tax in the year of purchase), which would further reduce the payback period (check the benefit of accelerated capital allowances for your farm with your accountant).

Conclusion

The methods deployed in the development of this tool utilised resources from multiple sources to package a suite of scientific outputs into a user friendly decision support tool. The DEDST can now be used by farmers and advisors to make informed decisions around energy use and technology investments on a case by case basis.

HEALTH & SAFETY

Health and safety management on dairy farms

John G. McNamara[1] and Francis Bligh[2]

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Summary

- 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
- Health of farmers is a crucial issue, requiring on-going attention
- Farm building construction have specific legal requirements.

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. Farm workplace deaths have shown a welcome decline during the first six months of 2021, with three deaths reported, while in the 12 months to end of June, nine deaths occurred (provisional HSA data). It must be emphasised that one fatality, serious injury or avoidable ill health case is one too many. Dairy farms have higher rates of both fatal and serious workplace injuries than other farm enterprises so health and safety management requires particular attention.

Legal duties of dairy farmers and employees to implement Safety, Health and Welfare at Work (SHWW)

Farm owners/managers have legal duties to manage safety, health and welfare under the Safety, Health and Welfare at Work Act 2005 and associated regulations. Employees have duties to comply with the legislation. Non-compliance with these legal duties leaves individuals liable to criminal prosecution.

An employer has the predominant duty for protecting the safety, health and welfare of their employees and all affected by work activity. 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, suitable personal protective equipment (PPE) must be provided 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 (e.g. advisor/consultant with health and safety knowledge) 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 to their employer defects in the place 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 and work on the farm.

Complete a risk assessment

A Risk Assessment and Code of Practice have been prepared for the Agricultural sector under the 2005 Act and these are available on the HSA and Teagasc websites. Teagasc and accredited consultants provide half-day training on completing the Risk Assessment document. Completion of the risk assessment document is also a requirement for both

Quality Assurance Schemes and Targeted Agricultural Modernisation Scheme 11 (TAMSII) grant payment. Note that final TAMSII applications must be submitted by 5th November, 2021.

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 provides an attractive workplace for staff. A Teagasc Farm Labour Manual is available on the web.

Farm building construction

Safety, Health and Welfare at Work (Construction) Regulations apply to farm constructions. An advisory booklet 'Build in Safety' prepared by Teagasc, HSA and FBD Insurance is available of the web.

Farmer health

Health is vital for both lifestyle and to farm effectively. In the longer term health, to a significant extent, is under one's own control. A recent study of Cardiovascular Disease (CVD) among farmers conducted at dairy co-op branches had two, or four or more, CVD Risk Factors in 97.5% and 68.8% of cases, respectively. Reduction of health risk requires having a regular health check, paying attention to diet and weight and gaining regular cardiovascular exercise of moderate/high intensity. These activities are positive also for cancer prevention in the longer term. Sun skin cancer prevention should be practiced in line with the national guidelines by keeping skin covered, using water resistant Sun Protection Factor (SPF) of 30+ and checking your skin regularly for changes. Fifty six per cent of farmers have had a musculoskeletal injury with the following body parts affected: Back (37%); Neck and Shoulder (25%); Hip, knee and Feet (26%). Reducing heavy lifting, pushing, pulling and carrying prevent of these injuries along with using correct lifting techniques.

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 www.teagasc.ie/health_safety/.

VISTAMILK

VistaMilk — precision dairying from pasture to plate

Francis Kearney[1,2] and Donagh Berry[1,2]

[1]*Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork;* [2]*VistaMilk SFI Research Centre*

Summary

- The VistaMilk SFI Research Centre continues to conduct cutting-edge research in all areas of the dairy supply chain
- VistaMilk has generated significant results across a range of areas, especially those associated with pasture imaging and growth predictions, methane emissions, dairy-beef, and the early prediction of mastitis onset. Many of the projects funded by VistaMilk are reported elsewhere in this booklet.

Introduction

The VistaMilk Science Foundation Ireland (SFI) Research Centre, co-funded by SFI, the Department of Agriculture, Food and the Marine, and over 50 industry partners, aims to digitalise dairy production and processing in Ireland all the way from the soil, through to the grass and animal, and eventually into the milk products while considering the impact at the level of the human gut. VistaMilk is hosted by Teagasc. The partners in VistaMilk include the Irish Cattle Breeding Federation (ICBF), Tyndall National Institute, the Walton Institute at Waterford Institute of Technology, Dublin City University and University College Dublin and Galway.

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.

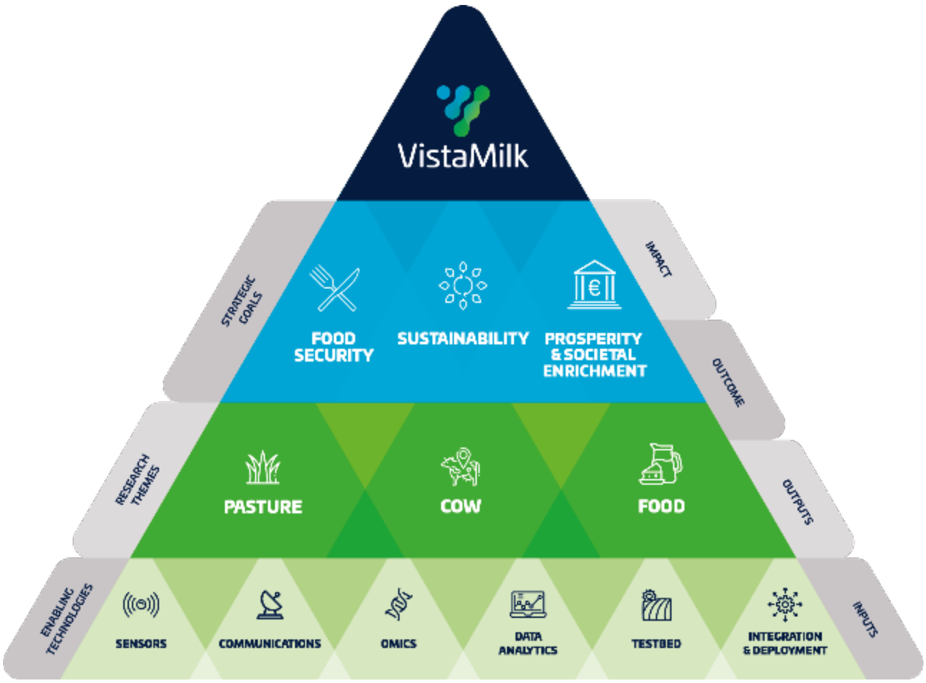

Figure 1. *VistaMilk strategic goals and research programme*

Highlights of the research programme to-date:

Pasture imaging and growth predictions: Two areas of significant research include the use of images from pasture swards to predict the quality and quantity of different species along with using state-of-the-art artificial intelligence to improve the predictions of grass growth. The ultimate aim is to be able to capture images from a phone, drone, or satellite to make the task of pasture assessment more automated and accurate. All research is undertaken in strong conjunction with PastureBase Ireland.

Genetic Indexes: An index for ranking beef bulls for use on dairy females has been developed, validated and released for use by industry. This dairy-beef index is now being used extensively by farmers and breeding companies and will address some of the welfare concerns that exist around low-value male calves from the dairy industry. Linked to this is the research on a genetic evaluation for age at slaughter. VistaMilk is also assessing the frequency and effect of different milk variants in the Irish dairy cow population (e.g., A2-beta casein milk).

Mastitis Prediction: Prevention is better than cure. Machine learning has been used to predict the onset of (sub-)clinical mastitis several days in advance using data already available on many farms.

Feed additives: VistaMilk has the only four machines in Ireland to measure methane in grazing cows. This equipment is being used not only to test alternative feed additives cited to reduce methane emissions, but also to gain an in-depth understanding of the dynamics of methane emissions across the life-time of the cow and the degree of influence of breeding and management on those dynamics.

Others: Other areas of research actively being pursed in VistaMilk include calf health and welfare, sire advice for beef-on-dairy matings, potential to breed for low emitting and nitrogen efficient cows, more efficient and accurate dairy cow genomic evaluations, pasture breeding, monitoring and predicting bulk tank milk quality and quantity, cow-calf separation, food digestion, and new dairy products with high nutritive value. Developing new sensors and the ability to communicate data wirelessly are a key feature of many of these projects. A newly announced project with Dairy Research Ireland aims to extensively quantify the carbon sequestration potential of Irish grassland as well as assess the impact of different farm management practices on the sequestration potential. This will be crucial for putting some facts and science between the commentaries on the contribution of agriculture to net carbon emissions. Another project is examining the fortification of dairy products with carotenoids which may help in the fight against degenerative diseases such as macular degeneration of the eyes and Alzheimer's disease.

Conclusion

VistaMilk has fostered close linkages among researchers from a range of different disciplines, broadening the armoury of tools available to address the problem statements of the dairy sector. A key focus for VistaMilk is to ensure growth can be achieved responsibly while also maintaining a high nutritive value of the products.

TEAGASC FOOD RESEARCH PROGRAMME

Seasonality and grass-fed milk

Jonathan Magan and Laura G. Gómez-Mascaraque
Teagasc, Food Research Centre, Moorepark, Fermoy, Co. Cork

Summary

- The majority of Irish milk is produced in a seasonal pattern, which leads to variable milk composition and quality throughout the year
- Research into grass-fed milk has identified significant distinctions between pasture-based milk and milk from conventional, indoor systems common in other parts of the world
- Research is ongoing into the use of diverse multispecies grassland swards in a seasonal production system.

Introduction

Irish milk supply is largely defined by a distinctly seasonal production pattern, whereby the majority of cows are spring-calving, with a two month dry period in mid-winter prior to the next calving. Milk derived from this process contributes to what is known as the "manufacturing milk" pool, representing approximately 85% of the total Irish milk supply. The remaining approximately 15% forms the "liquid milk" pool, which fulfils the requirement for a year-round supply of short shelf-life products. The dominance of the seasonal production system is due primarily to the economic benefit of coinciding the lactation cycle of the cow with that of the grass growth pattern throughout the year, resulting in significant peak to trough ratios between mid-lactation milk yields and those at the shoulder ends of the season. This is accompanied by substantial changes in the composition of milk throughout the progression of the season, with early and late-lactation milk considered as being of insufficient or inconsistent quality for certain processing applications, such as butter and cheese manufacture. These long shelf-life products dominate the product manufacturing portfolio in Ireland for this reason. In an Irish context, seasonal changes in milk composition arise due to two primary factors:

- *Stage of lactation:* Early lactation milk is typified by significantly increased milk solids and particularly protein content, as the immunoglobulin and overall whey fraction is elevated in colostrum secreted post partum, making it unsuitable for standard processing, due to the low thermal stability of the whey protein fraction and the high viscosity associated with high total solids content. Increases in total protein content, ratio of whey to casein, levels of saturated fatty acids, pH, osmotically active salts and ionic calcium, along with a decrease in fat globule size also render late-lactation milk unsuitable for heat processing and butter and cheese manufacture
- *Diet:* Changes in feed type as cows move from full outdoor grazing to indoor housing, feeding on conserved forages and concentrates can also have considerable effects on milk composition, most notably on the composition of the fatty acid profile, which impacts the hardness and spreadability of butter.

The differences in milk composition which arise due to the feed supplied to the cow have implications for its functional, nutritional and sensory quality. Several potential nutritional benefits, improved functional properties and distinct sensory qualities have been associated with pasture feeding in recent studies carried out in collaboration between the Teagasc Animal and Grassland Research and Innovation Centre and the Food Research Centre at Moorepark.

Previous research into pasture feeding at Moorepark

The “Profiling milk from grass” project (2015–2018) was undertaken to characterise the effect of two pasture-based feeding systems based on outdoor grazing of perennial ryegrass only or a mixture of perennial ryegrass with 20% white clover and an indoor total mixed ration-based system (TMR). This comprehensive programme investigated aspects of milk composition, raw milk and end product functionality, traceability and organoleptic quality from each feeding system, providing robust data to underpin the unique selling point of Irish grass-fed milk and dairy products. Pasture and particularly grass-based feeding has been shown to have a beneficial effect on concentrations of milk fat and protein and vitamins B1 (thiamine), B2 (riboflavin) and B7 (biotin), with further increases in cheese yield, development of firmer yoghurt gels and softer butter texture, relative to TMR-derived milk. In addition, the reduced levels of saturated fatty acids and greater levels of omega-3 fatty acids and conjugated linoleic acid have positive nutritional implications, particularly for their anti-thrombotic and anti-carcinogenic activities. In consumer sensory panels, a significantly yellower colour, creamier mouthfeel and distinct barnyard aroma have also been distinguished in grass-fed products. These studies have also explored the methods available to identify the origin of milk products based on dietary differences, with the means to verify grass-fed labelling claims by 1H-NMR, LC-MS/MS, fatty acid profiling and Raman spectroscopy clearly established.

Current research into effects of seasonality on milk composition and processabilty at Moorepark

This research is currently being expanded to investigate grazing platforms utilizing diverse multispecies swards under the FutureMilk project, funded by VistaMilk, which commenced in October 2020. The vision of FutureMilk is to address some of the challenges of the unique seasonal production system in Ireland. In particular, the impact of two different cow breeds (Holstein-Friesian vs. Jersey Holstein-Friesian crossbreed) and two different diets (conventional perennial ryegrass monoculture vs. diverse multispecies sward containing other grasses, legumes and herbs) on the composition, functionality and overall quality of milk and dairy products is being studied throughout the lactation period with weekly sampling. The data obtained will be linked to the three cow level factors studied (diet, breed and stage of lactation), and will be the basis for a predictive approach to identify the causes of industry relevant processability and product functionality issues. This project includes regular fatty acid and protein profiling and measurement of changes in the functional quality of milk samples (e.g. heat stability, ethanol stability, rennet coagulation) throughout the season. An upcoming research project commencing in October 2021 will examine the rumen microbiome and metabolome of cows grazing perennial ryegrass or multispecies swards, providing insight into the overall health status of the cow and a link to ongoing research on methane emissions. This project will also analyse butter and two cheese varieties produced from both diets, providing valuable information on key dairy commodities. Finally, the unique protein profiles of milk from individual cows selected by genetic merit will also be analysed across the season in an upcoming FutureMilk project.

Conclusion

As “pasture-raised” and “grass-fed” labelling claims become more widespread among dairy products, recent and ongoing pasture-based research at Teagasc has provided the scientific basis to set these products apart from the majority produced worldwide under conventional feeding. This is particularly significant following the establishment of the Bord Bia Grass-Fed Standard, which requires at least 90% of the cow’s diet to be provided as grass or grass forage on a fresh weight basis, a level of grazing which Irish farmers are uniquely positioned to achieve, with notable benefits for end-product quality.

Novel drying technologies for adding value to Irish dairy streams

Eoin Murphy
Teagasc, Food Research Centre, Moorepark, Fermoy, Co. Cork

Summary

Teagasc are currently instigating novel technologies which:

- Efficiently dry low value streams for which the energy requirements associated with spray drying are too high
- Improve the nutritional quality of existing products
- Allow for the development of novel product classes.

Introduction

Drying, and in particular spray drying, is a key enabler for the Irish dairy industry increaseing the reach of dairy streams through effective stabilisation and reduction of transport costs. As the last stage in the majority of dairy powder manufacturing processes, spray drying has an important influence on energy consumption and the quality of resultant products. While spray drying will likely remain the technological mainstay of the industry, Teagasc is currently investigating the potential of alternative drying technology for certain applications.

Driver 1: Energy Consumption — Milk, whey and other dairy products contain large quantities of water, which must be removed in order to make a stable powdered product (Figure 1). This is generally achieved in two steps. A pre-drying evaporation step removes the bulk of the water. This evaporative step, while very energy efficient, is limited to a certain concentration due to viscosity development, requiring the use of spray drying to remove the remaining water. The quantity of water removed during spray drying is much lower than in the evaporation step but due to the higher energy requirements total energy required is higher compared to evaporation (for the example in Figure 1). Reduction of drying energy is a key concern for the industry, particularly when drying low value products such as whey permeate, where the cost of the drying process may be higher than the sale value of the product.

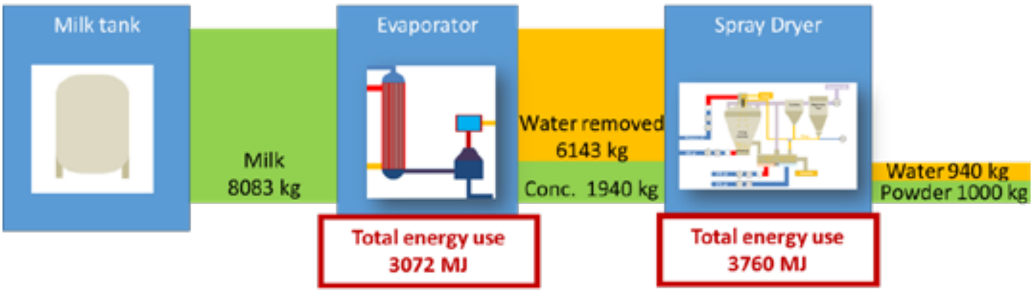

Figure 1. *Simplified process flow of milk powder production in relation to product flow (—) and water flow (—). Height of product and water flow bars are proportional to quantity. Figures are based on the assumption that milk with 12% total solids is evaporated to 50% total solids followed by spray drying to 97% total solids.*

Driver 2: Product quality — new and better products: While spray drying is a satisfactory technology for manufacture of many dairy powders, certain aspects can affect its successful application for drying of high value dairy products. Teagasc, through many interactions with industry partners, is in a position to see the challenges associated with encapsulation of fat within dairy powders. Many high value nutritional products are beset with issues surrounding free fat, fat flecking and oxidation of valuable lipid components. Such issues reduce the consumer perception and, hence value, of premium products, while also limiting further advances and development of novel products. Similarly, high outlet temperatures (80°C) of spray dryers can have detrimental effects on heat sensitive components, which may lose their nutritional functionality due to exposure to high temperature.

Novel technologies under investigation at Teagasc Moorepark

With the above drivers in mind, Teagasc is currently investigating three novel drying technologies:

- *Towerless Drying of low value dairy streams e.g. permeate:* While evaporation may be more energy efficient than spray drying, viscosity increases during concentration limit the extent of the evaporation step. Increasing beyond a critical concentration results in inefficient evaporation and drying. In extreme cases, blocking of either piece of equipment can occur. Therefore, Teagasc and Moorepark Technology Ltd. are investigating a novel technology, which will provide the capability to dry viscous, sticky by-product/waste streams in a compact system with significantly lower energy costs compared to spray drying. The technology will be assessed over the next two years in a project co-funded by Enterprise Ireland and multiple industry partners
- *Electrostatic spray drying for premium products:* This technology involves the application of an electrostatic charge to dairy products as they are sprayed into a drying chamber. Primarily, this allows for drying at lower temperatures, resulting in better preservation of heat sensitive materials. Additionally differences in uptake of charge by polar and non-polar components can have interesting effects. Polar components, such as lactose and water, readily uptake the charge and tend to migrate to the outside of the powder particle. In contrast, non-polar elements, such as fats, remain unaffected and tend to stay in the centre of the particle resulting in better encapsulation and less oxidation
- *Vacuum assisted microwave drying for premium solid-state products:* This solid-state dryer also allows for the low temperate drying of a wide range of food materials, from fruits and vegetables, to cheese and other structured dairy products. Teagasc is currently assessing the technology for its food reformulation potential, in particular in the area of high protein snacks or formulated cheeses which can be dehydrated for sale in far-away markets.

Conclusion

While spray drying remains, and will remain, the main technology for drying in the Irish dairy industry, there exists a number of other technologies that can add value. In particular, novel technologies have potential for drying products at either extreme of the value chain, i.e. through reduction of drying costs for low value materials or improvement of product quality and consumer perception for high value materials.

Cheese diversification for fast-growing emerging export markets

Prabin Lamichhane and Diarmuid Sheehan
Teagasc, Food Research Centre, Moorepark, Fermoy, Co. Cork

Summary

- Irish cheese industry is substantially investing to diversify from a heavy dependence on the production of Cheddar cheese into other cheese varieties
- Food research programme at Teagasc is supporting the Irish cheese industry in diversifying into other non-Cheddar cheese types in new markets
- Milk pre-treatment and modifications to cheese manufacture and ripening processes have been shown to improve the quality and consistency of continental-type cheeses
- New research focused on casein-polymer interactions is targeting new markets for cheese such as China and other Asian markets.

Introduction

The current global cheese market is valued at ~$140 billion, and global cheese consumption is expected to increase by ~13.8% between 2019 and 2029. The abolition of milk quotas in 2015 has significantly increased Irish milk production, and cheese has been targeted as a key end-product for this increased milk pool. In response to the increased milk production, increased market growth and consumer demand for other non-Cheddar cheese types in emerging markets, the Irish cheese industry is investing substantially to diversify from a heavy dependence on the production of Cheddar cheese into other cheese varieties, such as continental-type cheeses (e.g. Emmental, Maasdam, Jarlsberg, Gouda) and ingredient cheeses (e.g. mozzarella, grilled cheeses).

However, technological challenges exist to converting a highly seasonal Irish milk supply of varying composition into Continental-type and ingredient cheeses of consistent physico-chemical composition, with consistent mechanical and structural properties, ripening patterns and ultimately sensory quality from a textural, aesthetic and flavour perspective. The cheese research group at Teagasc Moorepark has been playing an important role in supporting the Irish cheese industry in diversifying into other non-Cheddar cheese types in new markets. The following sections provide an overview of some current and recently completed cheese studies at Teagasc Food Research Centre (TFRC), Moorepark.

Update on continental-type cheese study

It is noteworthy that consistency in quality for Continental-type cheeses can be much more demanding to achieve than for Cheddar, not least in the development of undesired split and crack defects. Such defects result in poor aesthetic quality (a key retail requirement) and poor performance under high-speed slicing for global foodservice markets, with consequent economic loss.

Research undertaken at the TFRC Moorepark has investigated the effects of milk pre-treatment and ripening conditions on the quality of Maasdam cheese (an example of continental-type cheese) produced from Irish milk. Some important findings from this research include:

- Bactofugation of milk before cheese-making was found to be a suitable method for controlling undesirable butyric acid fermentation without significantly altering the texture and other ripening characteristics of Maasdam cheese. However, the reincorporation of the high heat-treated bactofugate into cheese-milk, as practised commercially to retain cheese yield, resulted in increased moisture in non-fat substance levels and decreased hardness levels in Maasdam cheeses. This has the potential to influence the structural properties of the cheese matrix and thus its ability to retain eye-quality, so care is required when incorporating high heat-treated bactofugate into the cheese matrix

- Those cheeses with low levels of intact β-casein and/or insoluble calcium content were more likely to be shorter in texture, suggesting that these parameters are potentially significant causes of the development of splits and cracks in eye-type cheeses
- Further research utilised a novel dynamic in situ imaging technique for the first time to better understand the mechanism of splits and cracks formation within the cheese matrices. This study proposed that the presence of micro-cracks within the cheese matrix could be one possible factor for the development of split and crack defects within the semi-hard cheese matrices
- Among other factors, the behaviour of CO_2 gas within the cheese matrix, including solubility, is considered a critical factor in the development of eyes and splits or cracks within the cheese matrices. Research conducted at TFRC Moorepark in collaboration with the University of Copenhagen has found that the solubility or absorption capacity of protein matrices was significantly influenced by varying levels of moisture-to-protein ratio, salt-in-moisture content, pH, temperature and partial pressure.

Overall, the knowledge gained through these studies will help to develop strategies for minimising split and crack defects within Continental-type cheese matrices made from a seasonal Irish milk supply.

Overview of some current cheese research at Teagasc Moorepark

- The production of ingredient cheese, such as mozzarella, has grown worldwide because of the increasing popularity of pizza. Due to the high demand for ingredient cheese, such as mozzarella and grilled cheese, the Irish dairy industry has been investing in the production capacity of these cheese types. Research is currently being undertaken to enhance the functionality of heated and unheated ingredient cheese produced from Irish milk
- Although some specific groups of consumers may be aware of the nutritional quality of dairy, they avoid some dairy products, including cheese, for many reasons, sensory characteristics being one of them. Research is currently being undertaken to profile Chinese consumer preference for cheese sensory traits, and to exploit colloidal and casein-polymer sciences to incorporate non-dairy ingredients familiar to Asian consumers into cheese formulations/fermentations to achieve desired sensory properties (flavour and mouth-feel)
- Cheeses are generally nutrient-dense foods and are a valuable source of high-quality proteins, lipids, vitamins and minerals. Several research studies and meta-analyses have reported that cheese consumption has a potentially beneficial, or at least neutral, effect on cardiovascular risk factors despite its high level of saturated fat. Although exact causes are unknown, it is believed that the cheese matrix in which these nutrients are contained play an important role in such health outcomes. Research is currently being undertaken at Moorepark to get a deeper insight into the physico-chemical interactions between components of the cheese matrix, specifically calcium, phosphorous, phospholipids, and cholesterol, in model cheese systems and in model digestion systems.

Conclusions

Cheese is gaining popularity in countries where it was not traditionally part of the national diet, likely due to the Westernisation of the diet. The cheese research group at the TFRC Moorepark is conducting research to improve the quality and functionality of cheese for fast-growing emerging export markets, which support further expansion of the Irish dairy industry.

Evaluating methods to improve DNA sequencing of the milk microbiome

Min Yap, Conor Feehily and Paul Cotter
Teagasc, Food Research Centre, Moorepark, Fermoy, Co. Cork

Summary

- Microbiome analysis of milk is hampered by low microbial abundance and high levels of host DNA in the sample, resulting in inefficient and uneconomical DNA sequencing
- In a comparison of three commercially available kits, we determined that the MolYsis complete5 kit significantly improved microbial sequencing depth, allowing for improved classification of the milk microbiome through the generation of metagenome-assembled genomes (MAGs)
- Improved sequencing of the milk microbiome can benefit the agriculture and processing sectors in monitoring the safety and quality of milk.

Introduction

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

Study

Both bovine and human milk samples were used for the study. Bovine milk samples were collected from farms across Ireland and human milk was collected from mothers in the MicrobeMom study, following ethical approval and with informed consent. Milk samples underwent several washing steps to remove the sample fat before DNA extraction and host depletion/microbial enrichment with three methods. The three methods evaluated are the DNeasy PowerSoil Pro kit (Qiagen), MolYsis complete5 kit (Molzym GmBh & Co.) and NEBNext Microbiome DNA Enrichment kit (New England Biolabs). A 10-strain mock community (consisting of 10 known microorganisms) was spiked into a milk sample as a positive control. Shotgun sequencing libraries were prepared from the subsequent DNA samples before sequencing on the Illumina NextSeq500 platform at the Teagasc Sequencing Facility. Bioinformatic analysis on the shotgun metagenomic reads assigned both taxonomy (names of microorganisms) and genetic functional potential (what these microorganisms can do) of the milk microbiome.

Results

We found that the MolYsis complete5 kit (ML kit) was efficient in depleting host DNA enabling for greater sequencing depth of microbial DNA, compared to the other two kits evaluated (Figure 1). This method improved microbial reads by 20%.

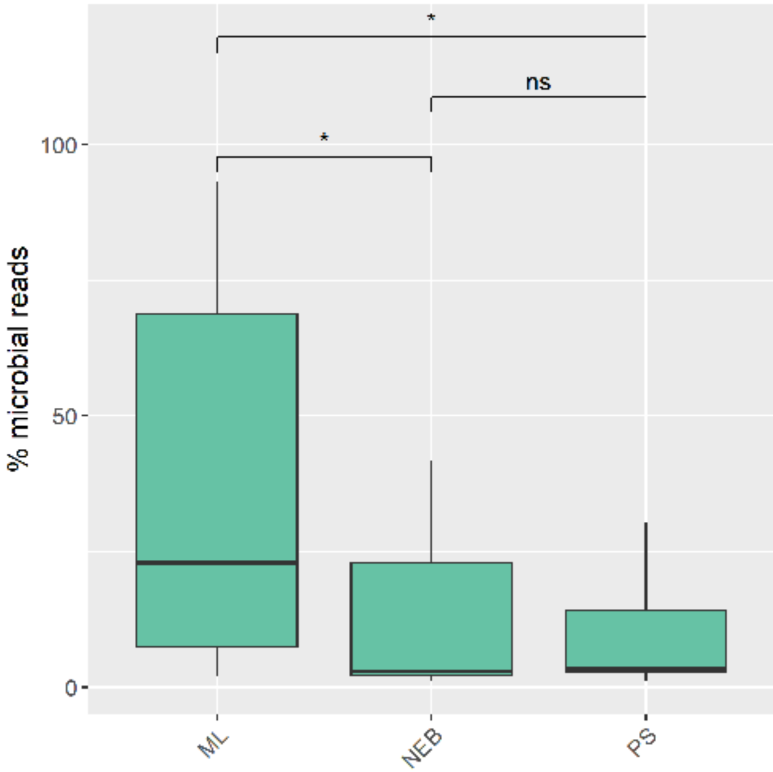

Figure 1. *Comparison of mean microbial sequencing reads for all samples between the evaluated methods*

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

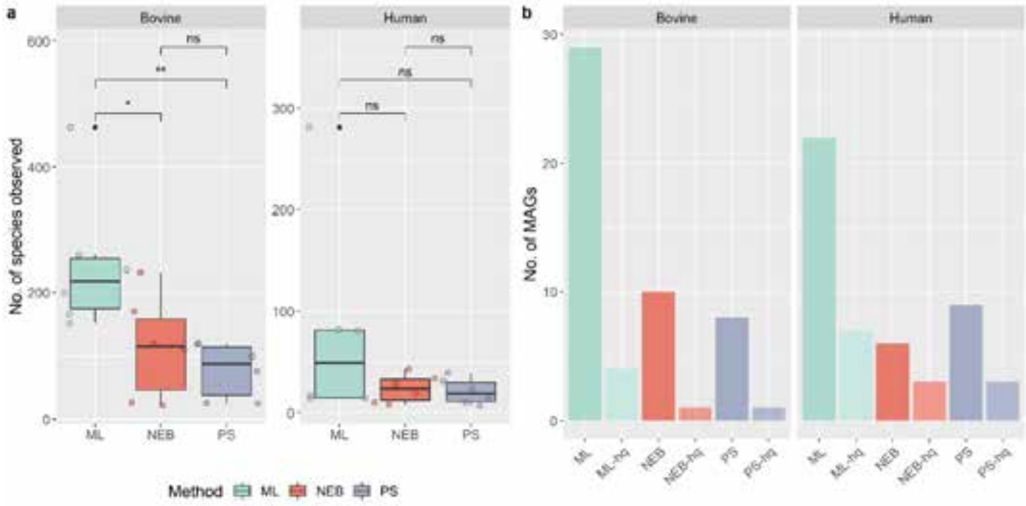

Figure 2. *Better characterization of the bovine and human milk microbiome was found for both observable species (a) and number of MAGs and high-quality MAGs (b) when the ML kit was used compared to the other two methods*

Conclusion

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

Acknowledgement

This work was funded by the Irish Dairy Levy and Science Foundation Ireland (SFI) under grant numbers SFI/12/RC/2273 and 16/SP/3827 with co-funding by PrecisionBiotics Ltd.

Teagasc
Agriculture and Food Development Authority

PastureBase IRELAND

Grassland Decision Support Tool

Tools include

- **Grass Wedge & Projected Wedge**
- **Spring & Autumn Rotation Planners**
- **Grass & Fodder Budgets**
- **Fertiliser & Slurry Recording**
- **PBI Grass – Offline App**

Additional features

- **Farm Mapping Tool**
- **Nitrogen Use Efficiency/ Nitrogen Surplus Calculator**
- **Nitrogen Planner**
- **Forecast & Actual Weather Data**
- **Many New Reports**

Grassland Decision Support Tool

PastureBase Ireland (PBI) is the first choice on-line grassland management platform for t
in recent years and PBI continues to expand its functionality to meet the needs of fa
measuring intensity continues to increase.

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 target.

thousands of farmers nationwide. A range of new tools and reports have been developed rmers. Each year the number of farmers using the application is increasing while the

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 environmental benefit. Farmers will be able to benchmark their NUE and farm gate nitrogen surplus values with top performing farms as well as their peer farmers.

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.

New Reports

An array of new report are now available to all users. These include; grass, milk, farm covers, soil fertility, paddock events and farm summary reports. These reports give an excellent insight to the grassland management on the farm and can be a useful resource when hosting a farm walk or discussion group. Farmers can compare different years which will aid their decision making to avoid any issues that they experienced in a particular year.

PADDOCK	SOIL TEST DATE	PH	P IND	K IND	TOTAL N (KG/HA)	TOTAL P (KG/HA)	TOTAL K (KG/HA)	TOTAL S (KG/HA)	NO OF GRAZING	NO OF SILAGE CUTS	GRAZING(KG DM/HA)	SILAGE(KG DM/HA)	TOTAL KG DM/HA
4/5 - 4	02/12/2020	7.10	3	2	227.55	4.78	71.35	34.08	7	1	10015	2244	12259
6/7 - 6	02/12/2020	6.40	3	4	188.41	22.20	141.15	32.76	7	0	11881	0	11881
8/9 - 8	02/12/2020	6.70	3	3	270.57	20.93	162.32	43.46	7	2	8109	4885	12994
9/10 - 10	02/12/2020	6.30	4	4	245.97	20.93	162.32	38.60	7	2	8394	4859	13253
11 - 11	02/12/2020	6.30	4	4	275.08	54.45	356.35	28.73	7	1	8742	2415	11157
12/13/14 - 12	02/12/2020	6.71	4	4	137.76	0.00	32.06	20.63	8	0	10796	0	10796
15 - 15	02/12/2020	6.20	4	3	136.53	0.00	14.84	23.74	8	0	10336	0	10336
16 - 16	02/12/2020	6.20	4	3	136.53	0.00	14.84	23.74	8	0	10595	0	10595
17/19 - 17	02/12/2020	6.60	4	3	183.27	7.38	29.60	28.59	8	0	10375	0	10375
18/20 - 18	02/12/2020	6.50	4	3	183.27	7.38	29.60	28.59	8	0	11232	0	11232
21/22/23 - 21	02/12/2020	6.45	4	3	120.94	56.79	209.10	14.81	4	0	8161	0	8161
24 - 24	02/12/2020	5.90	3	2	233.70	2.28	98.41	33.00	6	1	7649	2500	10149
25/26 - 25	02/12/2020	7.00	4	2	128.72	24.82	187.08	17.52	6	1	8635	2143	10778
27/28 - 27	02/12/2020	6.50	4	2	178.35	9.89	81.56	25.18	8	0	10589	0	10589

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

1. Minimise costs to cope with volatile world markets for dairy, beef and sheep products.
2. Maximise the proportion of grazed grass in the diet.
3. Increase nitrogen use efficiency.
4. Adopt greater precision in term of nutrient management.
5. Graze more grass in the spring an autumn, shorten the winter period.
6. Achieve target average farm covers at key times during the year.
7. 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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