Animal & Grassland
Research and Innovation
Programme

Dairy Calf-to-Beef Conference

Conference Proceedings

Clayton Whites Hotel, Wexford
16th – 17th October, 2024

Agriculture and Food Development Authority

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Overall Editor: Ellen Fitzpatrick

Sponsored by ABP

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Conference Programme

Teagasc/BSAS Dairy Calf-to-Beef International Conference

Clayton Whites Hotel, Abbey Street, Townparks, Wexford, Y35 C5PF

16th & 17th October 2024

Day 1 – Wednesday 16th October		
09.00	Registration and coffee	
09.45	Introduction/opening	Prof. Frank O'Mara
Session 1 (10.00-12.00) Dairy calf to beef production systems. Chair: Laura Awdry		
10.00	Evolution of Irish dairy-beef production in wake of market and policy change	Dr. Nicky Byrne (Teagasc, Ireland)
10.30	New Zealand pasture-based dairy beef production	Bob Thomson (AGFIRST, New Zealand)
11.00	Discussion	
11.30	Poster viewing	
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13.00	**Field trip "***Johnstown Castle and ABP Demo farm"*	
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Day 2 – Thursday 17th October

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09:10	Parasite control in young cattle	Dr. Dave Leathwick (AgResearch, New Zealand)
09:50	Trends in calfhood diseases	Ciara Hayes (Cork Regional Veterinary Laboratory, Ireland)
10:05	Calf welfare legislation	Stephanie Ronan (Department of Agriculture, Food and the Marine, Ireland)
10:20	Summer scour syndrome	Dr. John Donlon (Teagasc, Ireland)
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Session 3 (11:00–12:30) Panel Discussion on vertical integration. Chair: Phelim O'Neill		
11:00	Panel Discussion on Vertical integration of the dairy beef supply chain	
	Panel Members	Bob Thomson (AGFIRST, New Zealand) Gavin Hodgson (Sainsbury's) Kevin Cahill (ABP CEO) Laura Awdry (Nuffield Scholar) Pat Collins (Beef farmer Castlematyr) Shane Fitzgerald (Dairy farmer, Portlaw)
12:30	Lunch and poster viewing	

Session 4 (13.30-15:00) Calf Nutrition. Chair: Dr. Alan Kelly		
13:30	Calf nutrition: current feeding challenges from birth to yearling	Dr. Maria Devant (IRTA, Catalonia)
14:00	Impact of early life nutrition on lifetime growth and carcass characteristics of dairy bred beef cattle	Prof. David Kenny (Teagasc, Ireland)
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Session 5 (15:15 – 17:00) Breeding and reproduction. Chair: Michael Doran		
15:15	Harnessing reproductive technologies to accelerate integration of the dairy and beef sectors	Prof. Stephen Butler (Teagasc, Ireland)
15:40	The Dairy Beef Gene Ireland programme as a driver of the Dairy Beef Index and Commercial Beef Value in the Irish Dairy Beef industry	Niall Kilrane (ICBF, Ireland)
16:05	Experiences and future expectations on breeding schemes targeted beef on dairy	Dr. Jørn Rind Thomasen (Viking Genetics)
16:30	Potential to increase the rate of gain for Irish beef sires on the dairy beef index	David Kenny Peter Amer Fiona Hely John Crowley
16:50	Discussion	
17:00	Close of Conference	Prof. Pat Dillon, Teagasc

Foreword

Professor Pat Dillon
Director of Teagasc Research

Teagasc with its partners ABP, and BSAS are delighted to welcome all stakeholders to this timely international dairy-beef conference. The event aims to discuss advancements across the entire supply chain, from breeding and nutrition to health, processing, and marketing of beef calves originating from dairy herds.

Globally, food security continues to be a challenge due to continued increase in world population. It is acknowledged that meat is a rich source of nutrients and that eating meat and meat products also has health benefits when consumed as part of a balanced diet. Meat is an excellent source of vitamins, minerals, and essential micronutrients the human body can absorb easily.

The rise in dairy cow numbers in Ireland, coupled with increased availability of non-replacement calves for beef production, underscores the importance of improving beef production efficiency. This is particularly pertinent as around 60% of cattle used for beef in Europe come from the dairy herd. The use of sexed semen, advancements in reproductive technologies, and better beef sire selection offer opportunities for enhanced dairy-beef production efficiency.

Globally, there has recently been a major increase in research and innovation in an effort to make dairy-beef systems more environmental sustainable and economically more profitable at farm level. The conference provides a platform for the presentation of both current and historical research, alongside discussions of technological innovations aimed at promoting sustainability in the dairy-beef sector.

In addition to addressing economic and environmental challenges, the conference will cover topics such as the importance of high beef merit genetics, early-life nutrition, and the health of dairy-beef calves in both intensive and pasture-based systems. It will also explore the potential benefits and obstacles of vertical integration in the industry.

Professor Dillon expresses gratitude to the speakers and the organizing team, emphasizing the importance of this conference in supporting the future viability of both the dairy and beef sectors.

Dairy Calf-to-Beef production systems

Evolution of Irish dairy-beef production

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Abstract

Dairy-beef production contributes significantly to total beef output in Ireland (~60% of prime cattle finished) and is built around the efficient use of pasture, with 80-90% of animals lifetime feed requirement coming from grazed and conserved forages. The contribution of dairy-beef has grown dramatically in recent years due to increasing dairy cow numbers following the removal of milk quotas in 2015; however, this contribution is similar to that which prevailed prior to Ireland's entry to the European Economic Community (EEC). Despite the similarity in dairy-beef contribution to total cattle output, the breed and beef merit of today's dairy cow herd has reduced. Greater availability and use of reproductive and genetic selection tools provide opportunities for farmers to increase the quality of the dairy-beef calf crop by using higher merit beef sires. Research farm systems demonstrate that high-beef merit, early-maturing steers can achieve a net margin exceeding €1,300 per hectare, with a carbon footprint under 13.0 kg carbon dioxide equivalent (CO_{2e}) per kilogram of carcass produced. These steers are also finished approximately six months earlier than the national average for dairy-beef steers, which is typically 27 months of age. However, there is some disparity between commercial and research farm system levels of profitability, with a high level of farmers exiting dairy-beef production due to low financial returns. Breeding higher-beef merit animals, which can produce an 'in-spec' carcass at younger finishing ages and from a pasture-based diet will be an important strategy to increase farm profit and reduce agricultural emissions.

Key words; beef, carcass, dairy, farm system, pasture-based

Introduction

Ruminant production systems in Ireland are predominantly pasture-based, relying on the efficient growth and utilisation of grazed and conserved forage, with minimal reliance on concentrate inputs. The seasonal nature of these systems aligns calving and lambing with the onset of grass growth in spring, optimising pasture availability and reducing production costs (O'Donovan *et al.,* 2011; O'Donovan *et al.,* 2021). This pasture-based approach provides a comparative advantage for Irish milk and meat products, particularly in contrast to more intensive, concentrate-driven production systems.

The structure of ruminant livestock numbers in Ireland has evolved over time, influenced by policy changes and shifting market returns. Surplus calves from the dairy herd have been an important component of the cattle sector in Ireland for a long number of years. O'Connor (1959) described 'dry cattle rearing' systems whereby calves are purchased from dairy farmers, traded a number of times in their lifetime before being sold, typically for live export, as store cattle at 26 months of age in June, or as a finished animal at 30 months of age in October. The profitability of both systems were similar at approximately £13/acre. Government policy in the 1960s, most importantly the 'Calved Heifer Subsidy' and 'Beef Incentive' schemes, saw a substantial increase in the number of cattle in Ireland. Coupled with an increasing returns from milk production, most of the additional cows were for milk production (Baker *et al.,* 1973) although suckler beef cow numbers also increased. Between 1953 and 1973 the number of cows in Ireland increased from 1.2 million to 1.9 million with just over 60% of these being dairy cows (Baker *et al.,* 1973). There was a trend towards greater specialization. In 1960, 77% of cows were Shorthorn, which was considered a dual-purpose animal, with this breed being replaced by Friesian which increased from 6% of cows in 1960 to 50% in 1971 (Baker *et al.,* 1973). The main specialist beef breeds were Hereford and Aberdeen Angus which together accounted for 17% of cows in 1960 reducing to 14% of cows in 1971 (Baker *et al.,* 1973). Accession to the European Economic Community (EEC) in 1973 and resulting agricultural policy measures had a profound impact on the relative numbers of dairy and suckler beef cows.

In the early 1980s, prior to the introduction of the coupled payments under the Common Agricultural Policy (CAP) and the European milk quota system in 1984, dairy cow numbers stood at approximately 1.5 million, while suckler cow numbers were around 460,000. During this period, dairy-beef production dominated, with 75-80% of beef animals originating from the dairy herd (O'Ferrall and Ryan, 1990). The introduction of milk quotas eliminated further growth in dairy cow numbers as increasing yield per cow meant fewer cows were required to meet the quota available. In contrast, policy supports led to an increase in suckler beef cow numbers which peaked at 1.25 million in 1998. By 2000, dairy cow numbers had declined to approximately 1.2 million, while the suckler herd consisted of 1.1 million breeding beef cows (AIMS, 2001). Despite this expansion in the overall breeding herd since the early 1980s, the national cattle population had reduced by 800,000 head in 2000, driven by reduced slaughter ages. Since the abolition of milk quotas in 2015, dairy cow numbers have increased by approximately 40%, returning to 1.5 million, while the suckler beef cow herd has contracted to around 800,000 currently (AIMS, 2024).

Table 1. Number of ruminants ('000 head)

	1980	2000	2020	2023
Dairy cows	1,583	1,238	1,456	1,511
Suckler cows	460	1,121	923	819
Cattle other	4,587	3,749	4,092	4,149
Total sheep	3,292	5,130	3,863	3,995

This shift in livestock demographics reflects broader changes in Irish agricultural systems, driven by evolving policies, market dynamics, and a continued emphasis on efficient, pasture-based ruminant production.

Breeding policy in the dairy herd moved from Shorthorns to Friesians through the 1970s such that calves destined for beef production in 1980 were Freisian bulls (43%), Hereford crossbred bulls (14%), Continental crossbred bulls (8%), Angus, Shorthorn and other crossbred bulls (5%) and heifers of various crossbreeding (30%). Much as the present day, Friesian bull calves were born in early spring and beef crossbreds were born in later spring. Friesian genetics dominated due to their dual-purpose traits, offering moderate milk production and beef potential (Cunningham, 1983). However, their lower milk yield led to the rise of Holstein-Friesians in the late 1980s and 1990s, favoured for their higher milk output. The introgression of Holstein genetics led to a decline in beef merit with a study noting longer time to finish (estimated at 33 days) and poorer conformation (difference of 3.2 p/kg (22.3 c/kg) noted) for Holstein calves when reared to beef (Roche, 1981). Crossbreeding beef sires on the dairy herd was estimated to increase the value of the animal produced by up to 25% due to superior growth and carcass traits (Roche, 1981). Accordingly, the use of Continental sires increased considerably through the 1980s and early 1990s with 48% of the calf-crop being Continental crossbreds in 1993 (Drennan *et al.,* 1995).

By the early 2000s, Holstein-Friesians became the predominant dairy cow breed, though issues with fertility, longevity and maintenance highlighted the need for breeding objectives more aligned to pasture-based production systems (Prendiville *et al.,* 2010). Crossbreeding gained popularity, particularly with the Jersey breed, to enhance fertility, fat and protein composition, health and maintenance during a period of increasing herd size (Buckley *et al.,* 2014). Today, ~95% of Irish dairy cows are Holstein-Friesian/Friesian sired, while ~4% are Jersey sired (AIMS, 2024). The Economic Breeding Index (EBI) has supported genetic gain in the dairy herd with a focus on dairy (fertility, maintenance, and milk solid production) (Berry *et al.,* 2005) and carbon traits to increase the profit potential of cows within a pasture-based dairy system. However, due to the low relative economic returns from beef production and the negative relationship between dairy and beef production traits (McGee *et al.,* 2005) the relative emphasis on beef traits in the overall dairy breeding objective is low. Since the introduction of the EBI in 2000, there has been a steady decline in the genetic merit for both carcass weight and conformation of dairy x dairy animals (Mulhall *et al.,* 2024).

In recent years there has been a reduced level of dairy herd expansion and an increase in the uptake of sexed semen technology, leading to increased usage of beef sires on dairy cows. In 2023, 48% of calf registrations from the dairy herd were to a beef sire, and this is expected to be higher in 2024; with more than half of calves born in the dairy herd being sired by a beef breed. Indeed, dairy farmers are using more beef sires earlier in the breeding season. The increased proportion of dairy-beef calves has displaced dairy male calves (Figure 1) (Kelleher *et al.,* 2024).

Figure 1. *Proportion of dairy × dairy male, dairy female and beef × dairy calves for spring-calving cows (up to 20 April) in 2020 and 2024*

Early-maturing beef breeds (Angus and Hereford) are responsible for the highest number of calf registrations, followed by Holstein-Friesian and late-maturing beef breeds (Belgian Blue, Limousin etc.), respectively (Figure 2).

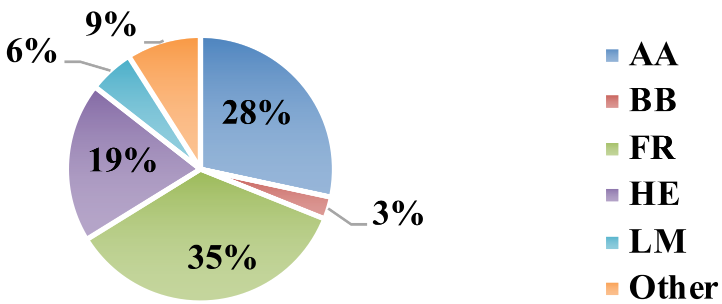


Figure 2. *Sire breed profile of calves registered from the dairy herd available for beef production*

Source: *Animal Identification and Movements (2023)*

Contrasting animal breed types and genders allow for a range of dairy-beef production systems to be implemented on farms to produce beef throughout the year, utilising predominantly forage-based diets. Nationally, there is a policy and market ambition to reduce finishing age so as to improve farm-level profitability and lessen the environmental footprint of beef, while maintaining carcass specification and grass-based credentials. Research has found dairy-beef steers to have a high probability of meeting overall market specification (i.e. weight, conformation, fat and age); however, dairy-beef heifers have the lowest probability of all prime cattle categories to meet market specification primarily due to light carcass weights and excessively fat carcasses (Kenny *et al.,* 2020).

Since 2010, the finishing age of beef × dairy steers has reduced by over three months to ~27 months, yet overall carcass specification (weight, conformation and fat) has been maintained. Given the increased use of genetic selection tools and breeding technologies, there should be an increasing proportion of beef × dairy cattle capable of achieving carcass specification at younger finishing ages, thus facilitating current policy ambitions to reduce finishing age by up to three months across all beef cattle. Breeding technologies such as sexed semen will result in 'low-value' dairy × dairy male calves being replaced with higher carcass merit beef × dairy calves of increased profit potential.

Market specification

In Ireland, carcasses are appraised under the EU beef carcass classification system (EUROP). This classification system uses the letters E (excellent), U, R, O, P (poor) to describe the conformation of the carcass, mainly the round, back and shoulder (Fisher, 2007). Fat classes, describe the fat cover on the outside of the carcass and in the thoracic cavity and are graded from 5 (very high), 4, 3, 2, 1 (low). Each of the five conformation and fat classes can be further subdivided into plus (+), equal (=) and minus (–) thereby providing a total of 15 grades for each (Pabiou *et al.,* 2009). In 2004, Ireland became the first member state to introduce video image analysis to classify beef carcasses, providing a more consistent and objective measure of carcass quality compared to human assessors previously used (Allen, 2007). These grades determine the market value of the carcass, as better-conformed and adequately fattened animals receive higher price per kilogram. The classification system directly influences farmer decisions regarding breeding, feeding, and finishing strategies to meet overall market specifications.

The ability of cattle to meet overall carcass market specification is included in all dairy and beef breeding indexes (Berry *et al.,* 2005; Berry *et al.,* 2019), as well as the Commercial Beef Value (CBV), because of its impact on carcass value and profitability. Within these national breeding objectives, animals are deemed to be within the market specifications ("in-spec"), once they achieve a conformation grade ≥ O=, carcass weight between 280 and 380 kg, a fat score between 2+ and 4=, and an age at slaughter ≤ 30 months (Kenny *et al.,* 2020). The ability of an animal to meet market specification determines the market returns, thus beef price received by farmers.

Conformation has the most impact on beef price received, as it is used as a proxy indicator of primal cut yield. Each conformation score above base generally represents an additional €0.06/kg carcass, while the initial conformation score below base represents a €0.12/kg reduction and €0.06/kg carcass thereafter. Importantly the national average carcass conformation for beef x dairy and dairy x dairy cattle is O=/O+ and O-/P+, respectively. Cattle of conformation scores ≤ O- either do not receive or are severely penalised on Quality Assurance (quality scheme administered by Bord Bia; 'in-spec' animals sold from QA certified farms attract a bonus of up to 20 c/kg carcass) and breed bonus payments (bonus paid to 'in-spec' early maturing cattle sold from farms participating in specific schemes).

The '30-month rule' was introduced in the late 1990s as a measure to reduce the risk of Bovine Spongiform Encephalopathy (BSE) entering the food chain and regain consumer confidence in beef products, since BSE was more likely to be found in older cattle (Matthews, 2003), however, this rule has remained part of market specification despite much lessened risk of BSE. This market signal has promoted reductions in slaughter age of the national herd due to its impact on beef price received.

Evolution of Irish dairy-beef systems

There is little information on dairy-beef production systems prior to the development of the integrated calf-to-beef systems at Teagasc Grange in the 1970s. Prior to that research focussed on component studies such as early calf feeding studies (O'Donovan, 1963), grazing studies (Conway, 1970) and finishing studies (Harte *et al.*, 1965). Flynn (1981) described a two-year old Friesian steer system. Carcass weight was 290 kg and total concentrate input was 600 kg. The stocking rate of this system was 2.2 animal units per hectare (approximately 2.1 livestock units (LU) per hectare). At this time typical finishing age for prime cattle in Ireland was 2.5-3 years of age (Riordan *et al.*, 1979). It was considered that the two-year old steer system described by Flynn (1981) was practiced by a small number of farmers. Net margin of this two-year old steer beef system was £140/head.

The availability of anabolic implants in the early 1980s increased carcass output by up to 40 kg per head in two-year old steer beef system (Keane *et al.*, 1986). Anabolic implants were banned in the late 1980s and in order to maintain carcass weight (320 kg/head) the production system evolved with concentrate feeding levels increased to 850 kg/head. The production system for two-year old steer production in the early 1990s was described by Keane and Drennan (1995) and is outlined in Table 2.

Table 2. Summary of two-year old steer system developed at Teagasc Grange in the early 1990s (Keane and Drennan, 1995)

Date	Number of days	Animal weight at start of period (kg)		Management
		Friesian	Charolais X	
Mid March	60	45	50	Rearing
Mid May	180	80	85	First grazing season
Early November	150	220	225	First winter
Early April	190	300	320	Second grazing season
Mid October	150/180	470	500	
Mid March	-	610	-	Friesian slaughter
Mid April	-	-	680	Charolais X slaughter
Carcass weight (kg)		320	380	

Conformation was O (80%) and R (20%) for Friesians and R (75%) and U (25%) for Charolais crossbreds. Total concentrate input was 850 kg for Friesians and 1,150 kg for Charolais crossbreds. The production system was operated at a stocking rate of approximately 2.6 LU per hectare with carcass output of 750 kg per ha. Nitrogen application was 240 kg per hectare. The margin cited for this system (half of each breed-type within an integrated system) was £210/head.

The support mechanisms of the EU Common Agricultural Policy (CAP) have had a critical bearing on the economics and management blueprints of dairy-beef systems. The CAP was introduced in 1962 to provide security of supply in food production following the shortages that prevailed during World War 2. An economic system of price and market support was put in place to increase agricultural productivity, ensure a fair income for farmers and establish secure supply chains for consumers. Major reforms of the CAP with significant implications for cattle farming in Ireland included the introduction of the milk quota system in 1984, which halted growth in dairy cow numbers, and the MacSharry reforms of 1992 which moved the CAP from commodity price supports to direct income supports for farmers based on land area of livestock numbers.

Of specific relevance was the availability of a Special Beef Premium (two payments were payable for steers at 10 and 22 months of age for steers), a Slaughter Premium (payment made on animals slaughtered between 1 January and 30 April to reduce 'seasonality') and an Extensification Premium (to support lower stocking rates and more extensive farming systems) (Drennan, 1993). In general, these premia encouraged two-year old steer production systems such as that described in Table 2 since cattle produced in these systems were eligible for both Special Beef Premium payments and also qualified for the Slaughter Premium. Keane *et al.* (2005) noted that total premia payments could amount to €600/animal which was much greater than the 'market-based' income that was attainable within these systems. Thus, premia contributed significantly to farm income and often subsidised production losses. However, they were also partly responsible for additional compliance costs and artificially inflated calf purchase prices. A major reform of the CAP in 2003 (the so-called 'Luxembourg Agreement') led to the decoupling of subsidies from production and the introduction of the 'Single Farm Payment'. It was also proposed to end the milk quota system in 2014/15.

In 2005, the national cow herd was evenly split between dairy and suckler cows. Over 83% of the dairy herd calved in the first five months of the year, with 65% of these births occurring in February, March, and April. This seasonal calving pattern played an important role in shaping dairy-beef production systems. In 2005, 56% of calves born in the dairy herd were sired by a dairy breed, with Holstein Friesian accounting for 47.1% of total registrations. Early-maturing breeds such as Angus and Hereford increased in popularity based on calf registrations from the mid-1990s and accounted for 14.7% and 12.8% of calf registrations from the dairy herd in 2005, respectively. Continental sires such as Limousin, Belgian Blue, and Charolais were also popular, accounting for 9.1%, 4.2%, and 4% of births from the dairy herd, respectively. Given the seasonal calving, breed, and gender profile of the dairy-beef calf crop during the mid-2000s, and the prevailing premia regimen that prevailed at that time, the predominant finishing systems involved under-24 month indoor or outdoor finishing during a second or third grazing season, with cattle aged either 18-21 months or 27-30 months, respectively.

The introduction of the Rural Environment Protection Scheme (REPS) in 1994, the stocking rate constraints introduced into the CAP regimen through the 1990s and the European Nitrates Directive (Directive 91/676/EEC with the first Nitrates Action Programme in Ireland in 2006) impacted farms' organic and inorganic nitrogen limits. This restriction on nitrogen limited stocking capacity and total herbage production during this period, the impacts of which are reflected in the carcass output of blueprint production systems shown in Table 3.

Dairy-beef systems, having undergone a period of de-intensification during the 1990s, were given the opportunity to increase carcass output in the era of decoupled payments. These improvements in carcass output were targeted through the use of high beef merit genetics and improved, modernized grassland management (Keane, 2002). Production blueprints focused on enhanced grassland management, which consisted of extending the grazing season and doubling the number of paddocks used in a rotational grazing system to increase animal live weight performance. Primarily, the grazing season was extended in the spring by 'strip' grazing swards intended for silage production, allowing for earlier turnout (Keane, 2002).

Leader/follower grazing systems, where calves graze ahead of yearlings to receive the highest quality pasture and reduce their parasite burden, were the favoured grazing management approach (Keane, 2002). However, leader/follower grazing resulted in significantly lower yearling live weight performance due to the reduced herbage allowance and quality of the sward provided. Based on the feed budget and animal units from the production blueprints outlined in Table 3, these systems would be required to grow from 8.8 t DM/ha to 9.6 t DM/ha to support stock numbers, assuming a herbage utilisation level of 80%.

Table 3. Production blueprint animal and farm system performance (mid 2000s)

Animal type	Steer				Heifer	
	Holstein Friesian	Early-maturing	Late-maturing	Late-maturing	Early-maturing	Late-maturing
Slaughter performance						
Finishing age, months	24	22	24	28	19	21
Slaughter weight, kg	620	570	650	710	460	550
Carcass weight, kg	320	295	350	390	235	290
Carcass conformation	O-	O+	R-	R-	O=	O+
Carcass fat	3+/4-	3+	3+	3+	3+	3+/4-
Lifetime feed input						
Grazed grass, kg DM	2,450	2,450	2,450	3,950	2,340	2,340
Silage, kg DM	1,460	1,050	1,460	1,580	500	910
Milk replacer, kg DM	25	25	25	25	25	25
Concentrate, kg	1,000	670	1,000	350	250	550
Farm system performance						
Animal unit/ha	1.8	2.1	1.8	1.2	2.7	2.2
Organic N, kg/ha	146	149	146	126	157	151
Inorganic N, kg/ha	114	105	114	110	94	104
Live weight output, kg/ha	1,116	1,197	1,197	866	1,243	1,222
Carcass output, kg/ha	576	620	630	476	635	644

Current research led dairy-beef production blueprint

The selection of a suitable dairy-beef system is contingent on several factors, including available land, labour, facilities, and the desired work-life balance. A key criterion for evaluating any chosen system is the financial return from the farm's most limited resource, often land. Consequently, net margin per ha is commonly used to evaluate farm systems. To optimise profit per ha, farmers generally have higher stocking rates and target younger finishing ages to support high beef output, through careful animal and grassland management. However, where systems are not restricted by facilities or land resources, and farmers are more focused on a work-life balance, lower stocking densities and finishing cattle older, during a 'third' grazing season, can provide a good return on labour input.

When aiming to reduce finishing age in pasture-based systems it is essential that animal growth is maximised throughout its life, but this must be done in a cost-effective manner during each stage of the animal's life. The management and minimum growth target for each performance period of a dairy-beef animal's life based on Teagasc research system production blueprints is as follows:

Calf rearing

Calf rearing is the most expensive and labour-intensive period in dairy-beef systems. Specialist dairy-beef producers are focused on minimising the number source herds to reduce possible disease challenges. Calves should be housed in a well-ventilated, draught free environment, with calves grouped by source, age and weight. In Teagasc Grange, calves receive 2 L (litres) of electrolytes on arrival, and receive initial intranasal vaccinations 24 hours post-arrival to boost immunity against bovine respiratory disease. Typically, calves arrive on-farm at three weeks of age, weighing 50 to 55 kg. For the first week on the farm, calves receive 6 L/day (0.75 kg solids) and *ad-libitum* access to concentrates, roughage and water. From four weeks of age, milk volume is reduced to 4 L/day (0.5 kg solids). This milk-feeding regime is based on research showing similar animal performance levels and reduced rearing costs compared to feeding higher milk volumes (Byrne *et al.,* 2024). This reduced milk feeding encourages increased concentrate intake, aiding rumen development. Weaning takes place when calves reach a target weight of 85 kg and are consistently consuming over 1.0 kg/day of concentrate. During the rearing phase, calves should achieve growth rates of 0.6 to 0.7 kg/day.

First grazing season

After weaning, calves are turned out to pasture from May onwards. They continue to receive 1 kg concentrate/day and have access to roughage (straw) for the first three weeks of the grazing season to ease the transition onto a grass diet, after which supplementation ceases. Recent research at Teagasc Grange found no benefit from supplementing February-born calves with concentrates throughout their first grazing season, when grazing high quality pasture (O'Driscoll, 2023). Due to declining pasture quality in the autumn, concentrates are reintroduced from mid-September until housing to maintain energy intake of calves. Calves should be offered high-quality pasture throughout the grazing season, with a target pre-grazing herbage mass of 1,200 kg dry matter (DM)/ha early in the grazing season and increasing to 1,400-1,600 kg DM/ha as calves become more accustomed to grazing. Typically, calves are offered silage aftermath as these swards have the longest 'rest' period and the lowest parasite burden. In dairy-beef system experiments at Teagasc Grange and Johnstown Castle, a post-grazing residual sward height of ~5 cm is targeted for calf and cattle grazing (Fitzpatrick *et al.,* 2024). The target average daily live weight gain (ADG) during the first grazing season for calves is 0.7 to 0.8 kg, resulting in a housing weight of approximately 200 kg for heifers and 230 kg for steers.

First-winter indoors

In order to avail of compensatory growth at pasture during the following grazing season, weanling cattle need to achieve a moderate growth rate over the first winter, 0.6 to 0.7 kg live weight/day. Where silage DM digestibility (DMD) is high (e.g. 75% DMD), this can be achieved with less than 1.0 kg concentrate/day, whereas when silage DMD is low (e.g. 65%), 1.5 to 2.0 kg/day of concentrate supplement is required.

Second grazing season

Typically, yearling heifers and steers are turned out to pasture in mid-March weighing approximately 280 kg and 310 kg, respectively. Over the second grazing season, an ADG of 0.9 kg is targeted from a grass-only diet. In order to achieve this, cattle need to be offered high-quality pasture in a rotational grazing system. A pre-grazing herbage mass of 1,400 to 1,600 kg DM/ha should be targeted during the mid-season, with excessively heavy grass 'covers' removed as surplus baled silage. Cattle should receive a new grass allocation every 2-3 days, and be grazed to a residual height of approximately 5 cm. Dairy-beef heifer and early-maturing steer systems may draft cattle off pasture if desired fat levels are achieved. However, heifers and steers destined for indoor finishing are typically housed by early-October, weighing approximately 480 kg and 500 kg, respectively, to reduce grass demand, allowing weanlings to avail of an extended grazing season into late-autumn.

Finishing

The selection of 'finished' cattle (drafting) is primarily dependent on their ability to meet market specifications for carcass fat score, which is between 2+ and 4=. Nationally, a relatively high percentage of animals are being finished at excessively high fat scores, which means additional days on feed, and associated economic and environmental costs. Across Teagasc dairy-beef herds, the majority of early-maturing heifers achieve the target fat scores from pasture during the second grazing season, avoiding the need for an indoor finishing period. For early-maturing steers and late-maturing heifers this level of fatness can be achieved after a 60 to 80 finishing period (indoors or at pasture), while Holstein-Friesian steers will require 100 to 120 days of indoor finishing. Finishing diets should consist of high quality pasture or grass silage (>75% DMD) *ad-libitum*, in addition to 5 kg of concentrate daily. As finishing periods increase in duration, the conversion of feed into carcass reduces, and ultimately a point is reached where feed costs exceed carcass gain benefits. It is essential that live weight gain and the level of fatness of finishing cattle are monitored regularly, allowing for timely drafting. Physically determining the body condition score (BCS) of each animal is essential, paying particular attention to the tailhead, rump, loin, ribs and the level of fat deposited between folds of skin. The 'fleshing' ability of animals will determine the frequency of drafting; this is generally completed every 10 days during the finishing period across research herds in Teagasc.

Economics of dairy-beef steer and heifer research systems

Steer system performance

Nationally, dairy-beef steers are finished at ~27 months of age during a third grazing season; however, with the policy ambition for younger finishing age, the economic efficiency of systems with lower finishing ages is of great interest.

An experiment was carried out in Teagasc Grange to investigate the potential of the CBV in predicting increased animal performance, as well as grass-based feeding strategies aimed at reducing finishing age. The CBV is a genetic index to identify beef cattle with higher merit for beef and feed efficiency traits. All calves on the study were born to Holstein-Friesian (HF) dams, and sired by Angus or HF sires. The Angus calves were subsequently split into two genetic groups, selected for being either 4-star or 5-star (High-CBV) or 1-star, 2-star or 3-star (Low-CBV) for CBV. This resulted in three genetic groups including HF. Within each genetic group, half of the animals were assigned to conventional management, receiving a grass-only diet during the second grazing season and being finished indoors from concentrates and grass silage (Conv.), and the other half received 4 kg of concentrates/head daily from the 1 July during the second grazing season until finished at pasture (Supp.). Finished steers were drafted based on meeting a BCS of 3.75 (5-point scale), deemed to be equivalent of a carcass fat score of 3+/4-.

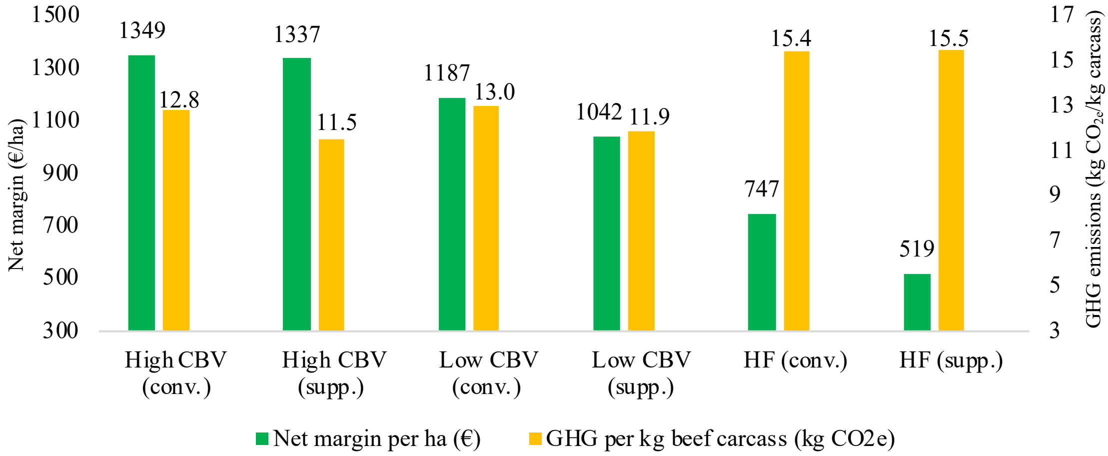
Overall, both Angus groups achieved a higher lifetime ADG than the HF steers. Finishing age was similar between the Low-CBV and High-CBV groups, indicating a similar 'fleshing' ability; however, High-CBV steers produced 18 kg more carcass than Low-CBV steers (Table 4). Animals are deemed to have met market specifications (i.e. "in-spec"), once they achieve a conformation score ≥ O=, carcass weight between 280 kg and 380 kg, a fat score between 2+ and 4=, and an age at finish ≤ 30 months. In terms of overall market specifications, 73% of High-CBV steers, 53% of Low-CBV steers and 22% of HF steers met the requirements. Failure to meet overall carcass specification was primarily caused by low carcass weights for Low-CBV animals, and poor carcass conformation for HF steers.

Table 4. Growth and carcass performance of 2020-born and 2021-born dairy-beef steers per feed management strategy and genetic group

	Conventional			Supplemented		
	High-CBV	Low-CBV	HF	High-CBV	Low-CBV	HF
Finishing age, days	641	652	717	603	601	711
Carcass weight, kg	314	306	311	310	284	328
Carcass conformation	O=/O+	O=	P+/O-	O+	O=	O-
Carcass fat	3+/4-	3+	3+	4-	3+	3+/4-
Finishing period, days	51	62	127	101	99	162
Finishing supplement, kg	248	306	628	403	403	933
Lifetime ADG, kg	0.91	0.88	0.82	0.92	0.86	0.85

Major improvements in beef production efficiency can be achieved from the use of high-beef merit genetics compared to HF. Although carcass weight was similar to HF, High-CBV animals were finished ~3 months earlier, requiring only half the number of finishing days indoors, which represents a major saving in feed costs.

Concentrate supplementation during the second half of the grazing season reduced finishing age of Angus steers by 1.5 months, which meant that an expensive indoor finishing period was avoided compared to their non-supplemented counterparts. In contrast, HF steers supplemented at pasture did not meet the desired fat level and required an additional 120 days of finishing indoors. High-CBV steers generate more profit, and produce beef with a lower carbon footprint compared to Low-CBV and HF steers, regardless of management system (Figure 3). The CBV, along with the national genotyping programme offers farmers an opportunity to make informed decisions at market, allowing them to purchase the most efficient and profitable animal for their system.



*Base price of €4.85/kg. Finishing concentrate price €375/t. Protected urea price €550/t. *__Net margin excludes land & labour charge__ and assumes a calf purchase price of €200 and €60 per head for early maturing (Angus) and HF bull calves.*

Figure 3. *Profit and carbon efficiency of dairy-beef steer systems of contrasting beef merit (High-CBV, Low-CBV and HF) and feeding strategy (Conventional vs. Supplemented)*

Heifer system performance

Despite the lower carcass weight of heifers compared to steers, grass-based dairy-beef heifer systems have the potential for very high carcass output/ha, due to increased numbers of animals finished at younger ages from pasture, which eliminates or reduces the need for an indoor finishing period. Carcass output, the level of inputs required and profitability can be optimised by grazing highly productive and high nutritive value pastures.

Clover and herb-rich swards have many benefits including increased sward nutritive value, animal performance, herbage DM production and biological nitrogen fixation. With chemical fertiliser nitrogen representing one of the highest costs in a grass-based system, reducing reliance on this is vital to improve the viability of dairy calf-to-beef systems. Grass-clover and multispecies swards (MSS) can produce similar DM yields to a perennial ryegrass-only (PRG) sward, despite receiving reduced chemical nitrogen fertiliser.

This means that nitrogen fertiliser input requirements are reduced representing a significant cost saving, and furthermore improving profitability for farmers. Recent research at Teagasc Johnstown Castle has shown that overall lifetime growth performance of early-maturing breed dairy-beef heifers consuming PRG plus red and white clover swards (CLOVER) and MSS (grass + clover + herbs (chicory and plantain)) was similar, but greater than PRG swards (Table 5). This resulted in a greater number of heifers being finished at pasture for the CLOVER and MSS treatments compared to the PRG treatment (86 vs. 75 vs. 68%, respectively). The indoor-finishing concentrate requirement was therefore, lower for the CLOVER (25 kg) and MSS (34 kg) treatments compared to PRG (62 kg). This represents a significant saving in costs associated with feed and housing, consequently increasing profitability. Results for the 2021-born and 2022-born calves showed that daily live weight gain over the first grazing season was greatest for MSS, whereas daily live weight gain as yearlings during the second grazing season was greatest for CLOVER (Table 5).

When dairy calf-to-beef heifers were drafted at a target fat score of 3=, CLOVER animals achieved the greatest net margin compared to the other two sward types (Table 6). This was due to a greater carcass weight, a lower chemical nitrogen application rate, and a greater proportion of these animals being finished at pasture during the second grazing season, which reduced overall costs. Incorporating clover or clover+herbs, meant that half the rate of chemical nitrogen fertiliser was applied and the same herbage production was achieved, resulting is significant cost savings.

Table 5. Effect of pasture type - perennial ryegrass-only swards (PRG), PRG plus red and white clover swards (CLOVER) and multispecies swards (MSS) - on daily live weight gain (kg) of 2021-born and 2022-born dairy-beef heifers

	PRG	CLOVER	MSS
First grazing season	0.61	0.62	0.79
First winter	0.65	0.65	0.68
Second grazing season	0.81	0.92	0.87
Lifetime	0.74	0.78	0.79

Despite having a light carcass weight, dairy-beef heifer systems have opportunity for high carcass output and are profitable, and this can be further improved by including clover or clover+herbs into pastures. The inclusion of clover or clover+herbs can generate an additional €100 to €150 net margin/ha, through improved animal performance and lower input costs, offering farmers an opportunity to improve efficiency, while also striving to meet sectorial climate targets.

Table 6. The effect of pasture type on animal, financial and environmental performance of dairy-beef heifers finished in 2022 and 2023

	PRG	CLOVER	MSS
Finishing performance			
% drafted from pasture	68	86	75
Age at finish, months	19.6	19.2	19.2
Slaughter weight, kg	482	492	490
Carcass weight, kg	243	250	249
Carcass conformation	O=	O=	O=
Carcass fat	3=	3=/3+	3=/3+
System			
Stocking rate, LU/ha	2.65	2.37	2.48
Animals finished on 40 ha	139	127	131
Organic N, kg/ha	220	191	201
Lifetime concentrate, kg DM/head	400	370	380
Carcass output, kg/ha	849	791	813
Farm level financial performance (40 ha farm) (€,000)			
Gross output	141	133	135
Variable cost	72	61	64
Gross margin	69	71	71
Fixed costs	31	28	29
Net margin	38	44	42
Net margin, €/ha	950	1,097	1,050
Net margin, €/head	273	347	320
Environmental			
GHG emissions (kg CO_{2e}/kg carcass)	12.37	12.88	12.91

*Base price of €4.56/kg; €0.20/kg QA payment and €0.20/kg breed bonus. Finishing concentrate price €400/t. Protected urea price €550/t. *Net margin excludes land & labour charge and assumes a calf purchase price of €150 per head for early-maturing breed heifer calves*

Industry challenges and opportunities

In Ireland there is a commitment to reduce agricultural GHG emissions by 25% by 2030; key strategies to deliver this reduction in terms of cattle production are to use more efficient animal genetics, lower concentrate input and reduce the finishing age of cattle by 3 to 3.5 months. In the delivery of reduced finishing ages, dairy-beef producers will face challenges to maintain carcass specification without additional concentrate input where animal genetics, health and nutrition are not fully optimised. The ability of an animal to meet market specification determines the market returns (marketability and processability), thus beef price received by farmers.

The number of male dairy x dairy calves born has decreased, with 100,000 fewer in 2023 due to increased use of sexed semen to breed dairy heifer replacements. This trend is expected to continue, replacing low-merit males with beef-sired calves, representing an overall improvement in the beef merit of the calf crop, however, the beef genetic potential (CBV) of the beef-sired calves has reduced, due to declining dairy dam carcass characteristics and the continued use of low carcass merit beef sires (Kelleher *et al.,* 2024). The decline in the beef merit of beef-sired calves is a result of negligible genetic gain for carcass traits within beef breeds used predominantly on the dairy herd and inadequate supply of both AI and stock bulls with favourable calving and carcass traits (Kenny, personal communication).

In 2023, approximately 182,000 and 26,000 calves born from the dairy herd were either exported or slaughtered under six weeks of age, respectively (AIMS, 2024). Such practices are perceived negatively by wider society, and are coming under increased scrutiny. If these calves are retained to adulthood in Ireland, the majority are likely to be reared in conventional dairy-beef systems where animals are slaughtered between 23 and 28 months of age. This would contribute significantly to methane and total greenhouse gas emissions thereby creating challenges in meeting the targets set in the national climate strategy.

In common with other EU member states, Ireland receives a derogation from the nitrogen limits as provided for in the Nitrates Directive. Revisions to Ireland's derogation have and could further reduce the stocking capacity of dairy-beef farms. Analysis of the stocking rate of commercial farms participating in the DairyBeef 500 Campaign (a farm improvement programme led by Teagasc involving a network of demonstration farms) in 2023, showed that to achieve a margin >€500/ha required a stocking rate of over 170 kg organic N/ha, meaning these farms needed a nitrates derogation. Across the DairyBeef 500 farms a reduction of 10% in stocking rate would result in a reduction in net margin of ~ €267/ha (Dillon *et al.,* 2024).

The National Farm Survey identified a wide range of disparity between the financial performances of commercial dairy-beef farms Table 7 (Dillon *et al.,* 2022), highlighting substantially lower net margins than those achieved at research and demonstration farm level. This low and often negative margin achieved creates major challenges for farmers and contributes to the high attrition rate of farmers from dairy-beef production. It has been established that over a 5-year period of dairy calf-to-beef production, only 39% of farmers continue purchasing and rearing calves (ICBF, 2021).

Table 7. Net margin (€/ha) of dairy-beef enterprises (National Farm Survey 2022)

Year	Top 1/3	Middle 1/3	Bottom 1/3
2021	433	182	-25
2022	229	85	-157

Dairy farmers generally use higher levels of AI compared to suckler producers (Berry *et al.,* 2020), with sexed semen becoming more commonplace to generate dairy replacement, increasing the proportion of beef-sired calves born. The high level of AI use across the dairy herd provides opportunity to make rapid and widespread improvement in the beef merit of the calf crop, provided bulls of high carcass merit are commercially available in increased numbers. Nationally, sexed semen has been found to be 95% as effective as conventional semen (Kelleher, 2023) and based on growing production capacity and usage potentially 70% of calves born in the dairy herd annually could be beef-sired. Given the decline in the beef merit of the national dairy cow herd (Mulhall *et al.,* 2023) and the low levels of improvement in the beef merit of beef-sires used in the herd, a dedicated breeding programme targeting increased genetic gain in beef traits within the DBI is required. The supply of dairy-beef calves, especially beef-sired calves is increasing, meaning that calves are likely to become more competitively priced, in accordance with their beef genetic and profit potential (Berry, 2021). Dairy-beef production offers greater flexibility compared to other cattle rearing systems, with relatively low capital/infrastructure requirements, especially where reared calves are purchased and cattle are finished before a second winter indoors. From high performing commercial and research farm systems it is clear that high levels of profitability are achievable from dairy-beef production. The greenhouse gas emissions intensity of early-maturing dairy-beef steers ranges from 12 to 14 kg CO_2e per carcass kg produced (Figure 3 and Table 6), in contrast to ~22 kg CO_2e per kg carcass for suckler bred early-maturing steers produced from similar grass-based system at a similar ages (Herron *et al*., 2021).

Dairy-beef cattle can produce an 'in-spec' product from a socially acceptable pasture-based system at young finishing ages (19-24 months), satisfying the growing demand for animal-based protein from more environmentally conscious consumers (Berry, 2021). Vertical integration (linking dairy farmers producing calves, beef farmers rearing these animals to finish and meat processors) provides opportunities, however such arrangements are uncommon in Ireland compared to other regions (Burke, 2016). Such agreements begin with the selection of high merit beef bulls for use on the dairy herd, with commitment by beef processor to purchase back resulting progeny meeting overall criteria. These calves are then provided to beef rearers where they are contract reared to a specific production blueprint, providing a consistent product produced to a high level of environmental efficiency, satisfying consumer requirements. This type of rearing agreement can reduce the risk for dairy-beef farmers by offering guaranteed forward price contracts.

Conclusion

Although the size and structure of the national herd and contribution of dairy-beef to overall beef production seems similar today to the early 1980s, producers have a greater range of tools/knowledge available to help achieve more financially and environmentally efficient farm systems. Genetic selection tools such as the DBI and CBV are of crucial importance to the industry. There has been a shift to greater use of beef breeds in dairy herds with the potential for greater beef merit in the resulting progeny. However, the beef genetic potential of these sires has been relatively lower than desirable limiting beef production efficiency and profit. Improving the beef merit of beef bulls used on the dairy herd, can contribute to rapid improvement in the quality of the calf crop due to increasing use of beef AI and a higher proportion of the calf crop being beef-sired. There is an onus on the dairy industry to produce calves with higher beef production efficiency and for dairy-beef farmers to seek information and procure calves based on CBV to encourage the continued breeding of profitable beef calves from the dairy herd. Improvements in the quality and profit potential of the beef calf crop from the dairy herd begins with reducing the number of dairy × dairy male calves in exchange for high-beef merit beef × dairy animals.

An increased contribution of dairy-beef to overall beef production can help Ireland meet agricultural GHG reduction targets, creating opportunity for profitable farm systems. These systems can make effective use of labour and facilities available, but must be based on the efficient use of grazed grass. The impact of policy and market requirements on farmer decision making and farm systems implemented in recent decades is evident. Farm policy and market specification need to promote the key technologies identified through the research farm systems outlined in this document. This involves facilitating the appropriate stocking rates, carcass weights and finishing ages to meet the needs of farm financial viability, environmental sustainability and societal acceptance. The disparity between research and commercial farm financial performance need to be better understood with targeted research with improved dissemination strategies.

References

Allen, P. (2007). New methods for grading beef and sheep carcasses, Evaluation of carcass and meat quality in ruminants. Wageningen Academic. p. 39-47.

Baker, T. J., R. O'Connor, and R. Dunne (1973). A Study of the Irish Cattle and Beef Industries. ESRI General Research Series Paper No. 72, July 1973.

Berry, D., P. Amer, R. Evans, T. Byrne, A. Cromie, and F. Hely (2019). A breeding index to rank beef bulls for use on dairy females to maximize profit. *Journal of Dairy Science*, **102(11):** 10056-10072.

Berry, D., S. Ring, A. Twomey, and R. Evans (2020). Choice of artificial insemination beef bulls used to mate with female dairy cattle. *Journal of Dairy Science,* **103(2):** 1701-1710.

Berry, D., L. Shalloo, A. Cromie, V. Olori, and P. Amer (2005). Economic breeding index for dairy cattle in Ireland. Irish Cattle Breeding Federation, Bandon, Cork, Ireland

Berry, D. P. (2021). Invited review: Beef-on-dairy—The generation of crossbred beef × dairy cattle. *Journal of Dairy Science*, **104(4):**3789-3819. doi: https://doi.org/10.3168/jds.2020-19519

Buckley, F., N. Lopez-Villalobos, and B. Heins (2014). Crossbreeding: implications for dairy cow fertility and survival. *Animal,* **8(s1):**122-133.

Burke, J. 2016. NUFFIELD IRELAND.

Byrne, N., J. O'Driscoll, P. Crosson, A. Dillon, and E. Fitzpatrick (2024). Dairy-beef systems for profitable production. In: M. McGee and P. Crosson, editors, Beef 2024 'Securing your future'. Teagasc. p. 184.

Conway, A. G. (1970). An operational model of the relationship between liveweight gain and stocking rate for grazing cattle, with an estimated production function for steers, under Irish conditions. Iowa State University.

Cunningham, E. (1983). Structure of dairy cattle breeding in Western Europe and comparisons with North America. *Journal of Dairy Science,* **66(7):** 1579-1587.

DAFM. (2000). AIM Bovine Statistics Report 2000.

DAFM. (2024). AIM Bovine Statistics Report 2023.

Dillon, A., T. Cox, F. Maguire, and G. Peppard (2024). Teagasc DairyBeef500 Campaign. In: BEEF 2024. p 184.

Dillon, E., B. Moran, and T. Donnellan (2022). Teagasc national farm survey 2022.

Drennan, M.J. (1993) Planned Suckler Beef Production. Teagasc, 19 Sandymount Avenue, Ballsbridge, Dublin 4.

Drennan, M.J., M.G. Keane and L. Dunne (1995) Outline of beef production in Ireland. In: Extensification of beef and sheep production on Grassland. Occasional publication number 2. Editors: MG Keane and A Pflimlin. Teagasc. Fisher, A. 2007. Beef carcass classification in the EU: an historical perspective. Evaluation of carcass and meat quality in ruminants:19-30.

Fitzpatrick, E., R. Fox, J. Cardiff, and N. Byrne (2024). Effect of pasture type on dairy-beef heifer production efficiency. In: 30th General Meeting of the European Grassland Federation (EGF2024): Why grasslands?, Leeuwarden, the Netherlands. p 819-821.

Flynn, A. (1981). Systems of beef production from dairy herd calves. *Calf to Beef, Handbook Series* (**17**):1-3.

Harte, F., S. Curran, and V. Vial (1965). The production of beef from young bulls, I. *Irish Journal of Agricultural Research*, 189-204.

Herron, J., T. Curran, A. Moloney, M. McGee, E. O'Riordan, and D. O'Brien (2021). Life cycle assessment of pasture-based suckler steer weanling-to-beef production systems: Effect of breed and slaughter age. *Animal* **15(7):** 100247.

Keane, M., A. Flynn, and F. Harte (1986). Responses to sequential use of different anabolic agents in young bull, young steer and two-year-old steer beef systems. *Irish Journal of Agricultural Research*, 153-166.

Keane, M.G. (2002). Development of an Intensive Dairy Calf-to-Beef System and Associated Grassland Management. Teagasc.

Keane, M.G., E.G. O'Riordan and P. O'Kiely (2005) Dairy Calf-to-Beef production systems. Teagasc, Oak Park, Carlow. Kelleher, M., J. McCarthy, K. Downing, and R. Evans (2024). The Commercial Beef Value (CBV): Potential catalyst for change. In: M. McGee and P. Crosson, editors, BEEF 2024 "Securing Your Future". Teagasc. p. 184.

Kenny, D., C. P. Murphy, R. D. Sleator, M. M. Judge, R. D. Evans, and D. P. Berry (2020). Animal-level factors associated with the achievement of desirable specifications in Irish beef carcasses graded using the EUROP classification system. *Journal of Animal Science,* **98(7):**skaa191.

Matthews, D. (2003). BSE: a global update. *Journal of Applied Microbiology,* **94(s1):**120-125.

McGee, M., M. G. Keane, R. Neilan, A. P. Moloney, and P. J. Caffrey (2005). Production and carcass traits of high dairy genetic merit Holstein, standard dairy genetic merit Friesian and Charolais× Holstein-Friesian male cattle. *Irish Journal of Agricultural and Food Research*, 215-231.

Mulhall, S., R. Sleator, R. Evans, D. Berry, and A. Twomey (2024). Impact on prime animal beef merit from breeding solely for lighter dairy cows. *Journal of Dairy Science,* **107(10):** 8150-8156.

Mulhall, S., R. Sleator, R. Evans, and A. Twomey (2023). Genetic and phenotypic trends for carcass traits in Irish beef cattle. *Irish Journal of Agricultural and Food Research*, 1-14. DOI: 10.15212.

O'Donovan, M., D. Hennessy, and P. Creighton (2021). Ruminant grassland production systems in Ireland. *Irish Journal of Agricultural and Food Research*, **59(2):**225-232.

O'Donovan, M., E. Lewis, and P. O'Kiely (2011). Requirements of future grass-based ruminant production systems in Ireland. *Irish Journal of Agricultural and Food Research*, **50(1):**1-21. doi: 10.2307/41348152.

O'Donovan, S. (1963). A comparison between a conventional and an early weaning system of feeding calves. *Irish Journal of Agricultural Research*, 95-98.

O'Ferrall, G. M., and M. Ryan (1990). Beef crossing: effects of genotype of the foetus on the performance of dairy cows. *Irish Journal of Agricultural Research,* 101-108.

O'Driscoll, J., Purfield, D.C., McHugh, N. and Byrne, N. (2023). Strategic concentrate supplementation in reducing slaughter age in pasture-based dairy-beef systems. In: 74th Annual Meeting of the European Federation of Animal Science, Lyon, France

Pabiou, T., W. Fikse, A. Näsholm, A. Cromie, M. Drennan, M. Keane, and D. Berry (2009). Genetic parameters for carcass cut weight in Irish beef cattle. *Journal of Animal Science,* **87(12):** 3865-3876.

Prendiville, R., K. Pierce, and F. Buckley (2010). A comparison between Holstein-Friesian and Jersey dairy cows and their F1 cross with regard to milk yield, somatic cell score, mastitis, and milking characteristics under grazing conditions. *Journal of Dairy Science*, **93(6):** 2741-2750.

Riordan, EB, Connolly, L, Dunne, L, Herlihy, P, Hickey, BC, Igoe, MH and Shanahan, U. (1979). Calves to Italy – an examination of factors influencing the trade. A study commissioned by the Irish Fresh Meat Exporters Society. An Foras Taluntais, Economics and Rural Welfare Research Centre, Dublin.

Roche, F. (1981). A strategy for the development of the Irish cattle and beef industry. Prepared on behalf of the Steering Committee of the Irish Fresh Meat Exporters Society Ltd.

Dairy-beef production in New Zealand

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Abstract

Dairy-beef is an integral part of the New Zealand beef production system with an estimated 74% of all beef originating from the dairy industry. Over the past three years between 0.86 and 1.04 million non-replacement calves (mostly bull calves) from the dairy industry were reared annually. An estimated 50% of these calves are reared by specialist rearers on low-cost once-a-day feeding systems for on-sale to beef finishers. These bull calves are processed at 2-3 years of age and at average carcass weights (CW) of ~300 kg. Many of these bulls are intensively farmed in beef systems which maximise grass growth and pasture utilisation. Increasing crossbreeding between Holstein-Friesian and Jersey genetics in the dairy industry has led to around 60% of dairy cows being crossbred. This, along with the use of low-quality beef sires, creates issues with the supply of quality calves as does the lack of a supply chain from dairy farm to market. Another issue of industry concern is the ~2 million calves processed annually for bobby veal at around 4 days of age. Farming of these calves would create disruption to the pastoral industry and lead to fewer cows in milk, significantly lower beef carcass weights and/or displacement of other stock.

Keywords: beef, dairy, quality, bobby veal, disruption

Introduction

New Zealand (NZ) livestock farming is based on using grazing animals to harvest pasture with low levels of supplementation and limited feedlot or indoor over-wintering of livestock.

In 1982, NZ sheep numbers peaked at 70 million supported by 5 million beef cattle and 2.1 million dairy cattle. Currently there are 23.3 million sheep, 3.7 million beef cattle and 5.9 million dairy cattle (Anon, 2024a). These changes have been associated with fluctuations in relative profitability, particularly with dairy farming, where economies of scale have driven change. On average, dairy farms now milk 441 cows, compared to 164 in 1990 and 124 in 1980. Other changes in land use have been a move to forestry plantings (mostly Pinus Radiata) for both timber and carbon farming. Between 1980 and 2023, forestry plantings increased from 1m to 1.8m hectares (ha), impacting both sheep and traditional beef farming. Between 1990 and 2015 there was a 34% reduction in sheep and beef land-used for sheep and cattle farming (Journeaux, 2017).

New Zealand produces approximately 3% of global milk production and is the world's top dairy exporter, accounting for approximately 30% of the world's internationally traded dairy products. A key difference between NZ and many other countries is that we have a relatively small domestic population and relatively low consumption of milk. Fonterra Co-operative Group is the dominant downstream processor in NZ with an 84% share of the NZ milk supply (Anon, 2023). Because most milk is further processed, NZ dairy farmers are paid on the fat and protein content of milk rather than volume in what is called "farm gate milk price". In 1970, Holstein-Friesians were the dominant dairy cow breed but crossbreeding with Jersey has led to increases in per ha profitability (Lopez-Villalobos *et al.,* 2000). These crossbred 'Kiwi' cows now comprise ~60% of the national dairy herd with Holstein-Friesian representing 24% and Jersey cows representing ~8% of the national herd in 2022-23 (Anon, 2023). The move to 'Kiwi' cows has had other benefits such as improved fertility, longevity and lower mature liveweight which has reduced treading damage from cows (Lopez-Villalobos *et al.* 2020). The move to smaller dairy cows with their lower growth potential has implications for the finishers of their progeny.

The relative profitability of different farming enterprises has driven much of the change in NZ land use. Financial returns per ha are vastly different because of the class of land and stock policies employed. Table 1 compares land use options and their relative return expressed in EBIT (Earnings before Interest and Tax) per ha (Journeaux, 2017, personal communication). Dairying shows an EBIT of 4.7 times that of intensive sheep and beef finishing and 8.5 times that of the more extensive sheep and beef breeding. Our estimates are that annual pasture production is 13, 9, and 6 tonnes of dry matter (DM) per ha on dairy, intensive finishing, and sheep and beef breeding land, respectively.

Table 1. EBIT/ha from intensive finishing and sheep and beef breeding relative to dairy

Land use	2021	2022	2023	10 year average
Viticulture	NA	$21,125	$18,565	$14,898
Kiwifruit	NA	$64,443	$49,843	$41,383
Dairy	$4,279	$5,355	$4,099	$3,399
Intensive finishing	$886	$934	$713	$718
Sheep and beef breeding	$375	$488	$429	$401

New Zealand's beef supply is dependent on traditional beef cattle born on sheep and beef farms and beef on dairy (dairy-beef) born on dairy farms. As dairy cow numbers have increased the amount of beef of dairy origin has increased. Edwards *et al.* (2021) estimated that 74% of total beef originates from the NZ dairy herd and comprises a mix of bobby calves, surplus heifers, steers, bulls and cull cows, including those raised on beef farms (Figure 1). Most steers, heifers and bulls are processed at between two and three years of age (Stevens *et al.*, 2022). Looking at B+LNZ industry data, averaged across the last five years, it is important to note that 68-73% of all beef processed originated from dairy farms. Within sheep and beef farms 52% of cattle processed were of dairy origin; 28% of steers, 52% of heifers, and 94% of bulls (Thomson R.D., personal communication).

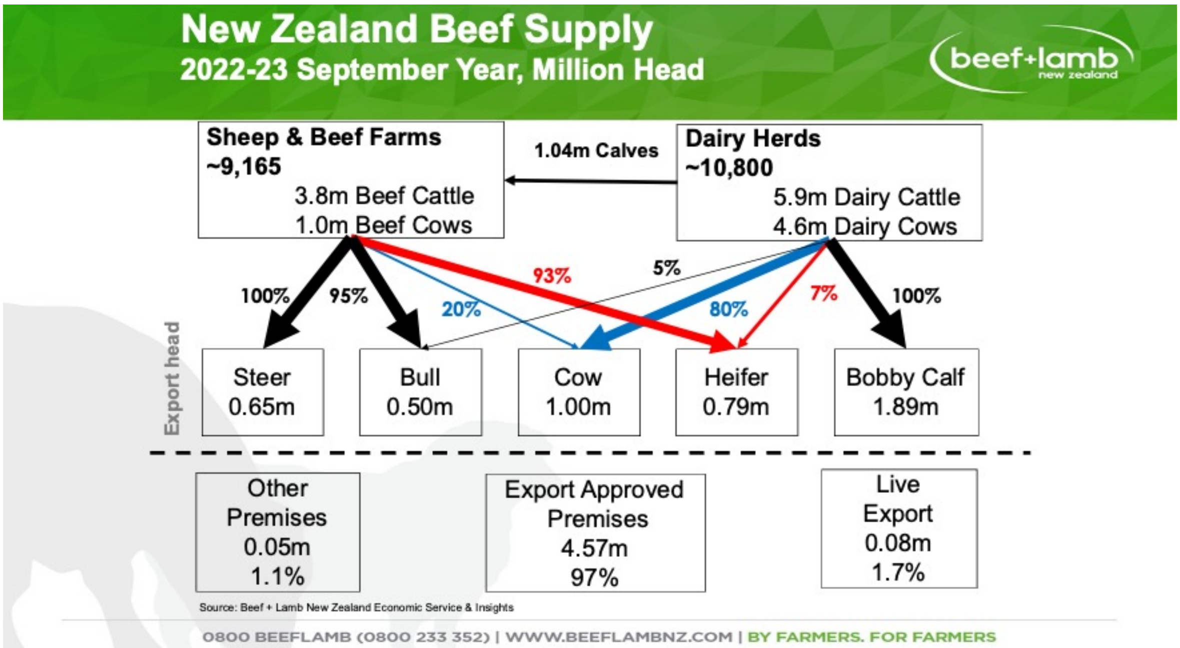

Figure 1. *Pattern of supply of New Zealand Beef*

Of the 0.94 million dairy origin calves that transferred from dairy farms to beef farms in 2023, an estimated 53% were Friesian bulls which are typically farmed across two-winters and then sold to meat processors in December and January. Bull beef farming is the most profitable livestock policy on drystock farms but not all farmers will tolerate the associated animal behavioural challenges and will farm steers and heifers by preference. The second most profitable policy option is dairy heifer grazing and dairy farmers would be unlikely to want their sheep and beef farmer graziers to exchange their dairy heifer grazers for dairy-beef animals (Thomson R.D., personal communication).

History of the NZ dairy-beef industry

In 1960, the beef breeding herd comprised 1.20 million cows and heifers with 3.01 million beef cattle in total. At that same time dairy cattle numbers were 2.97 million meaning that numbers for each were similar (Anon, 2024b) and very few calves born in the national dairy herd were reared for beef production. Improving beef prices through the 1960's and early 1970's led to large increases in the number of beef animals on NZ farms with beef cow numbers peaking at 2.3 million in 1975-76 (Anon, 2024).

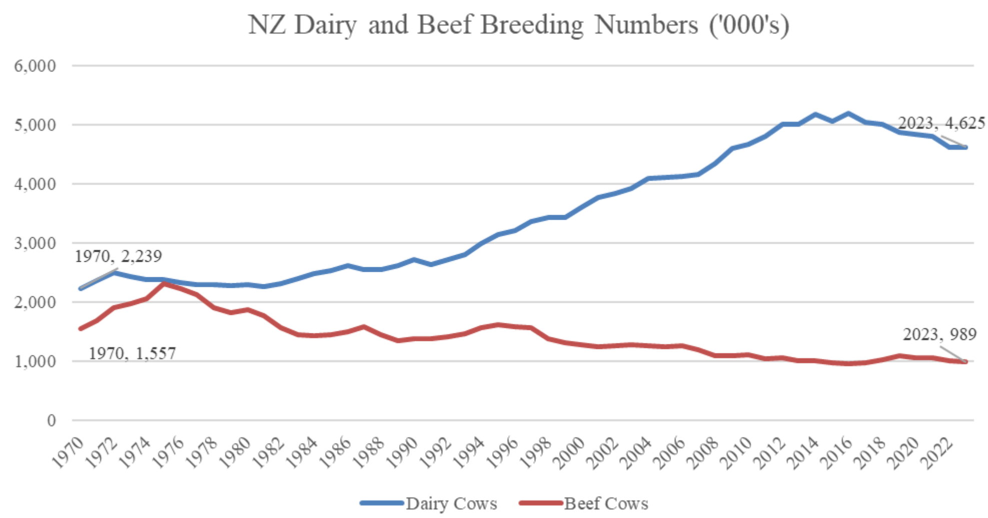

Figure 2. *Dairy and Beef Breeding numbers from 1970 to 2023 (Beef + Lamb Economic Service 2024)*

These increases in beef prices led to increasing interest in intensive production systems involving dairy-beef (e.g. Everitt & Ward 1974). Working with dairy-beef calves (Brougham *et al.,* 1975) showed that net carcass production of 1 000 kg per ha could be achieved by farming dairy bull calves between three and 15 months of age in an intensive all-pasture beef system.

Most of the interest in intensive dairy-beef systems has been in producing bull beef because of their faster growth rates and better profitability than both steers and heifers (Thomson, 2022). Moreover, bull beef prices have traditionally tended to be similar to prime beef and between 2018 and 2023 prime beef averaged $NZ6.01/kg and bull beef $NZ5.93/kg (Anon 2024a). In 2023-24 1.9 million steers, heifers, and bulls were processed in New Zealand, with bull beef accounting for 26% of the total beef produced (Anon 2024b). Whilst cull breeding bulls are included in this total, they account for a very small percentage.

As farming of bulls has become more accepted, carcass weights (CW) have steadily increased, from 170 kg in the early 1970's (e.g. Brougham *et al.,* 1975) to an industry average of 303 kg (Anon, 2024a). This is partly a result of better farming practices and pricing signals from meat processing companies to obtain heavier carcasses and improved processing efficiency. Virtually all bulls are sold as manufacturing beef and there is no price premium for slaughter at younger ages, so farmers are incentivised to produce heavier and older carcasses.

With changes in the relative profitability of dairy farming compared to sheep and beef farming cattle numbers have changed considerably. In 2022-23 there were 1 million beef breeding cows and 3.8 million beef cattle compared to 4.6 million dairy cows and 5.9 million dairy cattle. The number of dairy calves transferring from dairy farms to beef farms prior to 1990 is known to be very low however from the 1970's numbers gradually increased to reach between 750,000 to 905,000 in the early 1990's. These numbers then dropped to between 420,000 and 560,000 in the late 1990's, then gradually rose to a peak of 1.3 million in 2020, and this has now settled to between 900,000 to 1 million per year in the last three years. This means that in the early 1990's ~0.7 million surplus dairy calves were processed each year whereas in the 2020's ~1.8 million were processed each year.

Calf rearing

Dairy-beef calves in New Zealand are either reared by dairy farmers for on-sale or are purchased by specialist calf rearers. Most are reared from four days of age through to 100 kg liveweight (LW) (typically 12-14 weeks of age) with a few being farmed through to slaughter. Specialist calf rearers are usually physically and financially separate from dairy farms.

Farm surveys indicate that between 7 and 12% of dairy calves born are reared for beef on dairy farms (Thomson *et al.* 2018, Edwards *et al.,* 2021). The numbers actually reared will reflect the expected farm gate milk price, the amount of surplus colostrum and transition milk available and the expected beef prices. Our best estimate is that 50% of the dairy-beef calves are reared on dairy farms and the remainder on specialist calf rearing units.

Most (79%) dairy farmers feed their calves twice a day and tend to feed high milk volumes (316 litres of colostrum or milk/calf) and wean at 9.7 weeks of age (Thomson *et al.,* 2018). Dairy farm-reared calves are fed surplus colostrum and transition milk when it is available, but this reduces calf appetite for solid feed. This delays rumen development and the ability to wean early. On the other hand, most specialist calf rearers (71%) feed milk once a day, feed lower milk volumes (average of 155 litres/calf) and wean at 6.5 weeks. Compared to dairy farmers, specialist calf rearers are more aware of their cost inputs and use scales to monitor calf growth (Thomson *et al.* 2018). Nevertheless, calf rearers are typically squeezed between dairy farmers for calf purchases and beef finishers for the sale of their calves. As the majority of dairy-beef calves are born in spring, they usually hit the market in early summer as grass growth and quality declines. Rearers with small blocks are unable to carry these calves into summer and often become forced sellers. The reluctance of both dairy farmers and finishers to sign advance sale and purchase contracts means that calf rearing returns are volatile, with a 20% turnover of specialist calf rearers per year (Thomson *et al.,* 2018).

Historically, calf rearing outside of dairy farms was somewhat of a cottage industry and the preserve of small-block owners. As feeding twice-a-day on calf milk replacer put time limitations on the number of calves that could be reared. The introduction of once-a-day calf rearing systems in the 1990's (Muir *et. al.,* 2002) and ongoing refinement enabled calf rearing to be carried out at scale. A number of rearers now rear in excess of 5,000 calves annually with economies of scale around input costs such as labour, milk and meal. Most large rearing operations tend to be located in dairying areas close to the supply of calves and surplus milk. It is not uncommon for these large rearers to have their own stock truck and milk collection tanker. Transition milk collected early in the season can be stored in large tanks preserved with citric acid. Specialist calf rearers also tend to hold calves indoors for several weeks. Whilst this enables better calf management in inclement weather, a key reason is to encourage early uptake of a grain-based meal and better rumen development. Once consuming meal, milk intake (usually the most expensive input) can be reduced and animals moved to pasture. Calves can be weaned once they are consuming

1 kg/head of meal and this occurs between weeks four and five under a restricted milk system (Muir *et al.,* 2002). Whilst calves can be successfully reared on milk and pasture, greater quantities of milk are required. Similarly, harvested forage can be substituted for a grain-based meal but calf performance to 12 weeks is compromised (Burggraaf *et al.,* 2020). This matters in a NZ context where there is a price penalty for calves marketed late in the season.

Beef systemisation

Intensive beef systems have been developed to enable higher levels of production and profit in all-pasture farming systems. Systemisation involves rotational grazing with best practice pasture management to optimise annual pasture growth, beef production and profit per-hectare. The key considerations are mob size, rotation length, and shift frequency and these are largely dictated by winter pasture growth rate and stock class. Mob size may vary from 10 to 200 head depending on age and sex. Winter rotation length may vary from 60 to 160 days depending on pasture growth rate and shift-frequency may vary from 1-3 days. Soil type and topography have a large bearing on what age stock class farmers choose. Poorly drained or steep land is prone to treading damage and therefore are best suited for wintering younger and lighter animals e.g. sheep or cattle less than 300 kg LW. By farming the 'right' stock class on the 'right' land class farmers are able to farm in a way that is environmentally sustainable.

Beef systemisation started with research by a pasture agronomist (Ray Brougham) who optimised grazing management and defoliation height to maximise canopy light interception and pasture DM production (Brougham, 1975, Harris, 1996). This led to farmlet studies in the early 1970's with calves from 3 to 15 months of age with high stocking rates and daily shifts. Over 16 years, average daily growth rates were 0.63 kg/head/day and these young bulls required an average of 6.9 kg DM/kg liveweight gain (Clark and Brougham 1979). This work demonstrated that 1,000 kg CW per ha was possible (Cosgrove *et al.,* 2003). This was five times that being produced from local farms under the same farming conditions. This led farmers to replicate this level of production on-farm and resulted in the development of the Technosystem™ (Charlton and Weir, 2001). This is effectively a subdivision and grazing management program to better utilise available pasture.

Typically, a well-managed beef system on a steep-hill farm and growing 8 tonne DM/ha, would produce ~360 kg carcass/ha. A beef system on an easy-contoured farm growing 12 tonne DM/ha would produce ~540 kg CW/ha. These figures are based on the most widely practiced two-winter bull finishing policy which typically involves buying weaner bulls at 3 months of age (100 kg LW) in the spring or at 20 months of age (400 kg LW) in the autumn and then slaughtering them at ~300 kg CW across spring, summer and autumn from 26-30 months of age. These figures are much lower than those reported by Brougham *et al.* (1975) who was working with a one-winter system and much younger animals which are inherently more efficient with more feed energy diverted to growth (relative to maintenance) than occurs in older animals. A recent modelling analysis using Farmax™ showed that on the same land class a beef system will generate twice the production and profit as the industry average (Thomson, personal communication).

While Beef Systematisation is largely confined to bull farming, the principles can be applied to any beef finishing policy or any cattle growing program, whether growing replacement dairy heifers, or finishing prime steers and heifers. Traditional beef production and lower stocking rates tend to be associated with extensively farmed properties with breeding stock whereas dairy-beef production is more prevalent on finishing properties. Some of these beef systems are run on large-scale properties with up to 3,500 bulls finished annually.

Beef Systemisation affords the greatest opportunity for NZ beef farmers to increase farm production and profit. In almost every situation where beef systemisation has been adopted, production and profit have at least doubled.

Industry challenges and opportunities

An estimated 2.3 million surplus dairy calves are produced from NZ dairy farms annually, with 1.89 million calves processed as bobby calves at less than a week of age in 2022-23 (Anon, 2024). Processing of these surplus dairy calves has caused concern from some processors of NZ milk and beef products with the suggestion that these calves should have a 'useful life' and therefore not be processed until they are at least one-year of age. There are currently several initiatives to address the challenge of these surplus dairy calves and an industry view is that within five years, dairy farmers will have commenced demonstrating that their surplus calves have a 'useful life'.

Customers, like McDonalds, are now publicly stating that they will be looking to the greenhouse gas (GHG) profiles of the products they purchase. A positive advantage for beef on dairy (dairy-beef) compared to beef on beef (traditional beef) is that the maternal contribution of GHG is largely accounted for in the dairy herd and not the beef herd. While in NZ the surplus dairy calf is currently a challenge, due to their low quality, these calves potentially provide an opportunity as an alternative to traditional beef on the basis that they will allow a reduction in our GHG emissions. Our calculations show, that when cattle are finished at 300 kg CW, dairy on beef (dairy-beef) will produce 45% of the GHG emissions of a beef on beef (traditional beef) animal (Thomson, personal communication).

Dairy farming is the most profitable pastoral land use in NZ, over four times more profitable than intensive beef finishing farms (Journeaux 2017, personal communication) thus it is unlikely that dairy farmers will change land-use to finishing beef. As there is a finite amount of pastureland suitable for finishing cattle in NZ, the finishing of these surplus dairy-beef calves will inevitably need to displace some other land use.

As well as displacing other stock, there are three main alternatives to reduce the number of surplus dairy calves. First, finishing cattle one year sooner means that 50% more cattle could be processed. Farmax™ modelling (Thomson, 2023) shows that CW would reduce from ~300 kg (Anon, 2024), to ~200 kg if the same seasonal beef processing pattern is maintained. This would provide challenges for our processing plants which are geared for larger carcasses, and processors claim there would be a significant cost in processing efficiency. Secondly, dairy farmers could adopt an extended lactation whereby dairy cows would lactate for 1.5 to 2 years and this could reduce the number of calves by 30-50% (Glassey, personal communication). Finally, dairy farmers could reduce the number of dairy cows being milked and instead rear calves for beef on their dairy farms. The same modelling study showed that dairy farmers with spring calving herds would need to reduce their herd size by 16% to provide the pasture to rear their surplus dairy calves to 200 kg for sale in the autumn. In reality, if NZ is to provide a useful life for surplus dairy calves then the likelihood is that a range of options would be adopted.

There are a number of challenges in rearing large numbers of surplus dairy calves and a key problem is the wide range in genetics in the dairy industry and how these impact on the quality and growth potential of the dairy-beef progeny. Dairy farmers make mating decisions based on milk production, with beef production being a distant second. Most of the beef bulls used are naturally mated and do not have performance records for important traits like calving ease, gestation length and growth rate of their progeny. The increasing crossbred nature of dairy cows means slower growing progeny, with calves born to 14/16 Friesian dams reaching 100 kg weaning weight 6-9 days faster than calves from 10-13/16 Friesian dams. At slaughter, the respective LW of the progeny for these two groups was 594 kg and 575 kg, respectively, (Williamson *et al.,* 2022). Because of the better per-head performance of Holstein-Friesian calves there is a large amount of beef industry prejudice against crossbred calves. However, there was little difference in total output of beef per ha when Friesian type and better dairy crossbred bulls were stocked at a similar LW per ha (Everitt and Ward, 1974; Muir *et al.,* 2002).

Since virtually all bull beef is destined for the manufacturing beef market and exported, there is little or no consideration given to fat colour. However, if more surplus calves were to be farmed as steers or heifers then the yellower fat from Jersey genetics may become an issue.

Historically there has been limited appetite within dairy farmers to use beef semen over their dairy cows, instead preferring to use natural mating with cheap, low genetic merit beef bulls. However, there is now evidence that with the increasing use of 'wearables', with associated automated heat detection, that dairy farmers are more receptive to an extended AI period. However, choice of beef sire can impact on returns for beef finishers. Beef + Lamb New Zealand has been running a Dairy Beef Progeny Test since 2015 which now demonstrates that the choice of beef sire has a significant effect on Gross Margin per ha on beef finishing farms (Thomson and Hickson, 2022). Progeny sired by the top 15% of bulls in the Dairy Beef Progeny Test would return an additional $200 per hectare (+12%) more than an industry average beef sire. This advantage is largely attributed to LW gain advantage and therefore heavier CW.

Perhaps the biggest issue facing the NZ dairy-beef industry is the lack of a robust supply chain from the dairy farmer to calf rearer, beef finisher, beef processor and the market/consumer. Possibly the only commercial beef supply chain in New Zealand has been developed by Firstlight Foods (https://www.firstlight.farm/nz) who contract farmers to breed and rear Wagyu cattle from conception to consumer. The Firstlight program has control of the Wagyu genetics through the supply of bulls and semen to their breeders and the farmers own the cattle through to market as either backgrounder or finisher. Dairy-beef is an important part of the Firstlight program and has been more successful at meeting market specification than Wagyu crossed with traditional beef breeds. It is the price premiums being achieved for pasture fed marbled beef in overseas markets which have enabled a supply chain to be developed

Conclusions

New Zealand has increased dairy cow numbers by 70% in the last 30 years and, while an efficient milk producer, the process of getting cows in milk has resulted in a surplus of dairy origin calves. Many of these calves are currently processed at less than one-week of age and are considered low quality for beef production. Another factor is that NZ has a finite and reducing amount of pastoral land upon which beef cattle can be raised to create the 'useful life' that our customers are expected to demand.

The dairy and red meat sectors are working proactively to increase the number of calves that are reared for beef but will need to address the economics of dairy-beef, for beef and sheep farmers to consider changing their livestock policies.

There are three main options to meet these challenges. Firstly, our dairy farmers could extend the lactation length for dairy cows, without the administration of animal treatments, from one annual lactation to 1.5 to 2 years per cow which would reduce the number of surplus dairy-origin calves by 30-50%. Secondly, there is an urgent need to improve the quality of dairy-beef calves by mating with proven beef sires, such as those being performance-recorded in the NZ Dairy Beef Progeny Test, thereby increasing their land use competitiveness. Thirdly, our beef marketers have the opportunity to seek a market for lighter-weight beef from one-winter beef finishing systems compared to two-winter beef finishing systems and this approach could account for 50% more cattle being finished on the same land area. However, simultaneously, our beef processors will need to determine how they can process 200 kg CW one-winter cattle as efficiently as two-winter 300 kg CW cattle.

Dairy-beef is already well established in NZ, mostly through Friesian bull beef finishing which has been shown to be one of the most profitable drystock farming policies. We now have the opportunity to build on the bull beef legacy through better 'beef on dairy' genetics which has the potential to be as profitable as bull farming.

In conclusion, dairy-beef has the potential to be the most land-use competitive drystock farming option, however there are a number of practical solutions that will need to be implemented, if we are to look to a sustainable farming future.

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References

Anon (2022). Beef + Lamb New Zealand Economic Service 2001-02 Publisher Beef + Lamb. Wellington, New Zealand

Anon (2023) NZ Dairy Statistics 2022-23 Publisher Livestock Improvement Corporation Limited & DairyNZ Limited Hamilton, New Zealand

Anon (2024a) Beef + Lamb New Zealand Economic Service 2023-24 Publisher Beef + Lamb. Wellington, New Zealand

Anon (2024b) https:/teara.govt.nz/files/1_183_beef_ratios_0.pdf downloaded 2024 The Encyclopedia of New Zealand. Pub Ministry for Culture and Heritage NZ Wellington New Zealand.

Brougham, R.W, Causley, D.C. and Madgwick, L.E. (1975). Pasture management systems and animal production. Proceedings Ruakura Farmers Conference **27**: 65-9.

Burggraaf, V.T., Craigie, S.T., Khan, M.A., Muir, P.D., Thomson, B.C., Lowe K.A., Leath, S.R., Taukiri, K.R., Staincliffe, M. and McCoard, S.A. (2020). Effect of feeding forage or concentrate starter diets in early life on life-time growth, carcass traits and meat quality of Wagyu x Friesian cattle. *Animal Production Science*, https://doi.org/10.1071/AN19486.

Charlton, J.F.L. and Weir, J.H. (2001). Technograzing – a new grazing concept. *Proceedings of the New Zealand Grassland Association,* **63**: 33-36.

Clark, D.A. and Brougham, R.W. (1979). Feed intake of grazing Friesian bulls. *Proceedings of the New Zealand Grassland Association,* **39**: 265-274.

Cosgrove, G.P., Clark, D.A. and Lambert, M.G. (2003). High production dairy-beef cattle grazing systems: a review of research in the Manawatu. Proceedings of the New Zealand Grassland Association 65, 21-28.

Edwards, J.P., Cuthbert, S., Pinxterhuis J.B. and McDermott A. (2021). The fate of calves born on New Zealand dairy farms and dairy farmer attitudes towards producing dairy-beef calves. *New Zealand Journal of Animal Sciences and Production*, **81:** 179.185.

Everitt, G.C. and Ward, J.D.B. (1974). Bull beef production. Proceedings of the 26th Ruakura Farmers Conference, 64-70.

Harris, W. (1996). The contributions of Dr Raymond Wilke Brougham to grassland science and management. *Proceedings of the New Zealand Grassland Association,* **58**:23-48.

Journeaux, P, van Reenen, E., Manjala, T., Pike, S., Hanmore, I., AgFirst NZ., Millar, S. (2017). Analysis of drivers and barriers to land use change. A report written for and published by the New Zealand Ministry for Primary Industries, PO Box 2526, Wellington 6140, New Zealand.

Lopez-Villalobos, N., Garrick, D.G., Holmes, C.W., Blair, H.T. and Spelman R.J. (2000). Profitabilities of some mating systems for dairy herds in New Zealand *Journal of Dairy Science*, **83(1):**144-153.

Muir, P.D., Fugle, C.J. and Ormond, A.W.A. 2002. Calf rearing using a once-a-day milk feeding system: current best practice. *Proceedings of the New Zealand Grassland Association*, **64**: 21-24.

Moot, D.J., Davison, R. 2021. Changes in New Zealand red meat production over the past 30 year. *Animal Frontiers,* **11:** 26–31.

Muir, P.D., Fugle, C.J., Smith N.B. and Ormond A.W.A. (2001). A comparison of bull beef production from Friesian type and selected Jersey type calves. *Proceedings of the New Zealand Grasslands Association,* **63**:203-207.

Stevens *et al.* (2022). Sheep and Cattle Birth and Slaughter Dates Greenhouse Gas Inventory Research Fund – Final Report Agreement Number: 406622. Publisher Ministry of Primary Industries, Wellington, New Zealand

Thomson, B.C., Muir, P.D. and Ward K.R. (2018). Calf-rearing systems on dairy farms and specialist calf rearing units: results of a New Zealand survey. *New Zealand Journal of Animal Sciences and Production*, **78:** 173-176.

Thomson, R.D., Hickson, R.E. (2022). The Value of the Dairy Beef Progeny Test – a farm systems modelling review prepared for Beef and Lamb New Zealand Genetics PO Box 5501, Dunedin 9058, New Zealand.

Williamson, H.R., Schreurs, N.M., Morris, S.T., Hickson, R.E. (2022). Growth and carcass characteristics of beef-cross-dairy-breed heifers and steers born to different dam breeds. *Animals,* **12:**864.

Health and Welfare

Advances in management of respiratory disease in dairy beef and veal calves: how quick thoracic ultrasonography opened our eyes

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Introduction

Dairy calf to beef (dairy beef) is a sector that is likely to see significant changes in countries such as Ireland over the coming years. In the past, surplus Irish dairy bull calves were exported to veal calf rearing systems in countries such as Belgium and the Netherlands. However, it is likely that access to these markets may change over the coming years, in particular due to changes in European law regarding animal welfare. Surplus calves are 'in the eye of the storm' in the animal welfare debate and the upcoming change towards a minimum age of 28 days before transport is allowed may cause substantial change in the industry (EFSA, 2023). In general, these surplus calves are purchased in the pre-weaning period either directly from the farm of origin or through marts. In contrast to the mainland EU system of white veal calves, the Irish dairy beef system aims for early finishing age (20 months) with a predominantly grass based diet. Although this system is different to the veal calf production system, the main difference is just nutritional (Renaud and Pardon, 2022). The challenges related to transporting and mixing calves from multiple sources at high stocking density are identical, and make both industries dependent on (metaphylactic) antimicrobial use to maintain calves healthy and productive.

Respiratory tract infections (Bovine respiratory disease (BRD)) in calves/cattle are the leading cause of morbidity and a frequent cause of mortality in every cattle production system, but especially in those commingling animals from different sources. The pressure to reduce antimicrobial use stimulates a shift away from group antimicrobial treatment towards individual treatment. In recent years, the use of thoracic ultrasonography (TUS) in both research and applied on farm, became a real game changer. In contrast to any detection system based on clinical signs, TUS directly visualizes pneumonia with the highest diagnostic accuracy of all tests available on farm (Ollivett and Buczinski, 2016). Limiting antimicrobial therapy to calves with pneumonia is the cornerstone of rational use of antimicrobials. In this paper new insights and possible advances relevant to the dairy beef industry that originate from new research using TUS will be shared.

Preparing calves for the dairy beef and veal industry

For decades, it has been recognised that there is substantial variation between calves in regard to disease risk and production (Renaud and Pardon, 2022). Calves can be categorized into high and low-risk calves for disease based on multiple factors, of which body weight, failure of transfer of passive immunity status, presence of lung consolidation on TUS and vaccination have the largest impact (Renaud and Pardon, 2022).

Body weight has a substantial link with disease and mortality, evident in the majority of studies (but not all) (Renaud and Pardon, 2022). Based on available evidence a body weight of 50 kg was advised as a threshold to determine suitability for movement in calves under three weeks of age (Renaud and Pardon, 2022). However, the diagnostic accuracy of this cut-off remains low, meaning that it cannot be used to predict disease. Calves with a normal bodyweight, compared to lightweight calves, were better able to cope with transport stress and did not mount an acute phase response, resulting in lower odds of chronic pneumonia (Masmeijer *et al.*, 2021). Feeding practices are often different for females and males with the latter receiving less milk and more often raw or unsalable milk (Wilson *et al.*, 2023). Body weight may be underestimated in animals that are dehydrated upon arrival, which is mainly a risk in longer transports (> 110 km) (Maggard *et al.*, 2024; Ramos *et al.*, 2023). The relationship between body weight and disease is more consistently found compared to the relationship between age and disease. Both very young (more prone to diarrhoea and sepsis (Goetz and Renaud, 2024)) and older calves (e.g. one month) may have increased disease risk. Hence, it is currently unclear whether the new recommended minimum age (28 days) for transport will improve or aggravate the situation by increasing the number of calves arriving with pneumonia (EFSA, 2023). Calves should arrive in a healthy state. In veal calves, aged 2-3 weeks, around 17-19% already have lung consolidation upon arrival, which was linked with lower average daily gain and higher odds to develop chronic pneumonia (Jourquin *et al.*, 2023a; Jourquin *et al.*, 2023b). The majority of pneumonia present in calves is subclinical, typically there are three subclinical cases for each clinical case (Jourquin *et al.*, 2023b). These facts highlight the importance of using TUS to identify calves with pneumonia in a timely manner. Upon arrival lung scanning not only aids in early detection of pneumonia cases, but can also provide valuable feedback to the herds of origin and put pressure on prices.

Every farmer and agricultural consultant knows how important colostrum delivery is for early life health, with effects lasting up to puberty. This is a fact both for females as it is for males. However, a Canadian study showed that despite producers declaring equal feeding and care for male calves, the prevalence of failure of passive transfer of immunity (FPT) was higher in males, likely due to later delivery of less colostrum (Cheng *et al.,* 2024). The proportion of male calves arriving with FPT is substantial ranging between 16 and 40% (Maggard *et al.,* 2024). Between two and seven days of age FPT can be diagnosed by means of cheap tests such as total protein or brix measurement, but at the age of 2-3 weeks these tests can no longer be used due to the increase of albumin and decrease of γ-globulins (Pardon *et al.,* 2015). However, tests that directly determine γ-globulins or immunoglobulin G can still be useful. An association between γ-globulin levels < 7.5 g/L and an increased risk for clinical BRD was repeatedly found (Pardon *et al.,* 2015). In contrast, more recent work could not confirm this relationship with neither clinical BRD nor lung consolidation in a 442 head veal calf herd (Lowie *et al.,* 2024).

Either through appropriate colostrum delivery, early life infection or vaccination calves can arrive at the dairy beef or veal facilities with specific antibodies against respiratory pathogens. A seropositive status for bovine coronavirus (BCV) and bovine respiratory syncytial virus (BRSV) was associated with a reduction in the risk for clinical BRD in the first weeks after arrival by half (Pardon *et al.,* 2015). These results were recently confirmed for both viruses for the presence of lung consolidation, with calves seropositive for BCV and BRSV having reduced odds of 0.37 and 0.58, respectively (Lowie *et al.,* 2024). Vaccination on the farm of origin is the most logical option, conferring onset of immunity before confrontation with the pathogens. However, to-date the most practical option is to vaccinate upon arrival, a timing which in theory would be inefficient. However, a recent study in veal calves evidenced that vaccination upon arrival, intranasally or intramuscularly, followed by a booster one month later, reduced the odds of chronic pneumonia as detected by TUS in week 10 of production by 41% and 62%, respectively (Jourquin *et al.,* 2023a). Vaccination is certainly a key preventive measure, for which more studies are needed to identify the best schemes and vaccines for this purpose.

Dairy beef facilities, like veal calf farms, are with increasing herd size systematically confronted with basically all pathogens, (Pardon *et al.,* 2011). An annual BRSV epidemic typically occurs between November and April, peaking around December. In contrast BCV occurs in epidemic waves year round (Pardon *et al.,* 2020). Regardless of the time of the year, *Mycoplasmopsis bovis* (previously *Mycoplasma bovis*) is the most typical and systematic pathogen to be identified in any production system based on purchase and commingling of calves. In the EU mainland, prevalence is almost 100% in the veal calf industry. Recent estimates from McAloon *et al.* (2022) suggested that approximately 45% of dairy herds in Ireland are positive for *M. bovis*, which would lead to the logical consequence of a very high *M. bovis* incidence in Irish dairy beef farms. Because infection with *M. bovis* commonly occurs in the first weeks of life and because it can cause chronic pneumonia leading to losses in productivity, prevention (as opposed to treatment) of *M. bovis* is of paramount importance. Recently a vaccine for *M. bovis* became available in the EU, but whether it can be practically applied and will be effective under the challenging conditions of the dairy beef or veal industry remains to be seen.

Despite all this knowledge on factors to prepare calves for the dairy beef or veal industry, at least in the veal calf industry, the communication between dairy farms of origin and veal farms remains difficult. Programs aiming at selling low risk calves for a higher price have not been sustainable, or even not been initiated. Likely economic or just practical reasons given the complex trade structure are the explanation for this. Nevertheless, preconditioning/better preparing calves, before transport is clearly the key-factor in order to give the classic production system of commingling the calves another chance, before a complete rethinking of the system is due, due to the pressure to reduce antimicrobial use and improve animal welfare within the EU. Last but not least, there appears to be a direct effect of the auction market, or in extension the calf sorting centre, on the health status and body condition upon arrival (Ramos *et al.,* 2023). Equally important as preparing the calves for a life in the fattening farms is their preparation for transport and the conditions of that transport. Calves 'fit for transport' are clinically healthy, have a good body weight, no FPT, no lung consolidations on TUS and are vaccinated against respiratory pathogens. Proper transport holds multiple factors related to animal welfare which are outside the scope of this paper. The current mainstream thinking is that limiting the travel distance and the number of stops is key for health and welfare. However, a recent randomised clinical trial comparing a 16 h long-haul transport with a two times 8 h with an 8 h resting period in between could not evidence health or growth differences (Goetz and Renaud, 2024). Calves with the resting period did spend more time lying after arrival, potentially referring to more fatigue.

Disease detection and therapy

The incidence of respiratory disease is high in veal and dairy beef calves and because of the rapid spread and large numbers of animals present metaphylactic antimicrobial therapy remains a cornerstone of health management. However, pressure to reduce and rationalise antimicrobial use is high with a shift away from group antimicrobial treatments to individual treatments desired. After all, a meta-analysis on the efficacy of metaphylaxis in feedlots concluded only marginal gains with potentially high costs for public health (Baptiste and Kyvsgaard, 2017). Rational antimicrobial use would signify only treating calves unlikely to self-cure from a bacterial pneumonia with antimicrobials.

For decades individual treatment was based on clinical signs and since 2012, at least for research, scoring systems like the Wisconsin score have been used to standardise better. However, a recent study looking in dairy, veal and beef calves (both pre- and post-weaning) at clinical signs associated with pneumonia on TUS and evaluating existing clinical scoring systems showed very poor results for the scoring systems, only performing as well as cough as a single sign (Lowie *et al.,* 2022). The conclusion is that TUS is the optimal tool for timely and accurate identification of animals with pneumonia. A study in veal calves showed that as many as 80% of the calves develop pneumonia during production of which 70% presents as subclinical (Jourquin *et al.,* 2023b). A recent Irish study showed that calves with clinical BRD already 10 days earlier had subclinical pneumonia (Cuevas-Gomez *et al.,* 2021). Calves with clinical signs have higher odds for severe pneumonia (lung consolidations ≥ 3 cm in depth) and lower cure (Jourquin *et al.,* 2022). Also from our own follow-up in dairy farms the lesson "early detection, shorter treatment, better cure" was learned. Availability of TUS offers a completely different dimension to randomised clinical trials evaluating therapies and vaccines, showing meaningful effects where effects on clinical BRD are absent (Jourquin *et al.,* 2023a). TUS offers other possibilities to individualise antimicrobial therapy. In a trial in beef calves, the efficacy of florfenicol and oxytetracycline were compared in a TUS-guided approach in which antimicrobial therapy was stopped as soon as cure (defined as full lung reaeration) was reached (Jourquin *et al.,* 2022). A reduction of antimicrobial use compared to a standard seven day metaphylactic therapy of 64.5% and 50% was reached, respectively. Results of an unpublished study testing this approach in a veal farm setting will be shown at the conference.

Barn climate

Few farmers and veterinarians need to be convinced how important barn climate is for respiratory health, however, evidence on what factors are associated with pneumonia is actually scarce. Only a handful of TUS studies are available. In the study of van Leenen *et al.* (2020) wind speed at a cut off ≥ 0.8 m/s, measured at a single time point at the level of the animals, was associated with lung consolidation (odds ratio (OR) = 6.8 (95% C.I. = 1.2 - 38.5)). This cut off is substantially higher than the frequently used recommendation of 0.3 m/s. Also, ammonia was associated with lung consolidation, but not as a one-time point measurement. A 24 h measurement was needed and the time above an ammonia level of 4 ppm (much lower than the olfactory limit and then reported in earlier studies) was associated with lung consolidation (van Leenen *et al.,* 2020). Surprisingly, not a colder but a higher average temperature was associated with pneumonia in that study. In this work air bacterial count could not be associated with lung consolidation, which is in contrast to the original study which used clinical BRD as outcome factor (Lago *et al.,* 2006; Buczinski *et al.,* 2018). Also for CO_2 measurements and relative humidity no associations with lung consolidations were evidenced.

Given the many publications on the impact of particulate matter (PM) (fine dust) on human health, it is surprising to notice that the effects of PM on calf respiratory health are hardly explored. Van Leenen and coworkers determined PM_{10} in calf barns and found them (PM_{10}: average of 70 µg/m^3; $PM_{1.0}$: average of 16.3 µg/m^3) to be substantially lower than in pig and poultry housings (van Leenen *et al.,* 2021). However, exposure to $PM_{1.0}$ (ultrafine dust) was associated with lung consolidation ≥ 1 cm (OR = 3.3 (95% C.I. = 1.5 - 7.1)). In the same study airborne endotoxin was measured and also was positively associated with lung consolidation (OR = 13.9 (95% C.I. = 3.4 - 58.8) at a cut off of 8.5 EU/µg). The PM_{10} was associated with neutrophilia in broncho-alveolar lavage cytology, and $PM_{2.5}$ with *Pasteurella multocida* infection of the lower airways (van Leenen *et al.,* 2021). Clearly, the handful of studies is not sufficient to establish a good reference framework for healthy air, but it does give a direction. These results point to the fact that measurements of ammonia, PM, temperature and wind speed are most valuable when evaluating housing systems. In a recent study Mahendran and coworkers evaluated three dairy calf housing systems (shed, polytunnel, hutches) in summer and winter (Mahendran *et al.,* 2023). Exposure to heat stress was much higher in polytunnels and hutches compared to sheds. Lowest temperatures were detected in hutches, with no increase compared to the outside temperature. Both PM concentration and air bacterial count were highest in sheds, and lowest in polytunnel housing (Mahendran *et al.,* 2023). Design of an optimal calf housing system, both for summer and winter conditions, remains a huge challenge.

Is TUS realistic on farm?

In the author's humble opinion that is absolutely the case. The devices are the same as those for reproduction and scanning protocols with the focus on speed have been developed for use in larger groups. However, motivation and perseverance are needed, especially in the current situation with many bovine practitioners already overloaded with work. TUS can't be learned overnight. It requires training, part in theory, but mainly through practical sessions. The quick-TUS method has been evaluated in novice practitioners, showing reasonable diagnostic performance (sensitivity of 66% and specificity of 71%) after online and practical training (Jourquin *et al.,* 2024). In order to really be able to make a difference, to rationalize antimicrobial use, we absolutely need to ascertain that an operator can reliably apply TUS. Regular certification of one's TUS skills would be desirable, especially if TUS monitoring would be related to labels for animal welfare or sustainable production or be used as reference test for sensor development (which is recommended).

Conclusion

TUS provided multiple insights into BRD, starting with the awareness of the 'iceberg under the water' that subclinical pneumonia is, over the effects of barn climate, vaccines and antimicrobial treatment on pneumonia to the development of sensor technology. TUS findings have emerged as a cornerstone of BRD research but they should also be considered as a key strategic innovation for on farm use by cattle veterinary practices.

References

Baptiste, K.E., Kyvsgaard, N.C. (2017). Do antimicrobial mass medications work? A systematic review and meta-analysis of randomised clinical trials investigating antimicrobial prophylaxis or metaphylaxis against naturally occurring bovine respiratory disease. *Pathog Dis* **75.**

Buczinski, S., Borris, M.E., Dubuc, J., *et al.* (2018). Herd-level prevalence of the ultrasonographic lung lesions associated with bovine respiratory disease and related environmental risk factors. *J Dairy Sci, 101*:2423-2432.

Cheng, T.Y., Renaud, D.L., Proudfoot, K.L., Pempek, J.A., Habing, G.G. (2024). Dairy producers' colostrum practices, marketing, and attitudes toward male dairy calves. *J Dairy Sci*, **107:**3885-3898.

Cuevas-Gomez, I., McGee, M., Sanchez, J.M., O'Riordan, E., Byrne, N., McDaneld, T., Earley, B. (2021). Association between clinical respiratory signs, lung lesions detected by thoracic ultrasonography and growth performance in pre-weaned dairy calves. *Ir Vet J.,* **74**:7.

EFSA panel on animal health and animal welfare (AHAW); Nielsen, S.S., Alvarez, J., Bicout, D.J., Calistri, P., Canali, E., Drewe, J.A., Garin-Bastuji, B., Rojas J.L.G., Schmidt C.G., Herskin, M., Michel, V., Chueca, M.A.M., Padalino, B., Pasquali, P., Roberts, H.C., Spoolder, H., Stahl, K., Velarde, A., Viltrop, A., Jensen, M.B., Waiblinger, S., Candiani, D., Lima, E., Mosbach-Schulz, O., Van der Stede, Y., Vitali, M., Winckler, C. , 2023. Welfare of Calves. Efsa J.

Goetz, H.M., Renaud, D.L. (2024). A randomized controlled trial evaluating the effect of providing a rest period during long-distance transportation of surplus dairy calves: Part I. Impact on health, growth, and activity. *J Dairy Sci.* In Press.

Jourquin, S., Bokma, J., De Cremer, L., van Leenen, K., Vereecke, N., Pardon, B. (2022). Randomized field trial comparing the efficacy of florfenicol and oxytetracycline in a natural outbreak of calf pneumonia using lung reaeration as a cure criterion. *J Vet Intern Med,* **36:**820-828.

Jourquin, S., Lowie, T., Bokma, J., Pardon, B. (2024). Accuracy and inter-rater agreement among practitioners using quick thoracic ultrasonography to diagnose calf pneumonia. *Vet Rec.,* **194**: e3896.

Jourquin, S., Lowie, T., Debruyne, F., Chantillon, L., Clinquart, J., Pas, M.L., Boone, R., Hoflack, G., Vertenten, G., Sustronck, B., Pardon, B. (2023a). Effect of on-arrival bovine respiratory disease vaccination on ultrasound-confirmed pneumonia and production parameters in male dairy calves: A randomized clinical trial. *J. Dairy Sci.,* **106:**9260-9275.

Jourquin, S., Lowie, T., Debruyne, F., Chantillon, L., Vereecke, N., Boyen, F., Boone, R., Bokma, J., Pardon, B. (2023b). Dynamics of subclinical pneumonia in male dairy calves in relation to antimicrobial therapy and production outcomes. *J. Dairy Sci.,* **106:**676-689.

Lago, A., *et al.* (2006). Calf respiratory disease and pen microenvironments in naturally ventilated calf barns in winter. *J. Dairy Sci.,* **89**:4014-4025.

Lowie, T., Jourquin, S., Debruyne, F., Chantillon, L., Hoflack, G., Boone, R., Vertenten, G., Sustronck, B., Pardon, B., Bokma, J. (2024). Associations of serostatus upon arrival with clinical respiratory disease, lung consolidation, and growth in veal calves. *J. Dairy Sci.,* **107**:3836-3846.

Lowie, T., Van Leenen, K., Jourquin, S., Pas, M.L., Bokma, J., Pardon, B. (2022). Differences in the association of cough and other clinical signs with ultrasonographic lung consolidation in dairy, veal, and beef calves. *J. Dairy Sci.,* **105**:6111-6124.

Maggard, H.L., Habing, G.G., Renaud, D.L., Proudfoot, K.L., England, Z.A., Cheng, T.Y., Wilson, D.J., Moran, M., Pempek, J.A. (2024). Condition of surplus dairy calves during marketing: A cross-sectional study. *J. Dairy Sci.,* **107**:2444-2453.

Mahendran, S.A., *et al.* (2023). Comparison of environment quality measurements between 3 types of calf housing in the United Kingdom. *J. Dairy Sci.,* **106**:2461-2474.

Masmeijer, C., Deprez, P., van Leenen, K., De Cremer, L., Cox, E., Devriendt, B., Pardon, B. (2021). Arrival cortisol measurement in veal calves and its association with body weight, protein fractions, animal health and performance. *Prev Vet Med.,* **187**:105251.

McAloon CI, McAloon CG, Tratalos J, O'Grady L, McGrath G, Guelbenzu M, Graham DA, O'Keeffe K, Barrett DJ, More SJ. Seroprevalence of Mycoplasma bovis in bulk milk samples in Irish dairy herds and risk factors associated with herd seropositive status. *J Dairy Sci.* 2022 Jun;**105(6):**5410-5419. doi: 10.3168/jds.2021-21334. Epub 2022 Mar 26. PMID: 35346476.

Ollivett, T.L., Buczinski, S. (2016). On-Farm Use of Ultrasonography for Bovine Respiratory Disease. Vet Clin North Am Food Anim Pract., **32**:19-35.

Pardon, B., Alliet, J., Boone, R., Roelandt, S., Valgaeren, B., Deprez, P. (2015). Prediction of respiratory disease and diarrhea in veal calves based on immunoglobulin levels and the serostatus for respiratory pathogens measured at arrival. *Prev Vet Med***., 120**:169-176.

Pardon, B., Callens, J., Maris, J., Allais, L., Van Praet, W., Deprez, P., Ribbens, S. (2020). Pathogen-specific risk factors in acute outbreaks of respiratory disease in calves. *J. Dairy Sci.,* **103**:2556-2566.

Pardon, B., De Bleecker, K., Dewulf, J., Callens, J., Boyen, F., Catry, B., Deprez, P. (2011). Prevalence of respiratory pathogens in diseased, non-vaccinated, routinely medicated veal calves. *Vet Rec.,* **169**:278.

Ramos, J.S., Villettaz-Robichaud, M., Arsenault, J., Chorfi, Y., Costa, M., Dubuc, J., Ferraro, S., Francoz, D., Rousseau, M., Fecteau, G., Buczinski, S. (2023). Health indicators in surplus calves at the time of arrival at auction markets: Associations with distance from farms of origin in Québec, Canada. *J. Dairy Sci.,* **106**:7089-7103.

Renaud, D., Pardon, B. (2022). Preparing Male Dairy Calves for the Veal and Dairy Beef Industry. *Vet Clin North Am Food Anim Pract*., **38**;77-92.

van Leenen, K., *et al.* (2020). Associations of barn air quality parameters with ultrasonographic lung lesions, airway inflammation and infection in group-housed calves. *Prev Vet Med*., **181**:105056.

van Leenen, K., *et al.* (2021). Particulate matter and airborne endotoxin concentration in calf barns and their association with lung consolidation, inflammation, and infection. *J. Dairy Sci.,* **104**:5932-5947.

Wilson, D.J., Pempek, J.A., Cheng, T.Y., Habing, G., Proudfoot, K.L., Winder, C.B., Renaud, D.L. (2023). A survey of male and female dairy calf care practices and opportunities for change. *J. Dairy Sci.,* **106**:703-717.

Parasite control in young cattle – similar issues in Ireland and New Zealand

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Gastrointestinal nematodes

Gastrointestinal nematodes (gut worms) are the most common and important parasites of cattle. Very few, if any, pastures will not be contaminated with parasite larvae all year round so grazing calves will always be exposed to them. The life cycle of these worms is quite simple, with a parasitic (in the host) phase and a free-living (on pasture) phase. Adult worms living in the gut produce eggs, which pass out of the animal in faeces. Some of these hatch and the first two larval stages feed on bacteria in the faeces. The eggs, first (L1) and second (L2) larval stages are quite susceptible to adverse weather conditions (excessive heat or cold, or desiccation) and predation, and most do not survive. The third larval stage (L3), however, retains the outer skin from the second stage which means it cannot feed, but makes these larvae very tough and they can survive long periods of adverse conditions. The L3 migrate onto herbage from where they can be ingested by grazing livestock. If the host is suitable, the infective larvae exsheath and undergo further moults to reach the adult stage and the life cycle is complete.

Third stage larvae can survive long periods (many months in temperate climates) on pasture, and they can survive even longer in faeces and in soil which, in many parts of the world, serve as reservoirs of infection. Even if adverse conditions (e.g. a long hot dry spell of weather) makes pastures relatively clean of worm larvae, those present in faeces and soil can still migrate back onto pasture when the weather breaks. A common occurrence on New Zealand farms is an outbreak of 'worms' soon after it rains following a long dry spell over summer, when the rains allow larvae to migrate out of faeces and soil onto herbage. This persistence of larvae on pasture makes worm management more difficult because although anthelmintic (wormer) treatment may remove all the worms in the animals they are soon reinfected from the population of larvae on pasture.

Minimising this reinfection of animals with larvae on pasture is a key focus of managing parasites to achieve high growth rates with minimal use of wormers

There are numerous parasite species infecting cattle but the two most economically important species of gut worms in Ireland and many other countries are *Cooperia oncophora,* which lives in the small intestine, and *Ostertagia ostertagi,* which lives in the abomasum. These parasites differ in their biology in ways that can be quite important.

Cooperia species (there are several) are usually the most numerous worms in cattle under 1 year of age. Although *Cooperia* is generally regarded as the least pathogenic (damaging) of the cattle worms, if numbers build up, they can be very damaging, causing severe scour, lack of growth and even deaths. This worm has increased in importance globally, due to its propensity to become resistant to anthelmintic drugs (Sutherland and Leathwick, 2011). In New Zealand today, simultaneous resistance to benzimidazole, levamisole and macrocyclic lactone (ML) wormers is known to occur in *Cooperia* on some farms and is likely increasing. All the farms where this has occurred have, so far, been monocultures of cattle with large numbers of calves grazing together i.e. **certain farming systems are more likely to result in worm resistance to anthelmintics**. The issue of anthelmintic resistance on Irish cattle farms has received less attention than in New Zealand but ivermectin resistant *Cooperia* are now common on both dairy and dairy beef farms while *Cooperia* resistant to benzimidazole and levamisole have also been identified (O'Shaughnessy *et al.,* 2019; Kelleher *et al.,* 2020).

In *Cooperia*, this widespread development of resistance can be linked to the worm's biology and the common ways in which calves are raised on farms. When young cattle ingest infective *Cooperia* larvae with pasture, the larvae develop to adult worms which then act to block the establishment of new larvae (Sauermann *et al.,* 2018). If the animals are treated, worms susceptible to the drug are removed but resistant worms remain. Because most worms have been removed, a new crop of larvae is then able to establish (from pasture), some of which will be resistant. If this occurs repeatedly over a season the number of resistant worms in the calves increases and they continue passing resistant eggs onto the pastures. Thus, under regular treatment the pastures become progressively contaminated with resistant, but fewer susceptible, worm larvae over the summer-autumn. Whether animals are housed or not over winter no more eggs develop due to cold temperatures and by the following spring the animals are becoming increasingly immune to *Cooperia* infection and so even if they are infected, they pass few eggs onto pasture to develop. So, each new crop of young (weaner) calves is exposed to larvae on pasture which are largely derived from the calves repeatedly drenched over the previous summer-autumn. Many of these larvae are derived from adult worms which survived one or more drug treatments.

In contrast, *Ostertagia* has quite a different biology. For this worm, the presence of adult worms does not prevent new larvae from establishing, in fact ingestion of new larvae tends to cause adult worms to be pushed out of the animal, to be replaced by a new generation of adults. Hence adult worms surviving a wormer treatment tend to not live so long as they are continuously replaced. Further, cattle don't develop strong immunity to *Ostertagia* until the end of the second grazing season. Therefore, each spring older cattle (now yearlings) continue to pass eggs onto pasture, and as these animals get few anthelmintic treatments these eggs are likely to have a larger proportion which are susceptible to drugs (these worms would be '**in refugia'**).

These differences in worm biology and in farming systems where most anthelmintic treatments are given to calves, are the likely reason for resistance being very common in *Cooperia oncophora* but less common in *Ostertagia ostertagi*. It follows, then, that integrated grazing of young cattle with either older cattle or sheep, which reduces the number of *Cooperia* larvae on pasture and necessitates fewer treatments with wormers, should slow the development of resistance in this parasite.

The prevalence of anthelmintic resistance on beef farms in Ireland and New Zealand is similar, probably reflecting the way young cattle are farmed in both countries (Table 1).

Table 1. Prevalence of anthelmintic resistance in gastrointestinal nematodes on beef farms

	Benzimidazole	*Levamisole*	*Macrocyclic Lactone*
Ireland	60%*§	18%*	100%*§
New Zealand	76%*§	6%*§	>92%*§

**Resistant Cooperia detected; §Resistant Ostertagia detected*

Another factor which is likely to be contributing to the development of resistance in cattle parasites is how anthelmintics are administered. Around the world, products are registered as oral, injectable and topical (pour-on) formulations, and all will be registered on the basis that they kill worms susceptible to the active(s) they contain. **But that does not mean all products are the same**. It has become apparent that the concentrations of active drug components reaching the tissues of parasite location and found within the parasites themselves can vary significantly depending on how they were administered (Bogan and McKellar, 1988; Gokbulut *et al.*, 2010; Lloberas *et al.*, 2012; Lifschitz *et al.*, 2017). How effective drugs are against resistant worm genotypes can have major influences on the rate at which resistance builds up within a worm population (Georghiou and Taylor, 1977; Barnes *et al.*, 1995; Smith *et al.*, 1999; Leathwick and Luo, 2017). On-farm trials in New Zealand found that against *Cooperia oncophora*, orally administered ML products had higher efficacy than pour-ons or injections (Leathwick and Miller, 2013; Leathwick *et al.*, 2016), a consequence of oral administration resulting in higher concentrations of actives reaching the worms in the gut (Lloberas *et al.*, 2012; Leathwick *et al.*, 2020). However, this is not the case for all worm species. Injectable ML products get higher concentrations of drug to the gut mucosa, which is where *Ostertagia* species tend to live, and so injectables are associated with higher concentrations of active reaching these worms (Leathwick *et al.*, 2020). Both are superior to pour-ons; this route of administration is associated with greater variation in drug uptake, primarily due to ingestion of the drug by licking (either self or other animals) but also due to variation in absorption (hide thickness, hair length and dirt) and weather conditions (Laffont *et al.*, 2001). Efficacy of pour-ons is often lower in winter when temperatures are lower (Sargent *et al.*, 2009). Based on these results, in New Zealand today **it is recommended that in calves (where *Cooperia* is the primary target) anthelmintics should be orals, but in older cattle where *Ostertagia* is the target worm species, treatments should be by injection. Use of pour-ons is not recommended.**

When selecting an anthelmintic product, the persistency of the product should also be considered. Worms that survive drug treatment continue to shed eggs onto the pasture contaminating it with resistant genotypes until susceptible worms are ingested, mature and start to reproduce. Persistent products prevent the establishment of susceptible but not resistant worms thus increasing the period during which only eggs from resistant worms are shed (Dobson *et al.*, 1996). Therefore, such products have the potential to select for anthelmintic resistance if used inappropriately.

Detecting resistance is an important practice for farmers because using anthelmintics which are not working properly costs money through slower growth rates and allows the continued build-up of resistant worms on the farm. This is particularly important when resistance is common, as is the case in Ireland (Kelleher *et al.*, 2020). In a productivity study in New Zealand, using an ML pour-on (eprinomectin) which didn't effectively control *Cooperia* (mean efficacy = 51%) resulted in reductions in liveweight at 18 months of age between 0 and 13 kg (Candy *et al.*, 2018). These numbers are less than measured in other studies (Coop *et al.*, 1979; Armour *et al.*, 1987) probably reflecting the high levels of feeding in the study and emphasising the importance of nutrition in managing parasitism. It is note-worthy that all the recent cases of resistance diagnosed on New Zealand cattle farms were discovered because of overt clinical disease indicating that, if conditions allow, *Cooperia* can build up enough to cause serious problems.

Detecting resistance usually involves collecting faecal samples before and after anthelmintic treatment and calculating the percentage reduction in egg count as an estimate of effectiveness (Faecal Egg Count Reduction Test (FECRT)). However, these tests are often carried out in different ways, and some are far less informative than others. Current recommendations are that individual samples from the same 10 or more animals should be counted for FEC both before and after treatment (Kaplan *et al.,* 2023). This enables the calculation of confidence intervals around the efficacy estimate which are helpful in interpreting situations where resistance is not obvious e.g., when efficacy estimates are around 90-96%. Unfortunately, just counting the number of eggs present, even individual sample counts, can still miss detecting resistance. Larval cultures to measure the worm species present adds greatly to the usefulness of the test. For example, one on-farm FECRT recorded egg counts pre- and post- treatment with ivermectin of 185 and 5 eggs per gram (Waghorn *et al.,* 2016) which equates to a 97% reduction (i.e. susceptibility). But when the egg counts were apportioned based on the percentage of worm species in pre- and post-treatment faecal cultures the efficacy against *Ostertagia* was only 88% (i.e. resistance). Hence, resistance in the most important parasite of cattle would have been missed without the use of faecal cultures in the test. Even worse, this would likely have resulted in the farmer continuing to use an ineffective treatment, all the time believing that it still worked, and resulting in the continued escalation of resistance on his farm. Farmers are often reluctant to pay for what they see as expensive testing, but the longer-term cost of not detecting resistance early, far outweighs the investment in testing.

The same argument can be applied to using FEC to make decisions on whether to treat animals or not. Counting the number of eggs passed in faeces is easy but interpreting what the number means can be **one of life's great mysteries**. Obviously, if egg counts are very high or low, then making decisions about whether to treat or not can be straightforward. However, counts are often in the 'zone of uncertainty' where it is not clear whether a diagnosis of 'treat' is justified. A definitive threshold for treatment is seldom accurate because of the different species contributing to the egg count. Some species produce many eggs but are not very pathogenic (e.g. *Cooperia*) whilst others produce few eggs but cause substantial harm if numbers get high (e.g. *Ostertagia*) so relating worm impacts back to number of eggs counted will never be exact. Waiting weeks for a faecal culture and larval identification is often unacceptable to farmers (rightly so) so one approach used in New Zealand is to make a decision to treat or not based on visual signs (stockmanship) but to collect samples for FEC and culture, and then retrospectively evaluate the decision i.e. 'did I do the right thing?'. In this way farmers learn whether they are making good decisions on their farm without taking any risk from not treating. It is surprising how often farmers that do this regularly discover that what they 'see' as worms is, in fact, other problems such as trace element deficiency or pneumonia. **Monitoring leads to knowledge which leads to better decisions.**

As noted above, managing the cycle of reinfection from pasture is key to minimising parasite infection, maximising production and reducing anthelmintic inputs. Paddocks which have been cultivated for new grass or cut for hay or silage tend to have lower numbers of infective parasite larvae by virtue of not having been grazed for longer periods. Alternatively, grazing pastures with different age classes or species of livestock allows for the ingestion of parasite larvae by hosts which are unsuitable for their development. Thus, sheep can be used to 'clean' pastures of cattle worms and vice versa. Also, older cattle can be used to reduce *Cooperia* numbers on pastures because their more developed immunity will prevent larvae from establishing. Numerous combinations of integrated grazing are possible, but these tend to be specific to individual farms and so generalisations are difficult. What is clear is that running monocultures of a single species and stock class is the most difficult, most likely to require high anthelmintic inputs and most likely to result in the emergence of resistance.

Lungworm

Lungworm is another roundworm but is somewhat different to the usual gut worms. The parasite is widespread, and infections can be sudden and severe. As with other parasitic nematodes, infection is acquired by the ingestion of infective larvae from pasture, but with lungworm the epidemiology is complex, and outbreaks are often more unpredictable and more strongly linked to weather and the availability of moisture.

The lifecycle begins with adult worms in the lungs which produce eggs. These are coughed up and swallowed to then pass down the gastrointestinal tract. During passage the eggs hatch and L1 larvae are passed in the faeces, rather than eggs. **This is important because the normal egg counting method used to test for gut nematodes does not find lungworm larvae – you need a separate test to look for lungworm**. The larvae in freshly voided faeces tend to be sluggish and do not need to feed. The L3 stage can be reached within five to seven days but often takes longer at lower temperatures. The L3 can migrate from the faeces onto the herbage by themselves or by airborne spread utilising the fungus *Pilobolus*. If larvae are eaten, they penetrate the intestinal mucosa, and travel to the lungs where they moult to mature into adults between three and four weeks after infection.

In New Zealand, outbreaks of lungworm disease are relatively rare and difficult to predict. Most outbreaks occur in very young animals which have no previous experience of lungworm challenge. After that, symptoms are often (nearly always) associated with some other factor such as underfeeding (e.g., drought), infections such as Johne's disease or bovine viral diarrhoea, or mineral / trace element deficiencies. It is speculated that these 'other factors' affect the animal's immunity enabling the lungworm to flourish. In Ireland, lungworm outbreaks are more common but, as in New Zealand, calves are most at risk as they have not yet developed any immunity. Some recent work in deer (Chambers *et al.,* 2023) showed that lungworms are often present in a high proportion of healthy animals but at such low levels that they are unseen. Although this was done in deer rather than cattle, it supports the idea that healthy animals with good immunity are able to suppress lungworm to very low levels. It follows then that **maintaining stock in otherwise good health with adequate nutrition is a foundation for managing lungworm**.

Fortunately, lungworm are easy to control with anthelmintics, especially with MLs. Most ML anthelmintics will also have a degree of persistent activity against lungworm which may vary from 3-17 weeks (Campbell *et al.,* 2024) depending on the product. Fortunately, resistance in lungworm is rare, but it has been reported (Campbell *et al.,* 2024) so excessive reliance on anthelmintics is probably unwise.

As mentioned above, monitoring for lungworm requires a test different to that used for gut worms, although both tests can usually be run on the same sample. The test is labour intensive and as it is recommended that individual samples from a number of animals are taken (Sabatini *et al.,* 2023), monitoring for lungworm is potentially expensive. Also, although the test is quite sensitive in cattle, because the larvae are fragile (compared to gut nematodes), the samples must be transported and stored with care to prevent false negative results (Rode & Jorgensen, 1989). Persistent cough is the most common clinical sign of lungworm infection. Given the caveats associated with the diagnostic test, calves coughing while at grass are commonly treated for lungworm.

Liver fluke

Liver fluke, which is a flat worm, has quite a different lifecycle to the nematodes discussed above in that it requires an intermediate host – one of several species of snail. Because the fluke life cycle is dependent on presence of the snail, management practices can be useful in reducing risk. Fencing off wetter areas (springs, marshy areas, water courses) to keep stock away from snail habitat, especially those areas where animals graze when feed is short or restricting access to these areas during high risk periods (autumn) will reduce risk. Keep water troughs clean and free from snails and their habitat e.g., rank grass. If you don't have fluke on the farm, try to avoid introducing infected animals onto your property e.g., a quarantine treatment with an effective flukicide and keep them in a quarantine paddock for a day or two.

You can monitor fluke infections using either faecal samples to check for fluke eggs, a blood test for antibodies, or reports on liver damage from animals sent for slaughter. However, the period between initial infection and egg appearance (pre-patent period) is 10-12 weeks and faecal samples will test negative during this period. In addition, egg counts for fluke in cattle don't correlate well with infection levels as egg production by adult worms can be erratic. Normally samples from several animals (10-20) where you record the number of animals with a positive count can be helpful i.e., if 20% of animals are positive then a treatment might be worthwhile. Many farmers rely on reports of liver damage from animals sent to slaughter to decide on an annual strategic treatment. The winter housing period generally represents an opportunity to clear any liver fluke infection and prevent egg shedding the following spring. Different flukicides have efficacy against different stages of fluke and it is important to ensure the product used targets the correct stages of fluke. Resistance in flukes is known in cattle, and more so in sheep with triclabendazole resistant liver fluke identified in Ireland (Mooney *et al.,* 2009) so care and sound advice around flukicide use is warranted.

References

Armour, J., Bairden, K., Holmes, P.H., Parkins, J.J., Ploeger, H., Salman, S.K., and McWilliam, P.N. 1987. Pathophysiological and parasitological studies on *Cooperia oncophora* infections in calves. *Research in Veterinary Science*, **42 (3):**373-381.

Barnes, E.H., Dobson, R.J., and Barger, I.A. 1995. Worm control and anthelmintic resistance: adventures with a model. *Parasitology Today*, **11(2):** 56-63.

Bogan, J.A., and McKellar, Q.A. 1988. The pharmacodynamics of ivermectin in sheep and cattle. *Journal of Veterinary Pharmacology and Therapeutics,* **11(3):**260-8.

Campbell, P., Forbes, A., McIntyre, J., Bartoschek, T., Devine, K., O'Neill, K., Laing. R., and Ellis, K. 2024. Inefficacy of ivermectin and moxidectin treatments against *Dictyocaulus viviparus* in dairy calves. *Veterinary Record*, **195(3),** e4265.

Candy, P.M., Waghorn, T.S., Miller, C.M., Ganesh, S., Leathwick, D.M., 2018. The effect on liveweight gain of using anthelmintics with incomplete efficacy against resistant *Cooperia oncophora* in cattle. *Veterinary Parasitology,* **251**:56-62.

Chambers, A., Miller, C.M., Green, P., Candy, P., and Leathwick, D.M. 2023. The distribution of strongylid egg and lungworm (*Dictyocaulus eckerti*) larval counts in adult female farmed red deer (*Cervus elaphus*), and the implications for parasite control. *Veterinary Parasitology,* **327**:110080.

Coop, R.L., Sykes, A.R., and Angus, K.W. 1979. The pathogenicity of daily intakes of *Cooperia oncophora* larvae in growing calves. *Veterinary Parasitology,* **5**:261-269.

Dobson, R.J., Lejambre, L., and Gill J.H. 1996. Management of anthelmintic resistance: Inheritance of resistance and selection with persistent drugs. *International Journal for Parasitology,* **26(8-9):**993-1000.

Georghiou, G.P., and Taylor, C.E. 1977. Genetic and biological influences in the evolution of insecticide resistance. *Journal of Economic Entomology,* **70(3):** 319-23.

Gokbulut, C., Cirak, V.Y., Senlik, B., Aksit, D., Durmaz, M., and McKellar, Q.A. 2010. Comparative plasma disposition, bioavailability and efficacy of ivermectin following oral and pour-on administration in horses. *Veterinary Parasitology,* **170**:120–127.

Kaplan, R.M., Denwood, M.J., Nielsen, M.K., Thamsborg, S.M., Torgerson, P.R., Gilleard, J.S., Dobson, R.J., Vercruysse, J., and Levecke, B. 2023. World Association for the Advancement of Veterinary Parasitology (W.A.A.V.P.) guideline for diagnosing anthelmintic resistance using the faecal egg count reduction test in ruminants, horses and swine. *Veterinary. Parasitology,* **318**:109936.

Kelleher, A.C., Good, B., de Waal, T., and Keane, O.M. 2020. Anthelmintic resistance among gastrointestinal nematodes of cattle on dairy calf to beef farms in Ireland. *Irish Veterinary Journal,* **73**:12.

Laffont, C.M., Alvinerie, M., Bousquet-Mélou, A., and Toutain, P.L. 2001. Licking behaviour and environmental contamination arising from pour-on ivermectin for cattle. *International Journal for Parasitology,* **31**:1687–1692.

Leathwick, D.M., and Luo, D. 2017. Managing anthelmintic resistance-Variability in the dose of drug reaching the target worms influences selection for resistance? *Veterinary Parasitology,* **243**:29-35.

Leathwick, D.M., and Miller, C.M. 2013. Efficacy of oral, injectable and pour-on formulations of moxidectin against gastrointestinal nematodes in cattle in New Zealand. *Veterinary Parasitology,* **191**:293-300.

Leathwick, D.M., Miller, C.M., Sauermann, C.S., Candy, P., Ganesh, S., Fraser, K., and Waghorn, T.S. 2016. The efficacy and plasma profiles of abamectin plus levamisole combination anthelmintics administered as oral and pour-on formulations to cattle. *Veterinary Parasitology,* **227**:85-92.

Leathwick, D.M., Miller, C.M., Waghorn, T.S., Schwendel, H., and Lifschitz, A. 2020. Route of administration influences the concentration of ivermectin reaching nematode parasites in the gastrointestinal tract of cattle. *International Journal for Parasitology – Drugs and Drug Resistance,* **14:**152-158.

Lifschitz, A., Lanusse, C., and Alvarez. L. 2017. Host pharmacokinetics and drug accumulation of anthelmintics within target helminth parasites of ruminants. *New Zealand Veterinary Journal,* **65(4):**176-184.

Lloberas, M., Alvarez, L., Entrocasso, C., Virkel, G., Lanusse, C., and Lifschitz, A. 2012. Measurement of ivermectin concentrations in target worms and host gastrointestinal tissues: influence of the route of administration on the activity against resistant *Haemonchus contortus* in lambs. *Experimental Parasitology*, **131:**304–309.

Mooney, L., Good, B., Hanrahan, J.P., Mulcahy, G., and de Waal, T. 2009. The comparative efficacy of four anthelmintics against a natural acquired *Fasciola hepatica* infection in hill sheep flock in the west of Ireland. *Veterinary Parasitology,* **164(2-4):**201-205.

O'Shaughnessy, J., Drought, Y., Lynch, J., Denny, M., Hurley, C., Byrne, W., Casey, M., de Waal, T., and Sheehan, M. 2019. Ivermectin treatment failure on four Irish dairy farms. *Irish Veterinary Journal,* **72**:4.

Rode, B., and Jorgensen, R.J. 1989. Baermannization of Dictyocaulus spp. from faeces of cattle, sheep and donkeys. *Veterinary Parasitology*, **30**:205-211.

Sabatini, G.A., Borges, F.A., Claerebout, E., Gianechini, L.S., Hoglund, J., Kaplan, R.M., Lopes, W.D.Z., Mitchell, S., Rinaldi, L., von Samson-Himmelstjerna, G., Steffan, P., and Woodgate, R. 2023. Practical guide to the diagnostics of ruminant gastrointestinal nematodes, liver fluke and lungworm infection: interpretation and usability of results. *Parasites & Vectors,* **16(1):** 58.

Sargent, R.M., Chambers, M., and Elliott, T. 2009. Seasonal differences in the efficacy of pour-on formulations of triclabendazole and ivermectin or abamectin against late immature liver fluke (*Fasciola hepatica*) in cattle. *Veterinary Parasitology*, **161**:133–137.

Sauermann, C.W., Ganesh, S., Scott, I., Pomroy, W.E., and Leathwick, D.M. 2018. Establishment of *Cooperia oncophora* in calves. *Veterinary Parasitology,* **264**:64-68.

Smith, G., Grenfell, B.T., Isham, V., and Cornell, S. 1999. Anthelmintic resistance revisited: under-dosing, chemoprophylactic strategies, and mating probabilities. *International Journal for Parasitology*, **29**: 77-91.

Sutherland, I.A., and Leathwick, D.M. 2011. Anthelmintic resistance in nematode parasites of cattle – a global issue? *Trends in Parasitology,* **27**:176-181.

Waghorn, T.S., Miller, C.M., and Leathwick, D.M. 2016. Confirmation of ivermectin resistance in *Ostertagia ostertagi* in cattle in New Zealand. *Veterinary Parasitology,* **229**:139-143.

Summer scour syndrome in dairy calves: what do we know and what do we need to know?

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Introduction

In recent years, a novel digestive disorder affecting weaned dairy calves has been documented in Ireland (RVL, 2021a; Mee, 2022; Sheehan *et al.*, 2023; Male Here *et al.*, 2024). Private veterinary practitioners (PVPs) reported that this disorder had increased in prevalence, more than any other single calf health issue (Mee, 2022). A similar digestive disorder in calves has been reported in England, Wales and Scotland (Hateley *et al.*, 2018; Swinson *et al.*, 2023), New Zealand (O'Connell, 2017), and Australia (Hunnam *et al.*, 2021). The condition is termed summer scour syndrome (SSS) in Ireland and the UK, in Australia it is termed upper alimentary ulcerative syndrome (UAUS), and in New Zealand, calf ulcerative stomatitis (CUS). Calves affected with SSS are usually younger than 12 months of age. Where mixed age groups of calves are first turned out to pasture it tends to be the youngest calves which are affected (D. Murphy, pers. com.). The most noteworthy clinical signs include diarrhoea and abrupt weight loss following recent turnout to pasture during their first grazing season. In addition, other clinical signs such as oral and oesophageal ulcerations or even death have been found in some cases (Hunnam *et al.*, 2021; RVL, 2021a; Swinson *et al.*, 2023). In most SSS cases, affected calves are unresponsive to treatment but can recover slowly once removed from pasture i.e. re-housed, although recovered calves have been anecdotally described to have compromised growth performance (Swinson *et al.*, 2023). The syndrome is a group problem though not all calves in the affected group show clinical signs and severity can vary between calves (Male Here *et al.*, 2024). In Australian dairy herds, anecdotal reports indicate a herd-level morbidity and case fatality rate of 60% and 10%, respectively (Hunnam *et al.*, 2021). A UK surveillance report by Swinson *et al.* (2023) showed that the syndrome has a low herd prevalence, but the within-herd morbidity and mortality rates could range from 10 to 100% and 2 to 40%, respectively. Studies to date have not identified a consistent infectious agent responsible for this syndrome (Hunnam *et al.*, 2021; Swinson *et al.*, 2023), and the definitive cause/s remain unclear. Consequently, SSS is a diagnosis of exclusion (Sheehan *et al.*, 2023), where other diseases with similar clinical signs must be ruled out before confirmation of SSS cases (Swinson *et al.*, 2023; Male Here *et al.*, 2024). These diseases include parasitic gastroenteritis (PGE), coccidiosis, ruminal acidosis, mineral deficiencies or toxicities (copper and molybdenum), bovine viral diarrhoea (BVD), and salmonellosis. Additionally, ruling out chronic pneumonia should also be considered (Male Here *et al.*, 2024), as it can be a comorbidity and cause ill-thrift in calves that could be misdiagnosed as ill-thrift associated with SSS. Histopathological examination, particularly the identification of necrosis (cell death) in the oesophageal mucosa and the exclusion of BVD, is required to define UAUS in Australia (Hunnam *et al.*, 2021). Presently, there is limited research either nationally or internationally into the case definition, risk factors, pathology, and causes or control measures.

Gross pathology and histopathology

The gross pathological findings in SSS cases are primarily seen in the upper alimentary tract, with lesions of the lower alimentary tract variably present in some cases (Hunnam *et al.*, 2021; Swinson *et al.*, 2023). Recent reports from Regional Veterinary Laboratories in Ireland found muzzle and buccal ulcerations and oesophagitis (inflammation of the oesophagus; Figure 1) in calves affected with SSS (RVL, 2021b; 2022; 2023). In a UK study, oesophagitis was identified in all twenty submissions of SSS cases (Swinson *et al.*, 2023). Similarly, the presence of oesophagitis with varying degrees of ulceration and diptheritic membrane formation was described in UAUS cases in Australia (Hunnam *et al.*, 2021). Other upper alimentary lesions, including gum ulceration and superficial coalescing ulceration of the under surface of the tongue, were also present. In the histopathological examination of SSS, Sheehan *et al.* (2023) identified apoptosis/dyskeratosis (cell death/abnormal keratinocyte differentiation) in buccal and oesophageal mucosa (Figure 2). Consistent with this, Hunnam *et al.* (2021) found multifocal and coalescing necrosis of epithelial mucosa that were consistently present in the oesophagus. In addition, in some cases dilated crypts filled with mucus, cell debris and inflammatory cells were identified in the intestines, mostly limited to lower jejunum and ileum tissue. Hunnam *et al.* (2021) further described that histopathological lesions of UAUS cases cannot be distinguished from those resulting from BVD virus infection (mucosal disease), and thus, BVD must be ruled out before confirmation of UAUS cases. In the Irish context, BVD testing is compulsory for all newborn calves as part of the national BVD eradication program, and the prevalence is very low in Irish calves, with only 0.03% tested positive in 2023 (AHI, 2024). Despite this low prevalence, BVD remains an important differential diagnosis to be ruled out in the investigation/diagnosis of SSS cases in Ireland, due to the possibility for sporadic re-emergence and transient BVD virus infection.

Figure 1. *Severe oesophagitis in a calf diagnosed as SSS*[1]

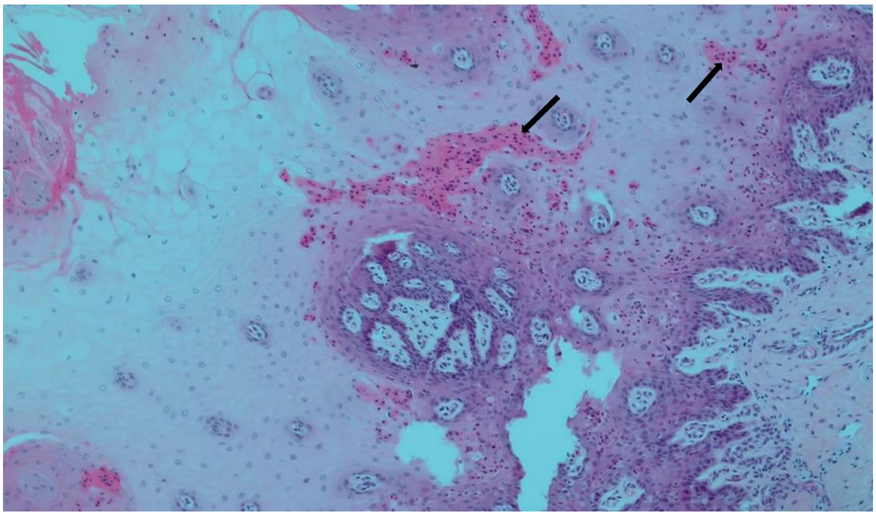

Figure 2. *Apoptosis/dyskeratosis of oesophageal tissue in a calf diagnosed as SSS*[1]

[1]*Images source: Regional Veterinary Laboratories, Department of Agriculture, Food and the Marine (DAFM)*

Risk factors and aetiological hypotheses

Nutritional and infectious causes have been investigated as potential aetiologies of SSS, both nationally and internationally. A recent survey of Irish PVPs indicated that they perceived grass quality and weaning management as the two most important risk factors (Mee, 2022). Grazing an abundant supply of lush grass that is high in crude protein and low in fibre is the common finding in herds affected by SSS (RVL, 2021b; 2024). However, any association between grazing lush grass and the development of SSS clinical signs is poorly understood, as there is a paucity of studies investigating this apparent association. Possible mechanisms whereby grazing lush grass may cause SSS include the development of sub-acute ruminal acidosis (SARA). Unlike acute ruminal acidosis which is characterized by severe ruminal pH depression and acute clinical manifestation, SARA is characterized by transient depression in ruminal pH, mainly after feeding, and delayed onset of clinical signs (Abdela, 2016). Grazing highly fermentable grass has been associated with an increased risk of SARA in dairy cows in pasture-based dairy systems, such as in Ireland (O'Grady *et al.*, 2008), Australia (Bramley *et al.*, 2008), and New Zealand (Westwood *et al.*, 2003). Ingestion of rapidly fermentable grass may increase acid production and its accumulation in the rumen, subsequently lowering the ruminal pH (Westwood *et al.*, 2003). This low rumen pH may result in impaired rumen functions (e.g. fermentation and bacterial breakdown), leading to diarrhoea (Oetzel, 2000; Kleen *et al.*, 2003). Another potential mechanism could be the association between grazing lush grass and inadequate rumen development. Lush grass typically contains high nitrogen content e.g. non-protein nitrogen (NPN). When ingested, NPN is converted into ammonia in the rumen (Zurak *et al.*, 2023). Rumen microbes utilize ammonia to produce microbial protein; however, the utilization rate is typically lower than the rate of ammonia production from nitrogen metabolism, resulting in excess ammonia in the rumen (Patra and Aschenbach, 2018). The excess ammonia is mainly absorbed into the bloodstream through the rumen wall (Zurak *et al.*, 2023). However, in calves with underdeveloped rumens, this absorption capacity may be impaired, potentially resulting in the accumulation of ammonia in the rumen. An *in vitro* study by Shen *et al.* (2023) reported that high ammonia levels reduce the abundance of rumen microbial populations (e.g. bacteria, protozoa, fungi, and methanogens) and subsequently inhibit ruminal fermentation. Currently, it is unknown whether grazing lush grass is an independent factor or, in conjunction with inadequate rumen development, contributes to SSS occurrence.

One alternative or contributing theory for the cause of SSS is suboptimal weaning management, which includes early weaning and a quick switch from a milk to a solid or forage diet. Existing evidence, however, contradicts this. In Scotland, it is reported that SSS generally occurs in abruptly weaned calves that had been turned out immediately to grass (Swinson *et al.*, 2023). In contrast, a recent study in Ireland reported SSS cases in dairy calves that had been gradually weaned (fully weaned at 10 to 12 weeks of age) and retained indoors for 2-3 weeks before turnout to grass (Male Here *et al.*, 2024). Future research is required to investigate the impact of suboptimal weaning management on SSS occurrence.

Viral infection has also been suggested as a primary cause for SSS. However, analysis of oral and oesophageal tissues from affected calves in Australia detected no common viruses (e.g. bovine herpes virus (BoHV-1), BVD) responsible for this syndrome (Hunnam *et al.*, 2021). In that study, only bovine popular stomatitis virus (BPSV) was detected in both affected and non-affected herds. Similarly, samples from the 20 submissions of SSS cases in the UK study (Swinson *et al.*, 2023) also tested negative for a range of viral infections, such as BVD, ovine herpesvirus, BoHV-1, bovine respiratory syncytial virus (RSV), and parainfluenza 3 virus. The presence of BPSV was detected in four submissions in that study. Infection with BPSV typically causes muzzle or oral lesions (Holliman, 2005). Although lesions caused by BPSV can have some similarity to lesions in calves with SSS, oral ulceration was not present in all calves with SSS, which may also suggest that BPSV is not the primary cause but rather a secondary/co-infection (Swinson *et al.*, 2023). In 2021, the detection of BPSV was also mentioned in a case reported by Kilkenny Regional Veterinary Laboratory in Ireland (RVL, 2021a). This report documented the findings in a five-month-old calf with a history of weight loss, which presented with multifocal ulcerations in the tongue and oesophagus. Although BPSV infection was identified, it was considered a co-infection for SSS. The observed lesions were considered attributed to SSS as the primary cause, as clinical presentation was consistent with SSS cases (RVL, 2021a).

Recent on-farm clinical investigation in Ireland

A recent farm clinical investigation study was conducted in June 2023 to describe the characteristics of SSS in dairy-bred calves on commercial farms in Ireland (Male Here *et al.*, 2024). In this study, five commercial farms with suspected SSS cases were visited 2 to 5 days following referrals from the PVPs. On the day of the farm visit, an interview with the herdowner was conducted to record the onset of clinical signs in the affected group, treatments, farm health history, and farm management practices such as turnout date, chemical or organic fertiliser use, vaccination status, milk feeding, and weaning management. Clinical examinations and thoracic ultrasonography (TUS) were performed on 8 to 10 randomly selected calves per farm that exhibited clinical signs. Additionally, biological samples, such as blood, rumen fluid, and faeces, were collected from each calf. Concentrates and herbage samples from the paddock where the calves had previously and were currently grazing on the day of visits were also collected.

Of the five visited farms, only three had problems consistent with SSS cases (case farms, CF; n = 3; e.g. Figure 3), whereas the other farms had calves positive for coccidiosis, and the majority of calves on those farms had chronic pneumonia problems based on TUS examination (non-case farms, NCF; n = 2). All case farms were dairy farms, whereas non-case farms comprised of a dairy-beef, and a mixed dairy and dairy-beef farm. Other differential diagnoses, such as BVD, rumen acidosis, and mineral deficiencies or toxicities, were ruled out as all farms had BVD-negative status, and sampled calves had normal rumen pH and normal blood copper and molybdenum levels. Farmers on the case farms reported to have observed calves experiencing clinical signs for two days to 2.5 weeks before the farm visit, and the onset of clinical signs varied from 2 to 6 weeks post-turnout to pasture (turned out in mid-April to mid-May). They also reported applying chemical nitrogen fertiliser, in the form of protected urea or nitrogen, phosphorus, potassium (NPK), 1 to 3 weeks before the calves grazed the paddocks. In addition, the farmers indicated a history of SSS-type problems in the previous years. On all farms, concentrates and forage feeding were provided to the calves during the pre-weaning period, and milk feeding was reduced gradually prior to fully weaning at 10 to 12 weeks of age. The predominant clinical signs in calves sampled on case farms included diarrhoea, weight loss, hypersalivation, and poor coat appearance, whereas lesions of healing oral ulcers were observed in five sampled calves.

Figure 3. *Calves with SSS that were removed from grass and re-housed*

Results from the blood, rumen fluid, and herbage analyses are presented in Table 1. One interesting finding from the clinical investigation was hyperammonemia in calves with SSS, as measured using the point-of-care ammonia analyser (PocketChem BA, Arkray, Japan). The blood ammonia concentrations exceeded the normal level (< 90 µmol/L; Buczinski *et al.,* 2007) and were substantially higher than concentrations in calves sampled on non-case farms. Interestingly, in the UK study (Swinson *et al.,* 2023), the authors suggested that histopathological lesions in SSS calves are consistent with chemical insults or elevated blood urea/ammonia levels. However, further research needs to substantiate this suggestion. The herbage crude protein and neutral detergent fibre from case farms were less than 20% and higher than 40%, respectively, which is not consistent with the perceived lush grass factor that is typically reported in SSS cases. This inconsistency may be explained by the time gap between the onset of clinical signs and the farm visit for collection of herbage samples.

Table 1. Calf characteristics, and results of blood, rumen fluid, and grass analysis from case farms (CF) and non-case farms (NCF)[1]

	CF			NCF		Reference values
	CF 1 (n = 10)	CF 2 (n = 10)	CF 3 (n = 10)	NCF 1 (n = 8)	NCF 2 (n = 8)	
Calf characteristics						
Calf sex (number)	Female (10)	Female (10)	Female (10)	Female(3); male (5)	Male (8)	–
Age (day) at turnout	67 (6)	100 (4)	100 (4)	51 (13)	85 (11)	–
Age (day) at visit	127 (6)	135 (4)	129 (4)	113 (13)	128 (11)	–
Body weight (kg) at visit	116 (12.4)	123 (11.7)	129 (10.2)	112 (10.8)	103 (21.4)	–
Blood sample						
Ammonia (µmol/L)	152 (49)[a]	129 (35)	223 (42)	25 (11)	22 (18)	< 90[c]
Blood urea nitrogen (mmol/L)	6.8 (4.6)	6.6 (4.4)	3.7 (1.9)	3.2 (1.3)	3.5 (1.0)	1.7 – 7.7[d]
Ammonia : blood urea nitrogen	20:1[a]	20:1	60:1	8:1	6:1	9 : 1[e]
Molybdenum (µg/L)	6.5 (3.5)	6.6 (2.4)	7.5 (2.6)	13.3 (5.1)	12.4 (8.6)	2 – 35[f]
Copper (µmol/L)	14.4 (1.7)	14.8 (1.3)	15.4 (1.4)	15.7 (4.0)	14.4 (1.4)	9.4 – 17.3[f]
Rumen fluid sample						
pH	7.09 (0.23)	6.75 (0.40)	6.67 (0.40)	6.88 (0.40)	6.43 (0.31)	> 5.8[g]
Ammonia (mg/L)	30 (16)	21 (19)	18 (16)	45 (16)	17 (9)	20 – 50[h]
Total volatile fatty acids (mM)	154 (37)	243 (83)	286 (67)	273 (49)	251 (93)	–
Herbage sample[b]						
Dry matter (DM) (g/kg)	268	272	245	258	179	–
Crude protein (g/kg DM)	106	177	125	151	186	–
Neutral detergent fibre (g/kg DM)	471	433	454	477	370	–

[1]Presented as mean (standard deviation), except for calf sex; [a] Five calves with complete blood ammonia results; [b] Samples from paddock where calves were grazing on the day of visit; [c] Buczinski et al. (2007); [d] Roadknight et al. (2022); [e] West (1997); [f] Herdt and Hoff (2011); [g] O'Grady et al. (2008); [h] Satter and Slyter (1974)

Current control strategies

Given the unclear aetiology/ies of SSS, the current control strategies primarily aim to minimise the exposure to perceived risk factors associated with the occurrence of this syndrome. Several control strategies have been recommended to prevent SSS on farms in Ireland (McAloon *et al.*, 2022); however, it is important to note that these recommendations are largely based on field observations and experiences of PVPs and expert opinion, and not yet experimentally confirmed or refuted.

One proposed strategy to prevent SSS is to implement proper weaning management. Weaning stress has a negative effect on the immune system, making calves more susceptible to diseases, potentially including SSS. To minimise weaning stress, a gradual weaning procedure is recommended for artificially reared dairy calves (Johnston *et al.*, 2016; Nielsen *et al.*, 2023). Gradual weaning typically involves a gradual reduction of milk feeding, which could be initiated at 14 days prior to weaning (Johnston *et al.*, 2016), allowing a smooth transition from a liquid to a concentrate and forage diet. Calves that were gradually weaned also had a stable rumen pH compared to abruptly weaned calves, independent of weaning age (Wolfe *et al.*, 2023).

Weaning calves at later age is reported to have positive effects on growth and rumen development compared with early weaning, and is therefore recommended (Welk *et al.*, 2024). However, the definition of 'late' and 'early' weaning age varied between studies (reviewed by Welk *et al.*, 2024), making it difficult to determine the favourable age for weaning. Dairy calves are commonly weaned between 8 and 12 weeks of age (Nielsen *et al.*, 2023). A study by Eckert *et al.* (2015) found calves that were weaned at eight weeks of age had higher solid feed intake, 3-times higher average daily gain, and better coped with transition from milk to solid feed, compared to calves weaned at 6 weeks of age. Schwarzkopf *et al.* (2022) reported a more developed rumen function in calves weaned at 17 weeks of age compared to those weaned at seven weeks of age, while Kehoe *et al.* (2007) found no difference in rumen papillae length, width or rumen wall thickness between calves weaned at different ages (i.e., 3, 4, 5, 6 weeks). In terms of microbial diversity, weaning at 8 weeks of age results in a gradual shift in the diversity of rumen and faecal microbiota (vs. an abrupt shift in calves weaned at 6 weeks of age), which potentially supports the weaning process (Meale *et al.*, 2017).

Retaining calves indoors for at least one week after weaning could serve as a strategy in preventing SSS, as this allows the calves to fully adapt to high-carbohydrate diet prior to grazing. A system of free access to both pasture and milk in the calf housing would also facilitate the transition to grazing.

Grazing lush grass is the common factor in SSS cases (RVL, 2021b; 2024), and thus, reducing the access to lush pasture or recently fertilised paddocks could be a key preventive strategy. Once at grass, allocating grass per strip using an electric fence (syn: strip-grazing) is one practical strategy to force calves to graze the grass stem material that is rich in fibre. Additional forage provision e.g. straw or hay, could be introduced at grass to provide adequate dietary fibre. Forage provision stimulates rumination and subsequent saliva production, which act as natural buffers to control ruminal pH (Khan *et al.*, 2016). In addition to abovementioned management changes, numerous commercial products have been promoted to manage SSS. However, to date published data on their efficacy are lacking.

Future research

The growing number of reported SSS cases in recent years and its unknown primary cause/s clearly highlights an urgent necessity for future investigation of this syndrome. One key priority is to enhance the understanding of risk factors pertaining to SSS occurrence. Grazing lush pasture and weaning management have been perceived and hypothesised as the contributing factors in SSS cases (Mee, 2022), however, no studies have experimentally demonstrated their underlying relationship. Therefore, future research is required to elucidate the involvement of these factors. The hyperammonemia finding in SSS cases is novel (Male Here *et al.*, 2024), but the significance of hyperammonemia and its causal relationship with the development of SSS is not yet fully understood and warrants further investigation. One particular area to explore is the potential link between practices of fertiliser use on farms during the grazing period or exposure to high nitrogen pastures and the development of SSS and hyperammonemia. Excess use of fertiliser has been associated with fast-growing pasture, which can increase the risk for nitrate or ammonia/NPN toxicity– hyperammonemia is one manifestation of this type of toxicity (Cope, 2018). The recent farm investigation study in Ireland provided an overview of the management practices on a limited number of farms affected by this syndrome (Male Here *et al.*, 2024), and thus it is uncertain whether these practices are representative of all farms with SSS cases. A more comprehensive epidemiological investigation would be needed to identify consistent patterns and correlations between management practices, nutritional factors, and the occurrence of SSS on affected farms. Considering that SSS affects calves in the post-weaning period also raises another concern about its long-term impact on their health and performance. Currently, the compromised growth performance in recovered calves is poorly described and is based primarily on anecdotal reports. Hence, empirical research to substantiate the long-term impacts of SSS is needed.

Conclusion

Studies to date have not identified consistent infectious agents as a cause of SSS in dairy calves. Exposure to grass is the only consistent factor reported in SSS cases, with clinical signs occurring within a month post-turnout of calves to grass. Several hypotheses exist regarding the potential causes, including grazing lush grass, poor weaning management, inadequate rumen development, and viral infection. Although some insights into the characteristics of SSS have been gained from recent farm clinical investigations, further research is necessary to fully comprehend the syndrome and identify the cause/s and to gain a better understanding of it.

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References

Abdela, N. 2016. Sub-acute ruminal acidosis (SARA) and its consequence in dairy cattle: A review of past and recent research at global prospective. *Achiev. Life Sci.,* **10**:187–196.

AHI. 2024. BVD Eradication Key Messages 2024. Animal Health Ireland. Available from: https://animalhealthireland.ie/assets/uploads/2024/04/BVD_KeyMessages_2024_FINAL.pdf

Bramley, E., I. J. Lean, W. J. Fulkerson, M. A. Stevenson, A. R. Rabiee, and N. D. Costa. 2008. The definition of acidosis in dairy herds predominantly fed on pasture and concentrates. *J. Dairy Sci.,* **91**:308–321.

Buczinski, S., J. Duval, M. A. d'Anjou, D. Francoz, and G. Fecteau. 2007. Portacaval shunt in a calf: Clinical, pathologic, and ultrasonographic findings. *Can. Vet. J.* **48**:407–410.

Cope, R. B. 2018. Nonprotein nitrogen (urea) and hyperammonemia. In: *Veterinary Toxicology*. 3rd Ed. Elsevier. p. 1093–1097.

Eckert, E., H. E. Brown, K. E. Leslie, T. J. DeVries, and M. A. Steele. 2015. Weaning age affects growth, feed intake, gastrointestinal development, and behavior in Holstein calves fed an elevated plane of nutrition during the preweaning stage. *J. Dairy Sci.* **98**:6315–6326.

Hateley, G., C. Mason, K. Henderson, S. Fagan, M. Millar, and S. Neale. 2018. Severe summer scour syndrome in recently turned out dairy calves. *Vet. Rec.,* **183**:300–300.

Herdt, T. H., and B. Hoff. 2011. The Use of Blood Analysis to Evaluate Trace Mineral Status in Ruminant Livestock. *Vet. Clin. North Am. - Food Anim. Pract.* **27**:255–283.

Holliman, A. 2005. Differential diagnosis of diseases causing oral lesions in cattle. *In Pract.,* **27**:2–13.

Hunnam, J. C., I. V. Jerrett, P. T. Mee, K. Moore, S. E. Lynch, G. T. Rawlin, and S. E. Salmon. 2021. An idiopathic upper alimentary tract ulcerative syndrome in weaned dairy calves in Victoria, Australia. Transbound. *Emerg. Dis.* **68**:3277–3287.

Johnston, D., D. A. Kenny, A. K. Kelly, M. S. McCabe, M. McGee, S. M. Waters, and B. Earley. 2016. Characterisation of haematological profiles and whole blood relative gene expression levels in Holstein-Friesian and Jersey bull calves undergoing gradual weaning. *Animal*, **10**:1547–1556.

Kehoe, S. I., C. D. Dechow, and A. J. Heinrichs. 2007. Effects of weaning age and milk feeding frequency on dairy calf growth, health and rumen parameters. *Livest. Sci.* **110:**267–272.

Khan, M. A., A. Bach, D. M. Weary, and M. A. G. von Keyserlingk. 2016. Invited review: Transitioning from milk to solid feed in dairy heifers. *J. Dairy Sci.* **99:**885–902.

Kleen, J. L., G. A. Hooijer, J. Rehage, and J. P. T. M. Noordhuizen. 2003. Subacute ruminal acidosis (SARA): A review. *J. Vet. Med. Ser. A Physiol. Pathol. Clin. Med.* **50**:406–414.

Male Here, R. R., C. McAloon, J. Donlon, M. McGee, M. Duane, D. Kenny, and B. Earley. 2024. Summer scour syndrome in weaned dairy calves: case series. *Ir. Vet. J.* **77**:14.

McAloon, C., C. Chavasse, M. Conneely, C. Cummins, G. Dwyer, B. Earley, T. Fallon, L. Gannon, J. Gilmore, C. Hayes, I. Hogan, E. Kennedy, M. Little, J. Mee, and K. Tiernan. 2022. Summer Scour Syndrome. CalfCare Leaflet Series Vol. 14. 1–6. Available from: https://animalhealthireland.ie/assets/uploads/2022/02/CalfCare-Scouring-Calf-Syndrome-2022-FINAL.pdf?dl=1

Meale, S. J., S. C. Li, P. Azevedo, H. Derakhshani, T. J. DeVries, J. C. Plaizier, M. A. Steele, and E. Khafipour. 2017. Weaning age influences the severity of gastrointestinal microbiome shifts in dairy calves. *Sci. Rep.,* **7:**1–13.

Mee, J. F. 2022. Dairy calf health issues, what are the modern challenges? In: Proceedings CAVI Conference. Charleville, Cork. p. 108-123.

Nielsen, S. S., J. Alvarez, D. J. Bicout, P. Calistri, E. Canali, J. A. Drewe, B. Garin-Bastuji, J. L. Gonzales Rojas, C. Gortazar Schmidt, M. Herskin, V. Michel, M. A. Miranda Chueca, B. Padalino, P. Pasquali, H. C. Roberts, H. Spoolder, K. Stahl, A. Velarde, A. Viltrop, M. B. Jensen, S. Waiblinger, D. Candiani, E. Lima, O. Mosbach-Schulz, Y. Van der Stede, M. Vitali, and C. Winckler. 2023. Welfare of calves. EFSA J. 21.

O'Connell, J. 2017. Calf ulcerative stomatitis update. In: Proceedings of the Dairy Cattle Veterinarians of the NZVA. New Zealand. p. 65–67.

O'Grady, L., M. L. Doherty, and F. J. Mulligan. 2008. Subacute ruminal acidosis (SARA) in grazing Irish dairy cows. *Vet. J.* **176**:44–49.

Oetzel, G. R. 2000. Clinical Aspects of Ruminal Acidosis in Dairy Cattle. *Am. Assoc. Bov. Pract. Conf. Proc.* **33**:46–53.

Patra, A. K., and J. R. Aschenbach. 2018. Ureases in the gastrointestinal tracts of ruminant and monogastric animals and their implication in urea-N/ammonia metabolism: A review. *J. Adv. Res.* **13**:39–50.

Roadknight, N., E. Jongman, P. Mansell, N. Courtman, D. McGill, G. Hepworth, and A. Fisher. 2022. Prevalence of failure of passive immunity transfer in Australian non-replacement dairy calves. *Aust. Vet. J.* **100**:292–295.

RVL. 2021a. Regional veterinary laboratories report - July 2021. *Vet. Irel. J.,* **11**:610–615.

RVL. 2021b. Regional veterinary laboratories report - September 2021. *Vet. Irel. J.,* **11**:731–735.

RVL. 2022. Regional veterinary laboratories report - June 2022. *Vet. Irel. J.*, **12**:536–540.

RVL. 2023. Regional veterinary laboratories report - July 2023. *Vet. Irel. J.*, **13**:547–553.

RVL. 2024. Regional veterinary laboratories report - May 2024. *Vet. Irel. J.*, **14**:459–466.

Satter, L. D., and L. L. Slyter. 1974. Effect of ammonia concentration on rumen microbial protein production in vitro. *Br. J. Nutr.* **32**:199–208.

Schwarzkopf, S., A. Kinoshita, L. Hüther, L. Salm, S. Kehraus, K. H. Südekum, K. Huber, S. Dänicke, and J. Frahm. 2022. Weaning age influences indicators of rumen function and development in female Holstein calves. *BMC Vet. Res.* **18**:1–15.

Sheehan, M., S. Faganz, C. Hayes, D. Murphy, D. Lynch, E. Ryan, D. Bochynska, M. McElroys, S. McGettrick, and J. Mee. 2023. A clinicopathological review of summer scour syndrome: case definition and histopathological lesions. In: Proceedings VET23 Conference. Cork, Ireland. p. 10.

Shen, J., W. Zheng, Y. Xu, and Z. Yu. 2023. The inhibition of high ammonia to in vitro rumen fermentation is pH dependent. *Front. Vet. Sci.*, **10**.

Swinson, V., L. Nabb, K. Henderson, and M. Millar. 2023. Update on severe summer scour syndrome in cattle. *Vet. Rec.*, **192**:285–287.

Welk, A., H. W. Neave, and M. B. Jensen. 2024. Invited review: The effect of weaning practices on dairy calf performance, behavior, and health—A systematic review. *J. Dairy Sci.,* **107**:5237–5258.

West, H. J. 1997. Clinical and pathological studies in cattle with hepatic disease. *Vet. Res. Commun.,* **21**:169–185.

Westwood, C. T., E. Bramley, I. J. Lean, and I. J. Lean. 2003. Review of the relationship between nutrition and lameness in pasture-fed dairy cattle. *N. Z. Vet. J.*, **51:**208–218.

Wolfe, A. R., P. Rezamand, B. C. Agustinho, D. E. Konetchy, and A. H. Laarman. 2023. Effects of weaning strategies on health, hematology, and productivity in Holstein dairy calves. *J. Dairy Sci.,* **106**:7008–7019.

Zurak, D., K. Kristina, and J. Aladrović. 2023. Metabolism and utilisation of non-protein nitrogen compounds in ruminants: a review. *J. Cent. Eur. Agric.*, **24**:1–14.

Calf nutrition

Calf nutrition: Current feeding challenges from birth to yearling

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In Spain, the beef fattening system is an intensive system where calves are commonly housed in partially open barns with straw bedding and 40% of the calves, mainly males, are from dairy origin (surplus calves). These calves are transported by road for long periods (up to 3-5 days) from their dairy origin farms to the rearing farm where they are typically fed low amounts of milk replacer for 6-8 weeks and concentrate and straw *ad libitum* in separate feeders from very young ages with a resulting concentrate to straw ratio around 90-80 to 10-20%. These calves are not castrated and slaughtered around 12 months of age. As a European country the use of hormones or growth promoters are not allowed. This dairy beef production system faces three main challenges and requires the design of nutritional strategies to: i) reduce the incidence of bovine respiratory disease (BRD) and the antimicrobial use of unweaned calves upon arrival, mainly focusing on the nutrition and management before arrival to the rearing farm and transportation and the recovery from negative energy balance, increased gut permeability, oxidative stress, anaemia, and the drop of feed intake ii) reduce the bulls aggressive and aberrant oral non-nutritive behaviours based on the modulation of inflammation processes to reduce the incidence of dark firm dry (DFD) meat; and finally to face one of the main challenges iii) reduce the environmental impact of this dairy beef production by decreasing methane (CH_4) and nitrogen (N) emissions, and to find alternative feed ingredients with a low life cycle assessment (LCA) impact.

Feeding strategies around transportation

Surplus dairy beef calves are often commercialized with poor colostrum management at birth and low level of nutrition during the time they spend at the dairy farm (Renaud *et al.,* 2017; Renaud *et al.,* 2018; Renaud and Pardon, 2022). It means that when calves are collected to go to an assembly centre or a market, they have a weak immune system due to the poor maternal immunity transfer and low energy reserves to face the contact with multiple pathogens from mixing calves from different farms. Additionally, the low level of colostrum and feed consumed also have a negative effect on the gastrointestinal tract development (Blum and Hammon, 2002). Assembly centres gather calves for several days until homogeneous lots are made to be transported to the rearing farms. During the days that calves spend at assembly centres, the level of nutrition is low, and the calves loaded to be transported for long distances are generally within a state of negative energy balance (Marti *et al.,* 2019). During transport calves are stressed due to motion, environmental conditions, noise, lack of rest, restriction of feed and water, etc., which weakens their already poor immune system and impairs the gastrointestinal functionality (Hutcheson and Cole, 1986; Marcato *et al.,* 2020; Marti *et al.,* 2021; Buckham-Sporer, 2023; Pisoni *et al.,* 2023). After many hours of transport calves arrive to the rearing farms and they are offered a restricted milk replacer program and *ad libitum* concentrate feed that, contrary to the expectations, may further deteriorate the health status of the calves and the recovery after marketing and transportation.

We have investigated this commercialisation process over recent years, and we have observed that calves fed 2 L of colostrum at birth and fed milk replacer or rehydrate solution at the assembly centre, took at least seven days to recover the same concentrate intake when compared with a non-transported calf (Pisoni *et al.,* 2023). However, a calf that was fed 10 L of colostrum at birth and fed milk replacer at an assembly centre, only took three days to recover the same concentrate intake than a non-transported calf. These results show the importance of feeding calves a high level of good colostrum in order to have a prompt recovery after periods of stress and feed restriction later in life. Physiologically, we have observed that calves fed 2 L of colostrum at birth and receiving rehydration solution at the assembly centre, arrived with lower levels of serum citrulline concentration indicating low levels of enterocyte mass in the small intestine, high concentrations of serum chromium ethylenediamine tetraacetic acid (Cr-EDTA) an inert marker that shows that those calves have low gastrointestinal permeability, or low mRNA expression of tight junctions in the jejunum, compared with calves fed or milk replacer at the assembly centre or/and had 10 L of colostrum at birth (Pisoni *et al.,* 2023). The consequences of those effects were that a greater number of calves with respiratory issues and diarrhoea after arrival at the rearing farm. In commercial situations, we have observed that calves have an average concentrate intake of 50 ± 21.8 g of concentrate dry matter intake during the first week at the rearing farm when fed 4 L of milk replacer a day at a concentration of 125 g. Therefore, seeking strategies before transport to minimize the gastrointestinal damage was our next objective.

We wanted simple management feeding strategies at the assembly centres which were easy to implement and low cost. For this, we chose to provide two feedings of milk replacer a day to the calves three days before transport, two feedings of milk replacer a day and *ad libitum* access to concentrate, two feedings of milk replacer a day and *ad libitum* access to acidified milk, or the combination of two milk replacer feedings a day an *ad libitum* access to concentrate and acidified milk (Pisoni *et al.,* 2022). Results from this study showed that the average concentrate intake during the first week after arrival was 185 g, 248 g, 251 and 194 g of concentrate dry matter intake, respectively. In addition, although these feeding management strategies did not prevent the increase of Cr-EDTA serum concentration due to transport, intake recovery was seen after 24 h after transport, and at 14 days post-transport calves fed *ad libitum* concentrate, or acidified milk had greater concentrate intake than non-transported calves. In this study we had 34% greater concentrate intakes and the results demonstrate that simple feeding management strategies before transport had big impact on the recovery of the calves.

Similarly, we wanted to investigate easy management strategies at arrival to improve the recovery of the calves. We have observed that, just at arrival calves, are hungry and therefore concentrate consumption peaks during the first 24 hours after arrival, with a consequent drop to 0 g of concentrate intake the following day, and a subsequent very low increase afterwards (Pisoni *et al.,* 2023). We have hypothesized that a peak of concentrate intake with the gastrointestinal dysfunction due to the previous feed restriction during transport observed, may further impair the recovery of the calves. The objective of the following study was to try to avoid the peak of concentrate intake and observe how calves recovered from transportation. To do that we offered the concentrate intake 24 h after arrival when calves already had their two milk replacer feedings and rested, or we offered the concentrate intake 10 hours after arrival but in between the two-milk replacer feedings, calves had access to *ad libitum* acidified milk (unpublished data). Results of this study showed that although calves that received concentre feed offered 24 h after arrival had a peak of concentrate intake on that day, their concentrate intake recovered faster than calves for which concentrate was offered at arrival; calves also offered acidified milk *ad libitum* at arrival had an excellent recovery with an additional 13% greater concentrate intake seven days after arrival.

Reducing bulls aggressive and aberrant oral non-nutritive behaviours

Management of intact bulls is challenging due to their tendency for aggressive and sexual behaviour, adding an element of risk to human caretakers. Aggressive behaviours in bulls may have different origins: i) inter-male fighting, adult males generally fight to win mates or territory, which is linked to serum testosterone concentrations, ii) aggression after grouping, unfamiliar animals are brought together, they fight and a social structure or hierarchy results, iii) resource defence, for example when feeding space is limited aggression increases, and iv) aberrant aggression & oral non-nutritive behaviours linked to nutrition (energy or fibre is restricted). Aggressive behaviours may have more than one origin. It is not easy to reduce aggressive behaviours, and it is necessary to identify the origin (regrouping, resources, nutritional strategies, weather) and understand animal behaviour and its relationship with age, nutrition, management and housing conditions. In this section we will focus on aberrant aggression and oral non-nutritive behaviours linked to dietary interventions. For finishing beef cattle, the most common behaviours indicative of poor welfare are aggressive behaviour and abnormal oral non-nutritive behaviours, and these behaviours are probably linked to anxiety. In rodents, behavioural responses related to anxiety, stress, and depression are affected when the commensal intestinal microbiota have been altered. Potential crosstalk mechanisms described in non-ruminant animals between the gut microbiota and the brain include the production and regulation of neurotransmitters, intestinal barrier integrity, modulation of enteric sensory afferents, bacterial metabolites, and mucosal immunity (Kraimi *et al.,* 2019). In ruminants, previous short-term experiments have indicated that nutrition affects some crosstalk mechanisms including rumen inflammation and barrier function. For beef cattle, the linkage between diet characteristics changes in potential mechanisms involved in crosstalk and behavioural responses have not been evaluated, however data from our research group indicate that some feed additives could decrease aggressive behaviour through the modulation of inflammation processes (Paniagua *et al.,* 2019; 2021). In a study (Devant *et al.,* 2016) the lack of straw supplementation decreased rumination and increased non-nutritive oral behaviours. Future research in this area (gut-brain axis) should be targeted at the interaction between different knowledge areas including feed presentation, feed palatability, digestive tract digestion at different sites, tissue integrity, immunity, inflammatory and behaviour. We also need to have in mind that there are other threats (including weather, pen density etc.) that have also been reported to cause anxiety and as a consequence aggressive behaviour that in combination with dietary strategies can exuberate aggressive behaviour episodes.

Reducing the environmental impact

The environmental impact of the dairy beef production system is low compared with other beef production systems, but there is still room for improvement. To reduce the environmental impact challenges should be focused on i) methane (CH_4)emissions from the digestion of feed (enteric emissions) and from manure management, ii) the environmental impacts related to the production and transport of feed ingredients and ration fed, and iii) the environmental pollution by the excess of nitrogen (N) and, to some extent, phosphorus from manure.

The most common dietary strategy to reduce N losses is to reduce crude protein (CP) intake, however this strategy needs to be carefully implemented to avoid detrimental effects on performance and on enteric and manure CH_4 emissions (described later). With excessive CP intake (above requirements) N excretion in the urine was increased, while only marginal effects on fecal N output were observed (Devant *et al.,* 2022). Reducing the dietary CP content in the growing and finishing phase can reduce the N excretion by 30 to 45% (Devant *et al.,* 2020 & 2022). Moreover, retrospective data from a Spanish study was used to simulate the theoretical the economic and environmental impacts of feeding beef cattle by adjusting the ration in terms of energy and protein, once or multiple times during the fattening period, according to the changing nutritional requirements (multiphase diet; Guarnido-Lopez, 2023). The implementation of a multiphase diet schedule in dairy beef cattle production could represent an improvement in feed efficiency, which furthermore may positively impact both the economic profitability and reduce the environmental impacts. However, further studies using a larger number of animals should confirm: 1) the optimal interval of body weights for the various phases, 2) the dietary energy and protein concentration required in each phase, and 3) the need to evaluate nutritional strategies with low dietary energy and greater fiber content that enable the simultaneous reduction of N and CH_4 emissions without detrimental effects on performance. Other dietary aspects that should be considered are straw presentation form; for example, providing unprocessed straw in separate feeders compared with chopped straw at 5 cm offered in separated feeders or in a total mixed ration (TRM) reduced N excretion by 17% (Genis *et al.,* 2021).

Moreover, *in vitro* data simulating potential manure management techniques indicate that the impact of dietary N reduction on N and CH_4 emissions from manure under aerobic and anaerobic storage conditions should also be considered (Devant *et al,* 2022). In certain cases, the reduction of dietary N concentration may increase N volatilization or CH_4 emissions when manure is stored under aerobic or anaerobic conditions, respectively.

When focusing in reducing enteric CH_4 emissions a first step is to decide which methods will be used to measure it. Some methods are based on equations to predict CH_4 emissions, others are based on "sniffer" CH_4 measurement system devices, and some of which are considered the gold standard: respiration chambers. An alternative strategy to reduce CH_4 emissions is to add fat or to use fat sources that are polyunsaturated in the ration. In a running study in Spain where the aim was to substitute palm oil by fat sources that are hoped to be sustainable and could reduce CH_4 emissions, preliminary results indicate that supplementing canola and soybean oil to diets when soybean meal is the main protein source is effective reducing CH_4 emissions. However, when corn (i.e., maize) dried distillers grain (DDG) is used, this protein source by itself already reduces CH_4 emissions regardless of the supplementary oil source used. Previous *in vivo* data suggest that the use of DDG has no detrimental effect on growth rate, so we expect that the net effect on carbon footprint (CF) per kg carcass will not be compromised (Devant *et al.,* 2023). Furthermore, most published studies only estimate the overall CH_4 production based on a short period of measurement. Thus, there is an urgent need to perform CH_4 measurement over longer periods during the fattening period; on newly weaned (3-4 months old), 6-8 months old as well as 10-13 months old animals to better estimate the lifetime CH_4 production. Currently, using a "sniffer" CH_4 measurement system we observed that substituting palm oil with sunflower oil at the beginning of the new fat source supplementation resulted in a decrease in enteric CH_4 emissions (Llonch *et al.,* 2024).

Finally, if the sector pursues a greater reduction in the total CF of beef, greater efforts in analyzing the main contributing factors and implementing good production practices will be needed. In a Spanish study, feed production and the origin of the feed ingredients, were the main contributing factors. So, finding ingredients with low CF will be one of the key aspects to reduce the environmental impact of dairy beef. Moreover, water footprint is a critical environmental indicator that cannot be overseen, mainly in Mediterranean countries like Spain where we foresee water scarcity in the coming future.

In summary, main dietary challenges include reducing N content of the ration without increasing N and CH_4 emissions and/or reducing animal performance. To achieve this goal, it is critical that dairy beef production systems have their own equations for adjusting N and energy requirements, and to estimate N and CH_4 emissions. Special attention to the requirements of crossbred animals and to the associated emissions are also needed. Furthermore, having a complete holistic view is needed to avoid counterbalanced dietary strategies that improve environmental impact but may reduce performance and, therefore, lead to a similar total CF per kg carcass produced. Also, evaluating the effects of feed ingredients and dietary formula on environmental impact needs further attention. Finally, high animal health status and low culling rate are needed for obtaining high efficiency in our dairy beef production – a prerequisite for keeping CF low.

References

Blum, J. W., and H. Hammon. 2000. Colostrum effects on the gastrointestinal tract, and on nutritional, endocrine and metabolic parameters in neonatal calves. *Livest. Prod. Sci.* **66**:151–159. https:/ / doi .org/ 10 .1016/ S0301 -6226(00)00222 -0.

Buckham-Sporer, K.; Earley, B.; Marti, S. Current Knowledge on the Transportation by Road of Cattle, including Unweaned Calves. *Animals* 2023, 13, 3393. https://doi.org/10.3390/ani13213393.

Devant, M., A. Ferret, J. Gasa, S. Calsamiglia, and R. Casals. 2000. Effects of protein concentration and protein degradability on performance, ruminal fermentation and nitrogen metabolism in crossbred heifers fed concentrate and barley straw from 100 to 230 kg body weight. *Journal of Animal Science,* **78**: 1667-1676. https://doi.org/10.2527/2000.7861667x.

Hutcheson, D.P. and Cole, N.A. 1986. Management of Transit-Stress Syndrome in Cattle: Nutritional and Environmental Effects. *Journal of Animal Science,* **62:** 555-560.

Devant, M., G. B. Penner, S. Marti, B. Quintana, F. Fábregas, A. Bach, and A. Arís. 2016. Behavior and inflammation of the rumen and cecum in Holstein bulls fed high-concentrate diets with different concentrate presentation forms with or without straw supplementation. *Journal of Animal Science,* **94**:3902-3917.

Devant, M. A. Pérez, C. Medinyà, J. Riera, J. Grau, B. Fernández, and F.X. Penafeta-Boldú. 2022. Effect of decreasing dietary crude protein in fattening calves on the emission of ammonia and greenhouse gases from manure stored under aerobic and anaerobic conditions. *Animal*, **16**: 100471. https://doi.org/10.1016/j.animal.2022.100471

Devant, M.; Llonch, L.; Marti, S.; Verge, G.; Riera, J.; Medinya, C.; Cucurull, J.; Pérez A.; Fernández, 2023.Substituting palm oil by plyunsaturated fatty acid rich oils reduces methane emissions at a different degree depending on concentrate formula of dairy beef calves: in vitro screening." ASAS-CSAS Annual Meeting & Trade Show. Albuquerque, New Mexico. Date of event: 16-20/07/2023.

Genís, S., M. Verdú, J. Cucurull, and M. Devant. 2021. Complete feed versus concentrate and straw fed separately: Effect of feeding method on eating and sorting behavior, rumen acidosis, and digestibility in crossbred Angus bulls fed high-concentrate diets *Anim. Feed Sci. Technol.,* **273**: 114820. https://doi.org/10.1016/j.anifeedsci.2021.114820.

Guarnido-Lopez, P.; Devant, M.; Llonch, L.; Marti, M.; Benaouda, M. 2023. Multiphase diets may improve feed efficiency in fattening dairy beef cattle: a retrospective simulation of the economic and environmental impact. *Animal*, **5**: 101030. https://doi.org/10.1016/j.animal.2023.101030.

Kraimi N, Dawkins M, Gebhardt-Henrich SG, Velge P, Rychlik I, Volf J, Creach P, Smith A, Colles F, Leterrier C. 2019. Influence of the microbiota-gut-brain axis on behavior and welfare in farm animals: A review. Physiol Behav. Oct 15;210:112658. doi: 10.1016/j.physbeh.2019.112658.

Marcato, F., H. van den Brand, B. Kemp, B. Engel, M. Wolthuis-Fillerup, and K. van Reenen. 2020a. Transport of young veal calves: Effects of pre-transport diet, transport duration and type of vehicle on health, behavior, use of medicines, and slaughter

characteristics. *Front. Vet. Sci.,* **7**:576469. https://doi.org/ 10.3389/

fvets.2020.576469.

Marti, S.; Velarde, A.; Quintana, B.; Moles, X.; Solé, A.; Devant, M. "Evaluation of different types of journeys on welfare indicators of un-weaned calves transported by road in Europe". *Journal of Animal Science,* **97**(Suppl 3):10 - 11. *Amer Soc Animal Science,* 2019. ISSN 0021-8812. DOI: 10.1093/jas/skz258.019.

Marti, S.; Moles, X.; Sole, A.; Farish, M.; Brims, M.; Mitchell, M.; Voas, A.; Devant, M.; Velarde, A. "Posture behavior and truck microclimate in a very long journey of unweaned dairy beef calves: A field study". Journal of Animal Science. 99(Suppl 3), pp. 222 - 222. *Amer Soc Animal Science,* 2021. ISSN 0021-8812 DOI: 10.1093/jas/skab235.404.

Llonch, L., S. Marti, M. Devant. 2024. Effect of substituting palm oil by sunflower oil in fattening dairy beef bulls fed high-concentrate diets on performance and enteric methane emissions. Book of Abstracts of the 75th Annual meeting of the European Federation of Animal Science, EAAP, page 325.

Paniagua, M., J. Crespo, A. Arís, and M. Devant. 2019. *Citrus aurantium* flavonoid extract improves concentrate efficiency, animal behavior, and reduces rumen inflammation of Holstein bulls fed high-concentrate diets. *Anim. Feed Sci. Technol.*, **258**: 114304. https://doi.org/10.1016/j.anifeedsci.2019.114304.

Paniagua, M., F. J. Crespo, A. Arís, and M. Devant. 2021. Effects of Flavonoids Extracted from Citrus aurantium on Performance, Behavior, and Rumen Gene Expression in Holstein Bulls Fed with High-Concentrate Diets in Pellet Form. *Animals*, **11**: 1387. https://doi.org/10.3390/ani11051387.

Pisoni, L.; Marti, S.; Bassols, A.M.; Saco, Y.; Pujols, J.; Gomez, N.; Devant, M. "Evaluation of pre-transport feeding strategies in bull calves' performance and gut permeability." EAAP Annual Meeting. City of event: Porto, Portugal. Date of event: 5-9/09/2022.

Pisoni L, Devant M., Bassols A.M., Saco Y., Pato R., Pujols J., Marti S. The effects of colostrum consumption and feed restriction during marketing and transportation in the recovery of dairy beef male Holstein calves. *Journal of Dairy Science*. pp. S0022 - 0302(23)00512. Elsevier, 2023. ISSN 0022-0302 DOI: 10.3168/jds.2023-23374.

Renaud, D., and B. Pardon. 2022. Preparing male dairy calves for the veal and dairy beef industry. *Vet. Clin. North Am. Food Anim. Pract.* **38**:77–92. https: //doi .org/10.1016/j.cvfa.2021.11.006.

Renaud, D. L., T. F. Duffield, S. J. LeBlanc, D. B. Haley, and D. F. Kelton. 2017. Management practices for male calves on Canadian dairy farms. *J. Dairy Sci.* **100**:6862–6871. https: / / doi.org/10 .3168/jds .2017 -12750.

Effect of early life nutrition on the performance of dairy origin beef cattle

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Introduction

Approximately 60-65% of beef output in the EU now comes from dairy progeny, highlighting the increasing emphasis on the sustainability of dairy calf-to-beef production systems. In grass-based dairy-beef operations, male beef production primarily involves steers, which typically reach slaughter specifications at 22-24 months of age, depending on their genotype. These systems aim to maximize the utilization of grazed grass within the farm's feed budget while strategically incorporating concentrate feeding to achieve carcass specifications without compromising growth targets.

A key strategy for mitigating greenhouse gas emissions in the Irish beef sector involves reducing variability in slaughter age and greenhouse gas emissions throughout the animal's lifetime. In line with the Teagasc Marginal Abatement Cost Curve analysis (Lanigan *et al.*, 2023), current policy aims to decrease the average age at slaughter of dairy-beef steers by 3 months, nationally, from an average of ca. 27.5 months in the base year of 2018 to 24 months by 2030. Achieving optimal carcass weight and fatness is crucial for facilitating earlier slaughter and minimizing the carbon footprint of pasture-based dairy-beef production systems.

At farm level, a significant source of biological inefficiency in many commercial grass-based dairy-beef operations is the failure to consistently achieve high growth performance during early life. Inadequate growth rates by weaning (8-10 weeks of age) and housing (typically 7-8 months of age) often result in lighter carcasses and delayed slaughter age, adversely impacting production efficiency, farm economics, and environmental sustainability. Notably, on-farm data indicates that up to 40% of the variation in final carcass weight can be attributed to calf performance during the first three to four months of life (Figure 1). Given that young calves (under six months of age) have a limited latent capacity to compensate for under-nutrition, it is crucial to achieve moderate to high growth rates during this period to consistently meet acceptable lifetime performance targets.

Enhanced early-life nutrition can significantly influence lifetime growth potential and carcass composition, although data on this topic remains limited. Key developmental programming windows during early calf life (under six months of age; Figure 2) play a crucial role in eventual carcass development. Strategic nutritional interventions aimed at promoting muscle cell hyperplasia, hypertrophy, and adipocyte development during these critical periods can positively affect carcass gain, composition, and meat quality. This paper will explore the importance of maximizing early-life growth potential and implementing targeted nutritional strategies for tissue development, highlighting both immediate and long-term impacts on animal performance, carcass yield, and the overall efficiency of sustainable pasture-based dairy-beef systems.

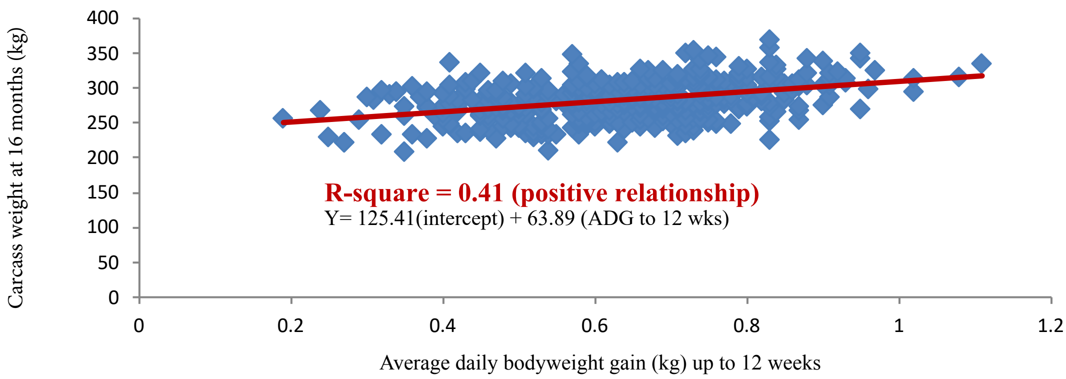

Figure 1. *Relationship between calf average daily gain up to 12 weeks of age and subsequent carcass weight at 16 months of age for Holstein Friesian bulls (n=1100; Kelly, 2024, unpublished)*

Importance of colostrum and development of immune status in dairy bred calves

At birth, dairy calves have a fully developed albeit immature immune system, making them particularly susceptible to diseases compared to older cattle (Hulbert and Moisá, 2016). Colostrum provides essential passive immunity, containing immunoglobulins (Ig), maternal leukocytes, growth factors, hormones, cytokines, and microbial factors that enhance the neonatal calf's defences against pathogens (Godden, 2008).

Passive transfer refers to the absorption of maternal Ig from colostrum through the calf's small intestine during the first 24 hours of life (Godden, 2008). If a calf absorbs less than 10 mg/ml of IgG (or fewer than 12 zinc turbidity test units), it is deemed to experience failure of passive transfer (Godden, 2008; Logue and Mayne, 2014). To maximize successful immunoglobulin transfer, it is recommended that dairy bred calves receive 10% to 12% of their body weight in colostrum during the first feeding. Since the calves' IgG absorptive capacity declines after 4 to 6 hours of life, it should ideally receive 3 litres of high-quality colostrum within 4 hours of birth (Lorenz *et al.*, 2011). On farm surveys suggest that a high proportion of Irish dairy calves do not absorb sufficient colostral Ig immediately after birth, significantly increasing their risk of disease and mortality (Todd *et al.*, 2018). Indeed, male calves, which represent the majority of surplus calves, are less likely to receive adequate colostrum compared to females, further elevating their risk of morbidity and mortality (Shivley *et al.*, 2019). Research indicates that dairy origin calves with low serum immunoglobulin (Ig) concentrations encounter significantly greater health challenges, including a threefold higher risk of mortality (11% vs. 3%), increased incidence of diarrhoea (21% vs. 14%), and a higher prevalence of respiratory diseases (36% vs. 28%) compared to calves with adequate Ig levels.

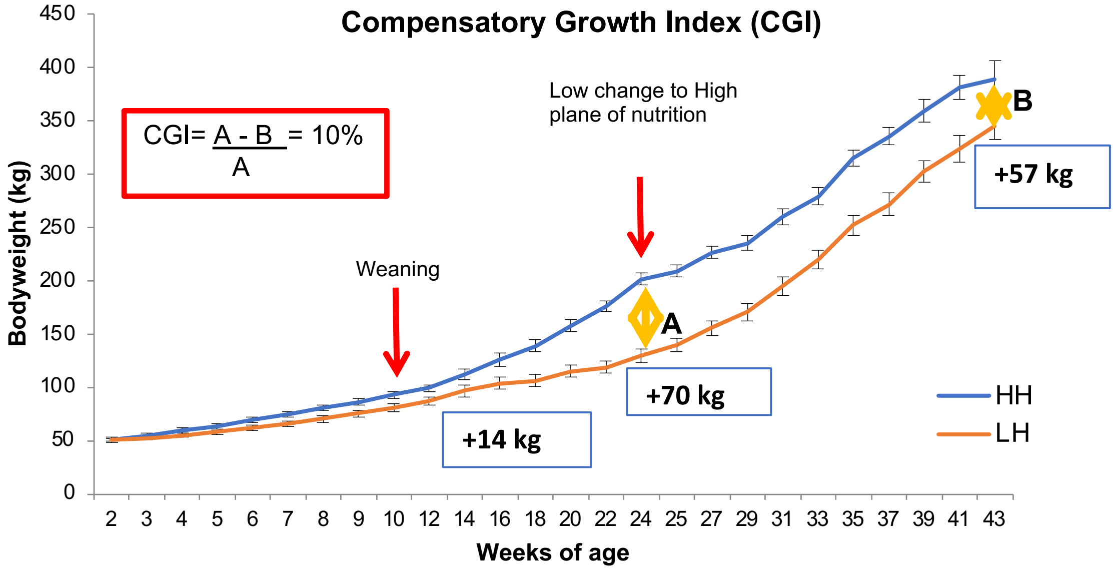

Figure 2. *Effect of plane of nutrition offered during the first [high (H) v low (L)] or second [high (H)] six months of life on bodyweight gain up to 42 weeks of age in Holstein Frisian bull calves on compensatory growth response (expressed as compensatory growth index. Adapted from research conducted at Teagasc Grange by Byrne et al. (2018). Relative growth advantage of calves offered HH compared with LH plane of nutrition up to six months of age was predominantly retained to 42 weeks of age despite the calves previously on L switched to the H (LH) plane of nutrition (concentrate ad libitum while on pasture) on reaching six months of age. Thus the LH calves only recovered 10% of the bodyweight forgone in the first six months of life.*

Pre-weaning nutrition

The amount of milk replacer (MR) offered will depend on its nutritional composition and the body weight and desired growth rate of the calf. For successful dairy calf rearing, the target is to achieve a pre-weaning growth rate of 700g per day, resulting in the dairy calf reaching a body weight of 100 kg at 12 weeks. To meet these growth targets a standard MR at a feeding rate of six litres (125g/l; split between two feeds), equating to 650-750g of powder per day has been typically recommended. Research from Teagasc Grange (Fallon *et al.* 2008) shows no calf growth advantage in raising the protein content of MR from 23% to 28%. Similarly other studies conducted at Grange clearly show no growth advantage following elevating milk replacer fat content beyond 17%. For this reason, once composed of good quality, undegraded ingredients, commercial MR containing 20 to 23% crude protein and 15 to 20% of a suitable fat source should be adequate to support acceptable pre-weaning growth in dairy-beef calves. In general, MR containing milk products (skim and whey based) are digested better than those containing vegetable proteins and are particularly beneficial for younger unsupplemented calves that may be more susceptible to stress. Additionally, most MR can also be fed as a once-a-day product with no difference in calf performance, if feeding guidelines are followed correctly.

Conventional (average daily gain (ADG) 500-700 g/day) versus Intensified (ADG > 800g/day) pre-weaning feeding for accelerated growth has been a hot topic in dairy calf management in recent years. Intensified rearing systems allow calves much greater intakes of MR in early life, with feeding rates approximately twice (MR input of more than 50kg) of those offered under conventional systems. Additionally, feeding a quality MR with a compositionally higher crude protein content (25 to 28%) to support the potential for rapid lean growth is typically advocated under such systems. Research shows that calf growth rate responds to increasing MR allowance to greater than 1000g/day pre weaning. However, from a dairy-beef perspective the economic payback for this additional investment is highly dependent on the cost of MR, the prevailing value of beef and the relative importance of meeting strict carcass specifications in a timely fashion (i.e. young bull beef systems). For instance, unlike dairy heifer replacement studies where high amounts of milk fed to calves pre-weaning may be justified by the positive impact of such a practice on inducing earlier puberty and improved lactation performance later in life (Soberon and VanAmburgh, 2013; Gelsinger *et al.,* 2016), this may not be as applicable in dairy calf-to-beef production systems. Indeed, studies in Ireland (Fallon *et al.,* 2005; Byrne *et al.,* 2017; Coen *et al.,* 2021) and elsewhere (Khan *et al.,* 2011; Hu *et al.,* 2020; Rosadiuk *et al.,* 2021) have shown that despite the advantages of increased milk supply on tissue and skeletal growth during the pre-weaning period, the practice is less attractive if growth advantages are relatively small (usually < 10 kg live weight at weaning) and/or relatively short-lived, with the practice typically associated with concomitant depression in consumption of solid feed pre-weaning. Indeed, the magnitude of the pre-weaning growth response to MR feeding level can be influenced by, among other things, the prevailing supplemental concentrate feeding practice i.e. restricted vs. *ad libitum* allowance. In a recent experiment at Teagasc Grange, no difference in pre-weaning gain, days to reach target weaning weight, ADG over the first grazing season lifetime growth and carcass performance of dairy calves offered either 4 L or 8 L of calf MR daily, equivalent to 500 and 1000 g DM of MR, respectively, and *ad libitum* access to concentrates. Calves offered the lower MR allowance consumed an additional 25 kg of concentrate over the rearing phase in that study (Byrne *et al.,* 2021 - unpublished). Overall, this research suggests that when concentrate is freely available, feeding a lower level of MR is offset by increased concentrate consumption resulting in similar calf performance pre-weaning. These findings are consistent with other recent research (Hu *et al.,* 2019). This implies that under this pre-weaning feeding regime the opportunity to influence dairy calf growth through enhanced MR feeding levels is relatively limited.

Exploiting post-weaning growth potential

Nutrient conversion into body weight gain is most efficient during the immediate post-weaning period in dairy-beef systems. In artificially reared calves, the pre-weaning phase is typically characterised by higher feed costs than those incurred during the post-weaning period. Therefore, optimizing management and feeding strategies to seamlessly integrate pre- and post-weaning nutrition is crucial for maximizing efficiency and enhancing lifetime performance. Furthermore, achieving early life weight-for-age targets is essential for improving the overall production efficiency of dairy-beef enterprises.

Recent studies at Teagasc Grange show that dairy calves fed high-energy concentrate-based diets post-weaning achieve growth rates of approximately 1.20 to 1.30 kg/day up to six months of age, about 50-60% higher than those on conventional diets (Byrne *et al.,* 2018; Kelly *et al.,* 2020). De Carvalho *et al.* (2021) found that feed conversion ratios (kg feed DM per kg bodyweight gain) for dairy calves on such diets during the early post-weaning phase (8-12 weeks) are approximately 3:1, increasing to around 5:1 from 12 to 30 weeks. This early-life feed efficiency is 2-3 times superior to that of finishing cattle receiving supplementary concentrates at pasture (Keane and Drennan, 2008). By strategically reallocating the concentrate feed budget from the finishing phase to the early-life phase in dairy calf-to-beef systems, producers can leverage calves' superior feed efficiency, and body muscle and fat deposition potential resulting in improved financial and biological outcomes. Additionally, our studies indicate that calves receiving a high plane of nutrition during early life (3 to 21 weeks) exhibit increased fat cell hyperplasia (cell numbers) and hypertrophy (cell growth) in subcutaneous adipose tissue by five months of age (Keogh *et al.,* 2020). This early nutritional advantage may predispose such animals to greater carcass adiposity later in life, aiding in the attainment of desired carcass fatness at an early slaughter age. Prioritizing early-life nutrition is essential for optimizing growth, efficiency, and overall production outcomes in dairy calf-to-beef systems.

Limiting weaning stress and growth retardation

A successful transition from the pre-ruminant to ruminant stage is essential for sustaining performance and health in dairy calf rearing. Poor management during this critical period can result in post-weaning growth setbacks, elevated stress, and increased vulnerability to health issues, particularly respiratory diseases. These challenges can significantly hinder the animal's long-term performance, leading to lasting deficits in growth performance, economic returns, and ultimately environmental efficiency in dairy-beef systems.

Adequate concentrate intake is crucial to preventing nutritional stress at weaning and is essential for ensuring a smooth transition and integrating optimal pre- and post-weaning performance in dairy-beef calves. The fermentation of solid feed stimulates the differentiation and expansion of rumen epithelial papillae (finger like projections of the rumen epithelium), allowing for a greater surface area for the absorption of volatile fatty acids (VFAs) produced by microbial fermentation (Nemati *et al.,* 2015). Fermentation of the starch component of grain produces volatile fatty VFA, particularly butyrate, which stimulates growth of rumen papillae, essential for the development of the absorptive capacity of the rumen. Indeed, the quantity of calf starter feed intake correlates well with the degree of rumen fermentative function as well as the physical development of rumen, pre-weaning. It takes about 3-4 weeks for appreciable development of the rumen papillae from when concentrate feed is initially offered. Thus, the earlier starch is digested by the calf, the faster rumen development occurs. From a management viewpoint, high-quality concentrate should be offered to the calf in the first few days after birth along with access to water (Chapman *et al.,* 2016). Ultimately pre-weaning nutritional management and, in particular concentrate feed supplementation, plays a crucial role in determining weaning age and potentially early post-weaning rumen health and functionality.

Practical nutritional strategies and recommendations to support improved rumen development

Concentrate feeding: high-quality calf starter should be introduced by four days of age, with a target intake of approximately 300 g per day by two weeks of age. This starter should contain 17-18% crude protein and have a minimum energy value of 12 MJ/kg (greater than 0.95 UFV/kg). Fresh, dust-free starter should be provided daily to maximize intake and stimulate rumen development.

Roughage feeding: Roughage (hay or chopped straw) should be introduced when calves consume at least 1.5 kg of concentrate, typically post-weaning. It supports the growth of the rumen's muscular layer and maintains epithelium health. Starting to offer roughage at week eight is advisable, with a concentrate-to-roughage ratio of 8:1 by weight or about 200 g of roughage per calf daily to prevent excessive intake that could dilute overall dietary nutrient intake and thus growth performance.

Weaning strategies

Weaning can occur between six to ten weeks of age, depending on the feeding strategy employed on the farm. Gradual weaning is preferred, achieved either by reducing milk intake over time (De Passillé and Rushen, 2016) or through a step-down approach (Khan *et al.,* 2007; Hill *et al.,* 2012). For calves receiving moderate to high milk volumes (750 g to >1 kg), a gradual weaning period of 14 days is a recommended minimum to prevent reductions in dry matter intake or ADG during and immediately after weaning (Hill *et al.,* 2012; Kelly *et al.,* 2020).

Weaning decisions should focus on solid feed intake rather than age. Calves should consume 1.3% to 1.5% of their body weight in dry feed to meet their nutritional needs for maintenance and growth. Ideally, they should be consuming at least 1 kg of calf starter daily for three consecutive days before liquid feed is discontinued. Monitoring starter intake allows for adjustments to be made, if necessary, to weaning schedules for calves not meeting pre-weaning growth targets. Additionally, stressors such as dehorning or vaccination should be avoided during weaning, as they can weaken the immune system and thus increase the risk of morbidity and mortality. A planned, gradual weaning strategy is essential for promoting solid feed intake and ensuring a smooth transition from pre- to post-weaning growth phases. It is important to recognize that post-weaning, a dairy-beef calf targeting a growth rate of over 800 g/day requires a daily solid feed intake of 2.2 kg DM (12 MJ/kg or >0.95 UFV/kg; NRC, 2021). Thus, ensuring adequate post-weaning feed intake and facilitating the development of a healthy, functional rumen are critical for meeting the calf's nutritional requirements and are essential to prevent growth setbacks while maintaining consistent, optimal growth performance.

Carry over effects of early-life nutrition on carcass weight and composition

Achieving a commercially acceptable carcass fat score (>6.0 units on a scale of 1 to 15) is a significant challenge where dairy-bred cattle are reared under a predominantly pasture-based production system and slaughtered at a young age (Murphy *et al.,* 2017). Since the ability of cattle to deposit subcutaneous fat, in particular, and achieve optimal performance at younger ages is critical for meeting industry specifications, understanding how nutrition during various developmental stages, particularly early life, influences final carcass composition is a key area of research.

Enhanced early-life nutrition in beef calves has been shown to have the potential to positively influence lifetime growth potential and carcass composition (Hausman *et al.,* 2009; MacPherson *et al.,* 2019; van Niekerk *et al.,* 2021), although there are little published data on studies that have monitored animal performance beyond the calf stage. Key developmental programming windows in early calf life are believed to affect carcass composition and development. Strategic nutritional interventions during these windows can enhance tissue hyperplasia and hypertrophy, potentially altering carcass gain, adiposity, composition, and meat quality later in life.

Myogenesis or muscle cell development begins while the calf is in the womb, and postnatal muscle growth primarily involves an increase in muscle fibre size and not necessarily the formation of new muscle fibres (Stickland, 1978). While the number of muscle fibres established during prenatal myogenesis is fixed, other skeletal muscle cells, such as satellite cells, have the potential to undergo postnatal cellular division (Rehfeldt *et al.,* 2000). Therefore, increased dietary intake during the pre-weaning and weaning periods can significantly influence overall skeletal muscle growth and development, which in turn affects lean growth and ultimately carcass composition and meat quality following slaughter (Rehfeldt *et al.,* 2000). Moreover, muscle tissue also comprises other cell types, such as adipocytes. Enhanced early-life nutrition can influence these cell types, impacting on the chemical composition and eating quality of the final product.

Fat cell or adipocyte development is characterized by hyperplastic growth, with preadipocytes appearing during embryonic life; however, significant postnatal development occurs in early calfhood when the number of adipose cells is established (Spalding *et al.,* 2008). Studies suggest that strategic nutritional manipulation during this critical phase could promote adipocyte hyperplasia (increased cell numbers) and hypertrophy (increased cell size) and consequently affect carcass fatness (Tikofsky *et al.,* 2001). Specific nutrient inputs, including lipid supplements in early life, have also been shown to enhance early adipocyte hyperplasia and differentiation (Mangrum *et al.,* 2016), leading to improvements in meat quality attributes such as higher lipid content in striploin steaks and enhanced marbling scores.

Studies with suckled beef calves clearly show an advantage of improved early life nutrition in the form of increased milk consumption on weaning weight and final carcass weight. Indeed a study conducted by Drennan *et al.* (2005) indicated that on average, each additional kilogram of milk consumed daily by pre-weaned suckled calves, resulted in an additional 6.8 kg in weaning weight, 5.2 kg at in slaughter bodyweight and 2.72 kg in carcass weight. A number of studies have also been conducted at Teagasc Grange with artificially reared dairy bred calves to examine the latent effects of early life nutrition on eventual carcass weight and composition. In general, while there have been some residual effects of early pre-weaning and/or post-weaning nutrition on aspects of carcass weight and composition, these have been modest and the economic feasibility of such interventions will depend on the relative response in carcass weight, the prevailing value of beef and the cost of feed.

Abbott *et al.* (2024, unpublished) examined the effect of pre- and post-weaning plane of nutrition on the lifetime performance of young Holstein Friesian and Angus sired dairy bulls slaughtered at 16 months of age. In that study, calves were offered either a moderate (M PRE) or high (H PRE) plane of nutrition from birth.

Calves on the M PRE treatment were offered 6L/day containing 750g MR for the pre-weaning period with a 2 week weaning period. Calves on H PRE treatment were offered 8L/day containing 1,200g MR for the initial 2 weeks, 10L/day containing 1,500g MR for the remaining pre-weaning period. A commercial calf rearing pelleted concentrate, 18% protein was offered *ad libitum* in the pre-weaning period. Post-weaning calves were balanced by age and live weight from within their respective pre-weaning treatment onto one of two, four week long post-weaning diets, moderate (M POST) or high (H POST), receiving 1.5 kg concentrates per day and *ad libitum*, respectively. Subsequently animals were managed in line with a standard technically efficient dairy calf-to-beef system and followed to slaughter as bulls at 16 months. Full details of the main results of this study can be found elsewhere in this publication. Briefly, no interactions were observed between the pre- and post-weaning diets and thus there was no evidence of compensatory growth on those calves offered a moderate plane of nutrition. Calves offered the H PRE diet had greater bodyweight at weaning compared to M PRE as did those calves offered H POST compared with M POST. Bodyweight differences were retained to housing for both pre- and post- weaning feeding regimes. At slaughter, while the relative differences in bodyweight were retained only those observed during post-weaning were statistically significant for bodyweight and carcass weight, with no differences in conformation or fat score between the dietary treatment groups. Importantly, the variation in carcass characteristics and the proportion of bulls meeting all market carcass criteria was higher for calves offered a high compared with the moderate pre- and post-weaning diets. Such uniformity has obvious implications for the overall value of carcasses from dairy bred bulls slaughtered at a young age as well as for the logistics of management (i.e. avoiding the requirement for staggered marketing). Ongoing research effort at Grange is examining variation in the duration and extent of concentrate supplementation of calves during their first grazing season on subsequent bodyweight gain and final carcass characteristics.

In other studies with young dairy bred bulls at Grange, we have examined the effect of the chemical composition of the milk replacer offered, pre-weaning, on lifetime performance and on detailed carcass characteristics. For example, Ferguson *et al.* (2019) offered 120 Holstein Friesian bull calves a milk replacer containing either one of two concentrations of supplemental fat *viz.* a high fat (HF; 21% CP, 30% fat) or a standard fat (CON; 21% CP, 18% fat)]. Milk replacer was offered at a rate of 6 L/day at 12.5% DM/L and all calves were offered a concentrate in pelleted form limited to 1kg/day. Pre-weaning performance and bodyweight at weaning was not affected by milk replacer fat content and neither was the chemical composition of a cuberoll cut harvested from a proportion of the calves in each treatment, just prior to weaning. The remaining calves on both pre-weaning milk replacer diets were reared under a standard 16 month old dairy bull beef system. During the finishing phase the young bulls were offered one of four concentrate based finishing rations balanced across the two original pre-weaning milk replacer based diets. The concentrate feed was composed of (i) either maize or barley (included at 70%, as fed) which in turn was (ii) either supplemented (5% as fed) or not with a rumen inert fat supplement, rich in palmitic acid. Animals were slaughtered before reaching 16 months of age. Selected carcass and rib-joint dissection measurements were taken at slaughter. Overall, there were no biologically significant interactions amongst the main dietary treatments for any of the economically important traits measured. There was no latent effect of calf rearing dietary regimen on any of the carcass measurements recorded. Similarly, no effect of cereal type (maize v barley) in the finishing ration was observed. In general, the inclusion of supplemental fat in the finishing ration depressed animal performance and, as a consequence, reduced carcass weight and associated fat and muscle classifications, which was, most likely, due to the negative impact of dietary fat inclusion on feed intake.

These findings by Ferguson *et al.* (2019) have implications for the nutritional management of young dairy bulls during finishing. There is anecdotal evidence from, or at least a perception within, the Irish feed industry that inclusion of processed maize and/or supplemental fat in the diet of young rapidly growing male cattle is a panacea for the lower carcass fat scores typically achieved with such animals. Our data does not substantiate this perception or indeed the hypothesis that higher fat intakes during the pre-weaning phase can predispose the animal to higher carcass fat cover in later life. In addition, our data indicates that, where economically appropriate, barley can be essentially entirely substituted for ground maize in the finishing diet of young cattle, without affecting animal performance, carcass characteristics and, in particular, carcass fat colour.

Conclusions

In the foregoing discussion we have outlined the advantages of ensuring that artificially reared, dairy bred calves, destined for beef production receive appropriate nutritional management from birth if target growth rates and eventual carcass specifications are to be consistently met. This process starts by these calves being offered an adequate supply of good quality colostrum. During the pre-weaning phase it is important that the milk replacer based feeding regimen employed supports the early consumption of concentrate and that calves are consuming at least 1 kg of concentrate for at least three consecutive days prior to weaning. The response in bodyweight gain to concentrate supplementation during the early post weaning period is high and this is a period during which the calf has a particularly high capacity for feed efficient growth. Indeed, the very limited number of studies that have followed the latent effects of early life plane of nutrition right through to slaughter suggest that bodyweight gains during the early post-weaning phase can be more or less retained to slaughter and that such interventions can result in a higher proportion of animals meeting target carcass specification, particularly when slaughtered at a young age. Where growth performance in calves is suboptimal during the first six months of life, this underperformance cannot be readily compensated for by offering a high plane of nutrition thereafter, again highlighting the importance of achieving target rates of gain throughout life if final carcass specifications are to be met in a timely fashion. In pasture-based production systems, concentrate supplementation regimens employed during the grazing season should be conducted in conjunction with a well-informed grazing management strategy (covered elsewhere in this publication) and utilised with the primary purpose of ensuring that target growth rates are achieved throughout the animal's life.

References

Byrne CJ, Fair S, English AM, Cirot M, Staub C, Lonergan P, Kenny DA. 2018. *Journal Dairy Science,* **101(4):** 3447-3459.

Byrne, C. J., Fair, S., English, A. M., Johnston, D., Lonergan, P. and Kenny, D. A. 2017. *Animal*, **11(9),** 1531-1538.

Chapman CE, Erickson PS, Quigley JD, Hill TM, Bateman HG 2nd, Suarez-Mena FX, Schlotterbeck RL. 2016. *Journal of Dairy Science,* **99(4):**2740-2747.

Coen, S.P., Keogh K, Byrne, C.J. Lonergan, P., Fair, S., Crowe, M.A. and Kenny, D.A. 2021. *Journal of Animal Science,* **1:99(8):**skab195.

de Passillé AM, Rushen J. 2016. *Journal of Dairy Science,* **99(5):** 3578-3583.

Fallon, R.J., Morrison, S., Dawson, L., Twigge, J. 2008. Beef Production Series No. 85, Teagasc, http://hdl.handle.net/11019/901

Ferguson, N. Kelly, A.K., Moloney, A.P. and Kenny, D.A. 2017. *Journal of Animal Science,* **95(S4):** 295-296.

Gelsinger, S.L., Heinrichs, A.J. and Jones, C.M. 2016. *Journal of Dairy Science,* **99(8):**6206-6214.

Godden S. 2008. *Vet Clin North Am Food Anim Pract.,* **24(1):**19-39.

Hausman GJ, Dodson MV, Ajuwon K, Azain M, Barnes KM, Guan LL, Jiang Z, Poulos SP, Sainz RD, Smith S, Spurlock M, Novakofski J, Fernyhough ME, Bergen WG. 2009. *Journal of Animal Science,* **87(4):**1218-1246.

Hu W, Hill T.M., Dennis T.S., Suarez-Mena F.X., Aragona K.M., Quigley J.D, Schlotterbeck R.L. 2020. *Journal of Dairy Science*, **103(3):** 2217-2232.

Hulbert L.E. and Moisá, S.J. 2016. *Journal of Dairy Science,* **99(4):**3199-3216.

Keane, M.G. and Drennan, M.J. 2008. *Livestock Science,* **115:** 2–3, 268-278.

Kelly, A. K., Byrne, C., McGee, M., Perry, G. A., Crowe, M. A., Sauerwein, H. and Kenny, D. A. 2020. *Journal of Animal Science*. **98(10):** 1-13.

Keogh, K., Kelly, A. K. and Kenny, D. A. 2021. Scientific Reports, **11(1):** 1-12.

Khan, M. A., Lee, H. J., Lee, W. S., Kim, H. S., Ki, K. S., Hur, T. Y., Suh, G. H., Kang, S. J. and Choi, Y. J. 2007. *Journal of Dairy Science,* **90(7),** 3376-3387.

Khan, M. A., Weary, D. M. and von Keyserlingk, M. A. 2011. *Journal of Dairy Science,* **94(3):** 1071-1081.

Lanigan G.J., Hanrahan K. and Richards K.G. (2023). Teagasc. https://www.teagasc.ie/media/website/environment/climate-action/climate-centre/MACC-2023.pdf

Logue, DN and Mayne CS. 2014. *Vet Journal,* **199(1):**31-38.

Lorenz I, Earley B, Gilmore J, Hogan I, Kennedy E, More SJ. 2011. *Irish Veterinary Journal,* **21:64(1):**14.

MacPherson J, Meale SJ, Macmillan K, Haisan J, Bench CJ, Oba M, Steele MA. 2019. *Animal*, **13(7):**1385-1393.

Murphy, B., Crosson, P., Kelly, A.K., & Prendiville, R. 2017. *Irish Journal of Agricultural and Food Research,* **56(1):**93-103. doi: https://doi.org/10.1515/ijafr-2017-0010

National Academies of Sciences, Engineering, and Medicine; Division on Earth and Life Studies; Board on Agriculture and Natural Resources; Committee on Nutrient Requirements of Dairy Cattle. National Academies Press (US); 2021 10, https://www.ncbi.nlm.nih.gov/books/NBK600606/

Nemati M., Amanlou H., Khorvash M., Moshiri B., Mirzaei M., Khan M.A., Ghaffari M.H. 2015. *Journal of Dairy Science,* **98(10):**7131-41.

Rehfeldt, C., Fiedler, I., Dietl, G. and Ender, K. 2000. *Livestock Science,* **66**: 177-188.

Rosadiuk, J. P., Bruinje, T. C., Moslemipur, F., Fischer-Tlustos, A. J., Renaud, D. L., Ambrose, D. J. and Shivley C.B., Lombard J.E., Urie N.J., Weary D.M., von Keyserlingk M.A.G. 2019. *Journal of Dairy Science,* **102(5):**4489-4497.

Soberon, F. and Van Amburgh, M. E. 2013. *Journal of Animal Science,* **91(2):**706-712.

Spalding KL, Arner E, Westermark PO, Bernard S, Buchholz BA, Bergmann O, Blomqvist L, Hoffstedt J, Näslund E, Britton T, Concha H, Hassan M, Rydén M, Frisén J, Arner P. 2008. *Nature*, **5**:453(7196):783-787.

Stickland NC. 1978. *Anat Histol Embryol,* **7(3):**193-205.

Tikofsky JN, Van Amburgh ME, Ross DA. 2001. *Journal of Animal Science,* **79(9):**2260-2267.

Timon, C.M., O'Connor, A., Bhargava, N., Gibney, E.R., and Feeney, E.L. 2020. *Nutrients,* **12(10):**3040.

Todd, C.G., McGee, M. Tiernan, K. Crosson, P., O'Riordan, E., McClure, J, Lorenz, I and Earley B. 2018. *Preventive Veterinary Medicine*, **159:**182-195.

van Niekerk J.K., Fischer-Tlustos AJ, Wilms JN, Hare KS, Welboren AC, Lopez AJ, Yohe TT, Cangiano LR, Leal LN, Steele MA. 2021. *Journal of Dairy Science,* **104(8):**8341-8362.

The role of grass in the diet of the growing calf

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Introduction

For livestock producers, production efficiency is essential to maintain long-term profitability and sustainability (Mulliniks *et al.,* 2015). Pasture-based beef production systems offer a competitive advantage over indoor systems, primarily because grazed grass is the cheapest feed available (Doyle *et al.,* 2022), and beef producers can capitalise on the ruminant animals' ability to utilise grazed grass which is not usable for other non-ruminant based livestock production sectors. If current food consumption patterns continue, the agriculture sector must provide significantly more food in the coming years from the available land area (Hennessy *et al.,* 2021). Some livestock systems directly engage in feed–food competition where arable land is used for livestock feed rather than as crops for human consumption, thereby reducing global food supply. However, Hennessy *et al.* (2021) has shown that Irish dairy beef systems are net positive producers of human digestible protein from the grazed pasture typically employed in such enterprises. The challenge now lies in continuing to increase the proportion of grazed pasture in the diet of the dairy-beef animal. For example, Kearney *et al.* (2024) has shown that maximising the proportion of grazed pasture in the diet of the animal, instead of using purchased concentrates, enhanced economic performance and improved human-edible protein and energy efficiency of dairy-beef production systems. Factors such as grazing season length contribute to achieving this goal, and also influence environmental impact, meat quality, and consumer choice (Phelan *et al.,* 2015). However, to ensure the future viability of pasture-based beef production systems, a more rapid adoption of innovative grazing management practices and tools, which increase profitability by optimising grazing management performance, is required (Mulliniks *et al.,* 2015). This paper details grazing management practices, which can be used to increase the proportion of grazed grass in the diet of the weanling dairy-beef calf, and outlines the performance that can be expected when such practices are undertaken.

Grazing management practices

Having successfully reared the calf from birth to weaning, thereby transitioning it to a young ruminant, the aim should be to have a healthy calf weighing ~100 kg at 10-12 weeks of age. As the majority of Irish dairy calves are February - April born the typical turnout date to pasture for these animals is mid-late May onwards, as six to eight weeks is the most common weaning age (Barry *et al.,* 2020). Once turned out, there are then a number of routes by which pasture can be offered to the young weanling.

Leader/follower compared to rotational grazing systems

One grazing option that dairy calf-to-beef producers can operate is the leader/follower system. In this system there are two animal age categories (calves and yearlings) on the farm at any one time and the challenge is to optimise the performance of each group. Since its inception, over 50 years ago, leader/follower systems have been used in a dairy calf-to-beef system. The system is characterised by calves (leaders) grazing ahead of the yearlings (followers) through a series of paddocks with the speed of movement within the grazing rotation determined by the followers (the yearlings) which move when their desired post-grazing height/herbage mass is reached.

Leader/follower grazing management could be expected to benefit the leaders (calves), and to disadvantage the followers (yearlings) as the leaders always have an abundant herbage supply and have the opportunity to select the highest quality herbage. The followers, on the other hand, may occasionally have herbage of lower quality because the leaders (calves) have selected the highest quality material leaving the residual to the followers. However, as yearlings are turned out to pasture some two months before the calves, and as the calves are initially supplemented with concentrates while at pasture, thus consuming little grass in the beginning, the impact on the yearlings should be limited. During mid-season, when calves are larger are not in receipt of supplemental concentrate, and are consuming sizable amounts of pasture, a restriction in the potential performance of the yearling animals might be expected.

Keane (2002) reported a study that compared three different iterations of a pasture based integrated dairy calf-to-beef system. In this study animals were allocated to one of the following grazing management systems: (i) leader/follower (LF) system; (ii) a rotational grazing system where calves and yearlings grazed separately (S) or (iii) calves co-grazed (CG) with yearlings in one mixed grazing management system.

The bodyweight responses to these three grazing management systems are outlined in Table 1. Mean calf bodyweight at turnout across all three groups was 115 kg. During the grazing season, bodyweight gain for calves was highest in the LF group and lowest for the calves in the S group (Table 1). After about 12 weeks at pasture, the LF calves were significantly heavier than the other two groups and remained so until the end of the following grazing season. Differences in calf weight between the CG and S groups were smaller but were, nevertheless, significant both at the end of the grazing treatments and at the final weighing one year later.

Table 1. Bodyweight (kg) of calves on three grazing management systems

	Leader/follower	Mixed	Separate	s.e.d.	Significance
1st turnout (14/5)	115	115	115	4.5	NS
End June (25/6)	147	141	132	5.8	NS
Early August (5/8)	183a*	162b	153b	6.6	**
End of treatments (23/9)	242a	205b	190c	7.3	***
1st housing (18/11)	259a	220b	208b	7.0	***
2nd turnout (24/3)	332a	290b	280b	8.6	***
2nd housing (3/11)	515a	493b	476c	8.3	**

within row, different superscripts indicate that grazing system mean bodyweights are statistically significantly different.

(From Keane (2002))

From the start to the end of the first grazing season the LF calves had a higher average daily bodyweight gain (ADG) than the other two groups of calves, and with the exception of the mid part of the season when the difference was not statistically significant, the CG calves had a higher ADG than the S calves (Table 2). For the entire period of the comparison, the LF calves had a 279 g/day higher ADG than the CG calves, which in turn gained 112 g more /day than the S calves. For the 8-week period from the end of the grazing treatments (late Sept) to housing (mid-November) there was no evidence of compensatory gain and there was no difference between the grazing management treatments in bodyweight gain during this period. Neither was there any evidence of compensatory gain over the following winter when all animals were fed similarly, and had similar bodyweight gain. However, there was some evidence of compensatory growth during the second grazing season. From turnout to the end of August, the CG yearlings gained significantly faster than their LF counterparts, and the S group tended to do likewise. For the entire period from calf turnout to the end of the second grazing season, the LF group gained bodyweight significantly faster than the CG group, which in turn gained significantly faster than the S group.

Overall, differences in calf performance between the systems were small. An important practical finding from this study was the negative effect of the leader calves on the follower yearlings suggesting the followers had either insufficient herbage or herbage of reduced quality for some or all of the grazing season. One advantage of the LF system is that it assists in the control of gastrointestinal parasites in the calves and with increasing incidence of anthelmintic resistance, this attribute may be of increasing importance.

Table 2. Bodyweight gain (g/day) of calves on three grazing management treatments during their first and second grazing seasons

	Leader/follower	Mixed	Separate	s.e.d.	Sig
1st turnout to end June (14/5 - 25/6)	774a*	612b	420c	53.2	***
End June to early August (25/6 - 5/8)	883a	509b	492b	41.8	***
Early August to end treatments (5/8 - 23/9)	1,194a	896b	771c	63.0	***
1st turnout to end treatments (14/5 - 23/9)	964a	685b	573c	28.8	***
End treatments to 1st housing (23/9 - 18/11)	301	256	316	69.7	NS
1st housing to 2nd turnout (18/11 - 24/3)	573	554	566	35.0	NS
2nd turnout to end August (24/3 - 25/8)	1,033a	1,171b	1,091a	38.9	*
2nd turnout to 2nd housing (24/3 – 3/11)	821	908	876	29.8	NS
1st housing to 2nd housing (18/11 – 3/11)	731	780	764	19.7	NS
Calf turnout to 2nd housing (14/5 – 3/11)	744a	702b	671c	13.5	*

within row, different superscripts indicate that grazing system mean bodyweights are statistically significantly different

(From Keane (2002))

Rotational compared to continuous grazing

Grazing management on dairy calf to beef farms is typically manifested as either a continuous/set stocking or rotational grazing system with the latter tending to be the preferred option. In continuous grazing management animals have unlimited and uninterrupted access to the pasture area (Sollenberger *et al.* 2020). Rotational grazing on the other hand, is a grazing method that involves the subdivision of a grazing area into two or more paddocks that are subjected to controlled periods of alternating grazing and rest (Windh *et al.* 2019).

It has long been established that controlled rotational grazing is superior to continuous grazing, in terms of supporting weight gain, for beef animals (Hull *et al.*, 1967; McMeekan and Walshe, 1963). Marley *et* *al.* (2007) reported that rotational grazing resulted in higher quality swards than continuous grazing, evidenced by higher pasture digestible organic matter in dry matter (DOMD) and lower acid detergent fibre (ADF) and neutral detergent fibre (NDF) content. This study also reported higher proportions of green leaf in swards rotationally rather than continuously grazed. Consequently, ruminants grazing rotationally grazed swards had higher weight gains than those continually grazing swards. When Penning *et al.* (1994) compared the effects of rotational grazing compared to continuous stocking on the feed intake and behavioural responses of ruminants, they found that grazing behaviour was altered so as to increase bite mass (dry matter intake) at the start of grazing a rotationally grazed plot. Marley *et al.* (2007) also suggested based on blood metabolite concentrations, that grazing on perennial ryegrass swards managed under rotational compared with continuous grazing may result in increased efficiency of nitrogen (N) use.

Within rotational grazing systems pre-grazing height and herbage allowance are some of the most commonly used technologies in grazing management (Costa *et al.,* 2022). Animal response to variables such as pre-grazing height (Hodgson 1985), post-grazing height (Minchin and McGee, 2010) and herbage allowance (Dougherty *et al.,* 1989) have been well defined in the literature for cattle. However, research is constantly advancing.

Grazing management practices

Grazing management practices, such as pre-grazing herbage mass and post-grazing height, can be major determinants of the growth, nutritive value and dry matter (DM) intake of grazed herbage, which are key contributing factors to performance of livestock grazing pasture (Frame and Laidlaw, 2011; Donaghy *et al.,* 2021).

Herbage mass

A balance between optimum sward production and quality dictates the level of pre-grazing herbage mass required during the grazing season. If pre-grazing herbage mass is too low (<1,000 kg DM/ha, >4cm), sward quality will be high, but dry matter intake may be reduced, animals may spend longer grazing trying to compensate for lower intake per bite, and production may be sacrificed (Tuñon *et al.,* 2011). Consistently maintaining a low pre-grazing herbage mass (<1,150 kg DM/ha) reduces pasture DM production and may increase the requirement for imported feed (Wims *et al.,* 2013). Conversely, if pre-grazing herbage mass is too high (>2,200 kg DM/ha, >4cm), dry matter intake, sward quality and animal performance are reduced (Tuñon *et al.,* 2011). A relatively high pre-grazing herbage mass results in increased rotation length (McEvoy *et al.,* 2009) but also results in increased accumulations of stem and dead material, leading to a reduction of overall quality of the pasture available (Hoogendoorn *et al.,* 1992). Grazing medium herbage mass (1,300 – 1,600 kg DM/ha, >4cm) pastures typically leads to increased output per ha and increased sward quality (McEvoy *et al.,* 2009; Wims *et al.,* 2014).

Doyle *et al.* (2023) previously reported improved weight gains of Charolais steers when pre-grazing herbage mass was 1,500 kg DM/ha compared to 2,500 kg DM/ha. The higher weight gains were attributable to lower mass swards being more digestible, higher in crude protein and lower in fibre. Anecdotally, some Irish farmers tend to offer calves low herbage mass swards after turnout post-weaning. However, caution should be exercised as fibre levels in these swards can be low and may pre-dispose the calves to poor health (AHI, 2022). Interestingly, PastureBase Ireland (Hanrahan *et al.,* 2017) data collected from farmers, in discussion groups that specialise in dairy-calf to beef production, showed that these farmers offer an average pre-grazing herbage mass of 1,300 – 1,600 kg DM/ha (>4cm; Hearne, per. Comm., 2024), which concurs with that recommended by Teagasc (2024).

Post-grazing sward height

Grazing swards to a low post-grazing sward height (PGSH) is a strategy for improving grass utilisation (Ganche *et al.,* 2015). When selecting a target post-grazing sward height a balance between maximising dry matter intake and maintaining sward quality needs to be achieved. Doyle *et al.* (2023) reported higher weight gains in suckler beef animals that grazed to 6 cm compared to 4 cm, and attributed it to higher dry matter intake across the grazing season. When Costigan *et al.* (2022) investigated weight gains of replacement dairy heifers grazed to either a higher (4.5 cm) or lower (3.5 cm) PGSH, on a sward of 1,600 kg DM/ha (>4 cm), higher weight gains were observed when grazing to 4.5cm. O'Riordan *et al.* (2024) also reported a post-grazing height of 3.5 cm significantly lowered liveweight gain of beef animals, when compared to those grazing to 5cm.

Grazing intensity is an important grazing management practice to maintain sward structure and quality; Tuñon *et al.* (2013) reported increased grazing intensity (< 4.5 cm) is a strategy to maintain high-quality grass throughout the grazing season. Lower PGSH are easier to achieve when pre-grazing herbage mass is at the recommended 1,300 – 1,600 kg DM/ha (>4cm; Ganche *et al.,* 2015). Currently a target post-grazing height of 4 – 5 cm is recommended for dairy-calf to beef systems (Teagasc, 2024).

Grazing tools and technology

The European Union (EU) is the world's third largest producer of beef (Hocquette *et al.,* 2018). Ireland's competitive advantage lies in delivering over 80% of gain from grazed grass. There are a number of key grazing management tools, which need to be utilised to ensure high quality feed is available for the beef herd to consume.

Measuring grass and using a tool such as PastureBase Ireland (Hanrahan *et al.,* 2017) helps enhance the decision making process around grassland management at farm level. At least 20 farm covers should be completed annually to determine the quantity of grass on each paddock, the average farm cover, and number of days grass ahead on a given day (Teagasc, 2024).

Spring

In the spring, the target opening average farm cover on beef farms is 600-700 kg DM/ha. As calves are generally not turned out until mid-May onwards swards, either will have been cut for an early silage harvest or will have been previously grazed by yearlings. If grazed by yearlings target post-grazing sward height should be 3.5-4 cm to ensure high quality pastures for subsequent grazing rotations. The spring rotation planner should be followed to ensure grass supply is correct for the second and subsequent rotations. Ideally, 33% of the farm should be grazed by March 1st, 66% by March 17th and the first rotation complete by April 1st (Kennedy *et al.,* 2016). In order to ensure high quality pasture is available for calves at turnout a grazing management plan will need to be implemented from the start of the year.

Mid-season

During the mid-season (mid-April to August), the main challenge is to maintain sward quality. A rotation length of 18-21 days is required to maintain pre-grazing covers of 1,300-1,600 kg DM/ha and a post-grazing sward height of 4-5 cm. The grass wedge is mainly a mid–season grazing management tool (Macdonald *et al.,* 2010). It indicates the amount of grass on a farm and its relationship to livestock demand. The grass wedge is generated from weekly pasture cover estimations and allows informed decision making around the implementation of grassland management strategies such as removing pasture surpluses when there is an excess, or reducing demand by introducing supplementation when pasture is in deficit (Hanrahan *et al.,* 2017). Using a grazing wedge enables U.S. beef producers to maintain forage in a vegetative state, improving both forage quality and production (Sexten, 2014).

Autumn

In autumn shorter days will see grass growth rates start to drop off, but with silage ground coming back into the grazing platform this will help extend grazing rotations. Planning for the following spring, begins during the previous autumn. The target closing farm cover is 450-600 kg DM/ha for dairy-beef and the autumn 60:40 planner should be used to close the farm and to continue grazing until at least mid-November, when grazing conditions allow (Teagasc, 2024).

Using grass to improve weight gain during the first year

Grass can be digested as efficiently by calves as by the mature animal (Gleeson, 1971). High quality pasture can be a major component of the diet from three weeks of age and the sole feed from eight to ten weeks of age if moderate weight gains are desired, however supplementary feeding may be necessary until 12 – 14 weeks of age (Gleeson, 1971).

Milk feeding at pasture

Keane and Harte (1982) reported that calves grazing grass (>14-15 weeks old) compared to those housed indoors grew at a faster rate when unsupplemented, but there was no difference in liveweight gain when supplemented (as would be the case in practice). Keane (1982) investigated feeding milk and supplements at pasture to 14-15 week old calves and reported a trend towards an increase in response to milk and a decrease in the response to concentrates with increasing level of feeding. This work suggested the most cost-effective strategy for supplementing grass-fed calves might be a continuation of milk feeding at a low level during the early period on grass followed by a gradual replacement of milk by concentrates as the calves get older and their dry matter intake capacity increases. Gleeson (1971) also suggested a response to feeding milk at pasture; calves weaned onto an all-grass diet at an early age (six-weeks) had a lower rate of liveweight gain than calves fed skim milk or concentrates for longer periods in addition to grass. The value of pasture in the diet of the young calf depends on its value as a replacement for skim milk, concentrates and hay (Gleeson, 1971).

However, if turning calves out to pasture at an early age caution needs to be exercised. Gleeson and O'Brien (2012) reported that turning calves outdoors at 38 days old had an initial negative effect on calf performance, which may have been due to the reduction in concentrate intake and the inclement weather conditions that prevailed at turnout. Muir *et al.* (2000) also demonstrated an improvement in performance with calves remaining indoors until 10 weeks of age on *ad libitum* concentrates compared to calves turned out to grass at four weeks on a restricted concentrate intake. However, where calves were turned out to grass at three-weeks of age and were provided with shelter from wind and rain they were healthier and less incidences of mortality occurred Conneely *et al.* (2011). Whalin *et al.* (2022) reported that when given a choice, calves spent less time outdoors as rainfall increases. Where calves were growing well and reared outdoors Conneely *et al.* (2011) reported higher weight gains during the pre-weaning period and at 10-weeks post-weaning.

Research at AFBI Hillsborough (Morrison *et al.,* 2010) also examined the rearing of spring born calves outdoors from two weeks of age and reported calves reared outdoors performed equally well to those housed indoors and there was evidence of a reduced incidence of scour and pneumonia. They also reported the requirement for the provision of a clean, dry, bedded shelter within the grazing paddock as a key component to this rearing system and the inspection of calves for signs of ill health being paramount. Regardless of rearing system typically, calves should achieve 100 kg liveweight at 12 weeks (Muir *et al.,* 2000).

Transitioning to a pasture based diet

When there is sufficient high quality grass available calves should continue to receive 1 kg/day of concentrate and have access to roughage (straw) for the first three weeks of the grazing season to ease the transition onto a grass diet, after which supplementation can cease (Byrne *et al.,* 2024).

Where pasture quality is high there is no benefit to feeding supplements to calves after 13-weeks of age; on poorer quality pastures there is a greater response to supplements when fed after 13-weeks of age (Walshe *et al.,* 1971). Hodgson (1968) observed that a close linear relationship existed between digestibility and herbage intake by grazing calves, suggesting that young ruminants are more sensitive to changes in diet digestibility than adult ruminants. Gleeson (1971) also observed a decline in grass intake when feed quality deteriorated. Age at weaning onto an all-grass diet had no effect on grass intake in the latter half of the grazing season (Gleeson, 1971). Calves weaned at 13 – 16 weeks to an all-grass diet have satisfactory weight gains without supplementary feeding (Gleeson, 1971). Similarly, Byrne *et al.* (2024) found no benefit from supplementing February-born calves with concentrates throughout their first grazing season, when grazing high quality pasture. Due to declining pasture quality in the autumn, the reintroduction of concentrates from mid-September until housing helped maintain energy intake of calves.

As outlined previously calves should be offered high quality, leafy pasture throughout the grazing season. While a pre-grazing herbage mass of 1,200 kg dry matter (DM)/ha (>4cm) can be offered early in the grazing season this should increase to 1,300-1,600 kg DM/ha as calves become more accustomed to grazing. If possible calves should be offered silage aftermath as these swards have the longest 'rest' period, and the lower the pasture larval burden will be when it is grazed next (Stromberg and Averbeck, 1999) but post-grazing height should only be to the height swards were cut for silage (e.g. 5cm) to prevent the calves having to graze poorer quality stubble. Forbes *et al.* (2000) reported a reduction in grazing time, and consequently reduced feed intake and liveweight gain, in grazing cattle infected subclinically with parasitic nematodes. During the grazing season it is advised to monitor parasite burden through faecal egg counts and follow a targeted parasite control plan, developed with a veterinary practitioner (AHI, 2021).

The target average daily live weight gain (ADG) during the first grazing season for calves is 0.7 to 0.8 kg, resulting in a housing weight of approximately 200 kg for heifers and 230 kg for steers. Costigan *et al.* (2022) reported that post-weaning growth rate of replacement dairy heifers had a greater influence on live-weight and linear body measurements throughout the rearing period compared to that of weaning age. Consequently, it is imperative that a sufficient quantity of high quality herbage is offered to ensure optimal weight gains during the first grazing season are achieved. Costigan (2021) reported the dry matter intake of replacement heifers was approximately 2.2 % of liveweight.

Multispecies swards

As outlined above, dairy-beef calves must achieve their target ADG during the first grazing season to maximise carcass gain, meat yield and overall economic viability of these animals. This is achieved by offering high quality pasture from the post-weaning period onwards. Typically, in temperate regions, perennial ryegrass (PRG; *Lolium perenne L.*) is the most commonly sown species, with the potential to grow up to 15 tonnes of DM per year of a highly digestible forage over a minimum 10-year period at a low cost for livestock farmers (O'Donovan *et al.,* 2011). However, swards of PRG are highly dependent on chemical N for growth, which has a negative impact on ground water quality and gaseous emissions. Nitrogen is also one of the most expensive input costs in a grass-based system (Wall *et al.,* 2014). One of the key factors in addressing the sustainability challenges associated with ruminant livestock production is reducing reliance on inputs of chemical fertilisers. Therefore, in recent years there has been a renewed interest in botanically diverse swards (containing PRG, clover (red and white; *Trifolium repens* and *Trifolium prantense*), and, herbs (plantain and chicory; *Plantago lanceolate* and *Cichorium intybus*)) for their environmental and productivity benefits (Khan *et al.*, 2023). At reduced N application rates, clover and herb rich (multispecies sward; MSS) pastures can achieve similar or greater DM production (Moloney *et al.*, 2020), and have superior sward nutritive values compared to PRG monocultures (McClearn *et al.*, 2019; Grace *et al.*, 2019).

A recent study at Teagasc, Johnstown Castle (Fitzpatrick *et al.*, 2024), concluded that dairy-beef heifer calves consuming MSS swards, had significantly greater ADG (+ 0.17 kg/day) during the first grazing season compared to calves consuming PRG or CLOVER pastures (Table 3).

Table 3. Effect of pasture treatment on live weight gain of dairy-beef heifers from pasture, managed on PRG-only swards (PRG), PRG plus red and white clover swards (CLOVER), and multispecies swards (MSS)

	PRG	CLOVER	MSS	SEM[1]	Significance
ADG (kg/day)					
1st grazing season	0.61[a]	0.62[a]	0.79[b]	0.052	***
1st winter	0.65	0.65	0.68	0.031	NS
2nd grazing season	0.81[a]	0.92[b]	0.87[b]	0.019	***
Lifetime	0.74[a]	0.78[b]	0.79[b]	0.010	**

*[1]SEM = standard error of the mean. NS = not significant (P>0.05); ** P<0.01; *** P<0.001; within rows, different superscripts means the effects are significantly different*

(From Fitzpatrick et al. (2024))

All treatments were offered a similar pre-grazing herbage mass (1,557 kg DM/ha) and grazed to a post-grazing height of 4.9 cm. The botanical composition of the MSS pasture treatment is outlined in Figure 1, and indicates that the 21% clover content, 25% plantain content and 6% chicory content encouraged greater levels of DMI and subsequently animal growth for dairy-beef heifer calves consuming MSS, despite the CLOVER treatment having a similar clover content of 22%. Similarly, Boland *et al.* (2022) reported that weaned calves consuming MSS pasture had a greater ADG, compared with calves consuming PRG-only swards. However, unlike Fitzpatrick *et al.* (2024), this study found that calves consuming grass-clover swards also had greater daily weight gains compared with PRG-only swards. The improved animal performance on more species diverse swards can be attributed to enhanced sward nutritive value encouraging greater dry matter intake (Handcock *et al.*, 2015; Pettigrew *et al.*, 2017).

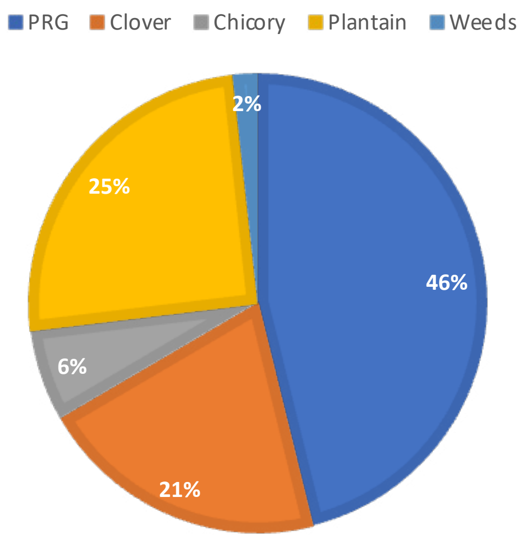

Figure 1. *Composition of the multi-species swards over the grazing season*

(From: Fitzpatrick et al. (2023))

Grace *et al.* (2019), reported that during the post-weaning period, MSS swards had a significantly lower NDF content compared to grass-clover swards, which resulted in greater slaughter weights for lambs consuming MSS. McGrane *et al.* (2023), also determined that increasing pasture diversity with binary sward mixtures improved lamb performance. The above outlines that MSS and grass-clover swards can play an important role in improving the performance of young stock in a pasture-based system with minimal concentrate supplementation. This is reflected in greater overall animal lifetime performance for dairy-beef animals consuming clover and MSS pastures (Boland *et al.*, 2022; Fitzpatrick *et al.*, 2024).

Byrne *et al.* (2024), determined that pasture type has a large influence on the financial performance of dairy-beef heifers, animals which consumed a MSS and a grass-clover diet from the post-weaning period to slaughter had an additional €100 and €150 net profit/ha, respectively, compared to animals consuming a

PRG-only diet. The additional ADG observed for calves consuming MSS swards, highlights that a potential "blue print" for dairy-beef farmers would be to have a proportion of the farm with MSS and the remainder of the farm with grass-clover swards, to maximise animal production potential. However, further specific dairy-beef calf investigations are warranted to determine the interaction between sward diversity and dry matter intake during the first grazing season.

Conclusion

Pasture-based beef production offers a cost-effective, sustainable system for dairy-beef farming, with grazed grass being the cheapest feed source. Increasing the proportion of pasture in the diet can improve economic and environmental efficiency. Grazing management practices such as rotational grazing are crucial for maximizing grass utilization and animal performance. Key factors like pre-grazing herbage mass (1300-1600 kg DM/ha) and post-grazing height (4-5 cm) significantly impact the growth and intake of calves, improving their weight gain. Calves weaned to an all-grass diet at 12 weeks can achieve optimal growth with minimal supplementation, though early access to high-quality pasture and parasite management is crucial. Proper grazing strategies ensure that dairy-beef calves meet their growth targets, which is vital for the profitability and sustainability of beef production systems. Offering multispecies swards, which include grasses, clover, and herbs, can further increase daily weight gains, as shown by recent studies where dairy-beef calves on multispecies swards outperformed those on perennial ryegrass or clover-only swards.

References

Animal Health Ireland (2021). A Guide to Parasite Control at Grazing. https://animalhealthireland.ie/assets/uploads/2021/06/PC-Parasite-Control-at-Grazing-2021.pdf?dl=1 (Accessed 15 September 2024)

Animal Health Ireland. 2022. Summer Scour in Calves. https://animalhealthireland.ie/assets/uploads/2022/03/AHI-Bulletin-March-2022-FINAL.pdf (accessed 09 September, 2024)

Barry, J., Bokkers, E.A.M., de Boer, I.J.M. & Kennedy, E. (2020). Pre-weaning management of calves on commercial dairy farms and its influence on calf welfare and mortality, *Animal*, **14(12):**2580-2587.

Boland, T.M., Godwin, F., Baker, S., Lynch, M.B., Evans, A.C.O., Murphy, P.M., Sheridan, H. and Kelly, A.K., 2022. Multispecies swards improve animal growth and performance at slaughter in a dairy calf to beef production system. In: Proceedings of the 29th EGF General Meeting 2022: Grassland at the heart of circular and sustainable food systems, 26th- 30th June, Caen, France, pp. 533-535.

Byrne, N., O'Driscoll, J., Crosson, P., Dillon, A. & Fitzpatrick, E. (2024). Dairy-beef systems for profitable production, in: M. McGee & P. Crosson (Ed) *Beef 2024* (Teagasc Grange, Teagasc) pp. 114-121.

Conneely M., Coughlan F., Murphy J.P., Lorenz I. & Kennedy E. (2011). Effect of pre-weaning housing type on calf weight gain and health. *Agricultural Research Forum 2011*.

Costa, C.M., dos Santos Difante, G., Miyake, A.W.A., Gurgel, A.L.C., Santana, J.C.S., Ítavo, C.C.B.F., Ítavo, L.C.V., Dias, A.M. & Júnior, M.A.F. (2022). Technologies used in ruminant grazing management: an integrative review, *Tropical Animal Health and Production*, **54(6):**357.

Costigan, H., Delaby, L., Walsh, S., Fitzgerald, R. & Kennedy, E. (2022). The effect of weaning age and post-weaning feeding regime on growth and fertility of pasture-based Holstein-Friesian and Jersey dairy heifers, *Livestock Science*, **256:**104812.

Costigan, H. (2021). Rearing Strategies for Dairy Heifers. *PhD thesis.* Department of Science. Waterford Institute of Technology).

Dougherty, C.T., Lauriault, L.M., Cornelius, P.L. & Bradley, N.W. (1989). Herbage allowance and intake of cattle, *The Journal of Agricultural Science*, **112(3):**395-401.

Donaghy, D, Bryant, R, Cranston, L, Egan, M, Griffiths, W, Kay, J, Pembleton, K and Tozer, K (2021) Will current rotational grazing management recommendations suit future intensive pastoral systems? NZGA: *Research and Practice Series*, **17:**225–242.

Doyle, P, Tubritt, T, O'Donovan, M and Crosson, P (2022). Economic value of grass and grass-white clover. Swards for the future. Conference proceedings. September 2022, Teagasc, Moorepark, Co. Cork.

Doyle, P.R., McGee, M., Moloney, A.P., Kelly, A.K. & O'Riordan, E.G. (2023). Effect of pre-grazing herbage mass and post-grazing sward height on herbage production and intake and performance of suckler-bred steers within a weanling-to-beef production system, *The Journal of Agricultural Science*, **161(2):**297-312.

Fitzpatrick, E., Fox, R., Cardiff, J., and Byrne, N. Low-input, high-output grass-based dairy-beef heifer systems. In: Teagasc National Beef Conference, "Improving our Beef Sector's Green Credentials," 2023, pp. 17-22.

Fitzpatrick, E., Fox, R., Cardiff, J., and Byrne, N. Effect of pasture type on dairy-beef heifer production efficiency. In: Proceedings of the 30th EGF General Meeting 2024: Why Grasslands, 9th- 13th June, Leeuwarden, the Netherlands, pp. 148-150.

Forbes, A.B., Huckle, C.A., Gibb, M.J., Rook, A.J. & Nuthall, R. (2000). Evaluation of the effects of nematode parasitism on grazing behaviour, herbage intake and growth in young grazing cattle, *Veterinary Parasitology,* **90(1):** 111-118.

Frame, J and Laidlaw, AS (2011). Improved Grassland Management. Marlborough: Crowood Press.

Ganche, E., O'Donovan, M., Delaby, L., Boland, T.M. & Kennedy, E. (2015). Does post-grazing sward height influence sward characteristics, seasonal herbage dry-matter production and herbage quality? *Grass and Forage Science*, **70(1):** 130-143.

Gleeson, D. & O'Brien, B. (2012). Effect of milk feed source, frequency of feeding and age at turnout on calf performance, live-weight at mating and 1st lactation milk production, *Irish Veterinary Journal*, **65(1):** 18.

Gleeson, P.A. (1971). Grass as a feed for calves, *Irish Journal of Agricultural Research*, **10:** 151-159.

Grace, C., Boland, T.M., Sheridan, H., Lott, S., Brennan, E., Fritch, R. and Lynch, M.B. (2018). The effect of increasing pasture species on herbage production, chemical composition and utilization under intensive sheep grazing. *Grass and Forage Science,* **73:**852-864.

Handcock R.C., Hickson R.E., and Back P.J. (2015). The use of herb mix and lucerne to increase growth rates of dairy heifers. *Proceedings of the New Zealand Society of Animal Production,* **75:**132-135

Hanrahan, L., Geoghegan, A., O'Donovan, M., Griffith, V., Ruelle, E., Wallace, M. & Shalloo, L. (2017). PastureBase Ireland: A grassland decision support system and national database, *Computers and Electronics in Agriculture*, **136:** 193-201.

Hennessy, D.P., Shalloo, L., van Zanten, H.H.E., Schop, M. & De Boer, I.J.M. (2021). The net contribution of livestock to the supply of human edible protein: the case of Ireland, *The Journal of Agricultural Science*, **159(5-6):** 463-471.

Hocquette, J.F., Ellies-Oury, M.P., Lherm, M., Pineau, C., Deblitz, C. & Farmer, L. (2018). Current situation and future prospects for beef production in Europe - A review, *Asian-Australas J Anim Sci*, **31(7):** 1017-1035.

Hodgson J. (1985). The control of herbage intake in the grazing ruminant. Proceedings of the Nutrition Society, 1985; **44:** 339-346.

Hodgson, J. (1968). The relationship between the digestibility of a sward and the herbage consumption of grazing calves, *The Journal of Agricultural Science*, **70(1):** 47-51.

Hoogendoorn, C.J., Holmes, C.W. & Chu, A.C.P. (1992). Some effects of herbage composition, as influenced by previous grazing management, on milk production by cows grazing on ryegrass/white clover pastures. 2. Milk production in late spring/summer: effects of grazing intensity during the preceding spring period, *Grass and Forage Science*, **47(4):** 316-325.

Hull, J.L., Meyer, J.H. & Raguse, C.A. (1967). Rotation and Continuous Grazing on Irrigated Pasture Using Beef Steers, *Journal of Animal Science*, **26(5):** 1160-1164.

Keane, M.G. (1982). Supplementation of Grass-Fed Calves: 2. Effects of Different Levels of Milk and Concentrates on Intake and Performance, *Irish Journal of Agricultural Research*, **21(2/3):** 117-127.

Keane, M.G. (2002). Development of an intensive dairy calf-to-beef system and associated grassland management. End of Project Report, Project No. 4582, Beef Production Series No. 41, Grange Research Institute, Teagasc.

Keane, M.G. & Harte, F.J. (1982). Supplementation of Grass-Fed Calves: 1. Effects of Milk Feeding Method and Concentrates with and without Protected Protein on Intake and Performance, *Irish Journal of Agricultural Research,* **21(2/3):** 105-115.

Kearney, M., O'Riordan, E.G., Byrne, C.J., Breen, J. & Crosson, P. (2024). Identifying and quantifying key sustainability indicators for pastoral dairy-beef production systems, *Applied Animal Science*, **40(4):** 570-590.

Kennedy, J., Carty, D., McCarthy, J., Kennedy, E. & O'Donovan, M. (2016). Grazing Guide 2 (Irish Farmers Journal).

Khan, A.S., Finn, J.A., Menezes, A.B.D., Kirwan, S.F., Waters, S.M. and Krol, D.J., 2023. Effects of multispecies and monoculture forages on nutrient digestibility and fermentation responses using an in vitro rumen simulation technique (RUSITEC). *Animal-Open Space*, **2**: 100052.

Macdonald, K. A., Glassey, C. B., & Rawnsley, R. P. (2010). The emergence, development and effectiveness of decision rules for pasture based dairy systems. In Proceedings of the 4th Australasian dairy science symposium (Vol. 31, pp. 199-209). Caxton Press.

Marley, C.L., Fraser, M.D., Fisher, W.J., Forbes, A.B., Jones, R., Moorby, J.M., MacRae, J.C. & Theodorou, M.K. (2007). Effects of continuous or rotational grazing of two perennial ryegrass varieties on the chemical composition of the herbage and the performance of finishing lambs, *Grass and Forage Science*, **62(3):** 255-264.

McClearn, B., Gilliland, T.J., Delaby, L., Guy, C., Dineen, M., Coughlan, F. and McCarthy, B. (2019). Milk production per cow and per hectare of spring-calving dairy cows grazing swards differing in *Lolium perenne* L. ploidy and Trifolium repens L. composition. *Journal of Dairy Science*, **102:** 8571-8585.

McGrane L., McHugh N., Boland, T.M. and Creighton, P. (2023). The effect of the addition of a companion forage to a perennial ryegrass sward on ewe and lamb performance. *Livestock Science*, **275:** 105294.

McEvoy, M., O'Donovan, M., Kennedy, E., Murphy, J.P., Delaby, L. & Boland, T.M. (2009). Effect of pre-grazing herbage mass and pasture allowance on the lactation performance of Holstein-Friesian dairy cows, *Journal of Dairy Science*, **92(1):** 414-422.

McMeekan, C.P. & Walshe, M.J. (1963). The inter-relationships of grazing method and stocking rate in the efficiency of pasture utilization by dairy cattle, *The Journal of Agricultural Science*, **61(2):** 147-166.

Minchin, W. & McGee, M. (2010). Effect of post-grazing sward height on grass production and performance of four beef heifer genotypes, *Advances in Animal Biosciences*, **1(1):** 324-324.

Moloney, T., Sheridan, H., Grant, J., O'Riordan, E.G. and O'Kiely, P. (2020). Yield of binary-and multi-species swards relative to single-species swards in intensive silage systems. *Irish Journal of Agricultural and Food Research*, **59(1):** 12-26.

Morrison, S. Carson A., Matthews, D., Kilpatrick, D., McCliggage, L. & Mulholland, M. (2010). Latest research on calf management for performance. Making progress through research – a seminar for specialists. Dairy genetics and heifer management. In: Proceedings of an AgriSearch seminar held at the Agri-Food Biosciences Institute Hillsborough, pp. 68 - 99

Muir P.D., Nieuwenhuis G., & Smith, N.B. (2000) A comparison of rearing systems for dairy beef calves. Proceedings of the New Zealand Grassland Association 2000, **62:**9–11.

Mulliniks, J.T., Rius, A.G., Edwards, M.A., Edwards, S.R., Hobbs, J.D. & Nave, R.L.G. (2015). FORAGES AND PASTURES SYMPOSIUM: Improving efficiency of production in pasture- and range-based beef and dairy systems, *Journal of Animal Science*, **93(6):** 2609-2615.

O'Donovan, M., Lewis, E. & O'Kiely, P. (2011). Requirements of future grass-based ruminant production systems in Ireland. *Irish Journal of Agricultural and Food Research*, **50:** 1-21.

O'Riordan, E., McGee, M., Egan, C., Crosson, & Doyle, P. (2024). Beef production from grass forage-based systems In: M. McGee & P. Crosson (Ed) Beef 2024 (Teagasc Grange, Teagasc) pp. 114-121.

Penning P.D., Parsons A.J., Orr R.J. and Hooper G.E. (1994). Intake and behaviour responses by sheep to changes in sward characteristics under rotational grazing. *Grass and Forage Science,* **49:** 476–486.

Pettigrew E.J., Morris S.T., Back P.J., Kenyon P.R., Berry J., Donald A.J., Lane A.L. and Hickson R.E. (2017). Growth of weaned Friesian bull calves on a herb sward or with concentrate supplementation during late summer and early autumn. *New Zealand Journal of Agricultural Research,* **60(1):** 70-79.

Phelan, P., Morgan, E.R., Rose, H., Grant, J. & O'Kiely, P. (2016). Predictions of future grazing season length for European dairy, beef and sheep farms based on regression with bioclimatic variables, *The Journal of Agricultural Science*, **154(5):** 765-781.

Sexten, W. (2014). Using Grazing Wedges to Match Beef Cattle Nutrient Need with Pasture Resources while Reducing Feed and Fertility Costs. Final Project Report. https://www.researchgate.net/profile/William-Sexten/publication/242535294_Project_teachs_new_pasture_budgeting_techniques_to_beef_producer_groups_allowing_them_to_make_objective_management_decisions_regarding_cow_and_calf_management_while_effectively_managing_input_costs_pa/links/546677b20cf25b85d17f629c/Project-teachs-new-pasture-budgeting-techniques-to-beef-producer-groups-allowing-them-to-make-objective-management-decisions-regarding-cow-and-calf-management-while-effectively-managing-input-costs-p.pdf (Accessed 09 September 2024).

Sollenberger, L.E., Newman, Y.C. and Macoon, B. (2020). Pasture Design and Grazing Management. In Forages (eds K.J. Moore, M. Collins, C.J. Nelson and D.D. Redfearn). https://doi.org/10.1002/9781119436669.ch44

Stromberg, B.E. & Averbeck, G.A. (1999). The role of parasite epidemiology in the management of grazing cattle, *International Journal for Parasitology,* **29(1):**33-39.

Teagasc (2024). Grazing management for dairy-beef systems. DairyBeef 500 factsheet. https://www.teagasc.ie/media/website/animals/beef/dairybeef-500/Grazing-Management-for-dairy-beef-systems.pdf (Accessed 09 September 2024).

Tuñon, G., Kennedy, E., Horan, B., Hennessy, D., Lopez-Villalobos, N., Kemp, P., Brennan, A. & O'Donovan, M. (2014). Effect of grazing severity on perennial ryegrass herbage production and sward structural characteristics throughout an entire grazing season, *Grass and Forage Science*, **69(1):**104-118.

Tuñon, G., Lopez-Villalobos, N., Kemp, P.D., Kennedy, E., Hennessy, D. & O'Donovan, M. (2011). Effect of pre-grazing herbage mass on grazing behaviour, grass dry matter intake and milk production of dairy cows. *Proceedings of the New Zealand Society of Animal Production* (Invercargill, New Zealand Society of Animal Production) **70**: 28-31.

Wall, D., McDonald, N. & Lalor, S. (2014). Potential to optimise fertiliser N inputs based on soil N supply. "Harvesting the Production Potential of Soils", 2014 Horse and Jockey, Thurles, Co Tipperary. The Fertilizer Association of Ireland. Available at https://www.fertilizer-assoc.ie/wp-content/uploads/2014/10/FAI-2014-Proceedings-No-49.pdf

Walshe, M.J., Kelleher, D. & Connolly, J. (1971). Calf Rearing: 1. Effect of Age at Putting out to Pasture on Performance of Spring-Born Calves, *Irish Journal of Agricultural Research*, **10(1):** 81-94.

Whalin, L., Weary, D.M. & von Keyserlingk, M.A.G. (2022). Preweaning dairy calves' preferences for outdoor access, *Journal of Dairy Science,* **105(3):** 2521-2530.

Wims, C.M., Delaby, L., Boland, T.M. & O'Donovan, M. (2014). Effect of pre-grazing herbage mass on dairy cow performance, grass dry matter production and output from perennial ryegrass (*Lolium perenne* L.) pastures, *Animal*, **8(1):** 141-151.

Windh, J.L., Ritten, J.P., Derner, J.D., Paisley, S.I., Lee, B.P. (2019). Economic cost analysis of continuous-season-long versus rotational grazing systems. *Western Economics Forum,* **17:**62-72.

Breeding and reproduction

Harnessing reproductive technologies to accelerate integration of the dairy and beef sectors

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Introduction

As global scrutiny on livestock farming increases, the dairy and beef industries are challenged to improve sustainability, animal welfare, and resource efficiency. One particular focus is on reducing waste and delivering high-quality food products while addressing environmental and ethical concerns. Advances in reproductive technologies provide a promising avenue for improving both the productivity and sustainability of seasonal-calving dairy systems, which aim to maximize the use of pasture for both milk and beef production. Innovations in breeding strategies, such as sex-sorted semen and in vitro embryo production, are increasingly being utilised to improve efficiency and meet industry demands, while also addressing welfare issues associated with male dairy calves (Ritter *et al.,* 2019; Haskell, 2020).

In temperate regions where pasture-based systems dominate, dairy herds are managed with a seasonal focus, concentrating calving in late winter and early spring to match the availability of fresh pasture. The goal is to efficiently convert grazed grass into milk, but this requires optimal reproductive performance to align the herd's calving pattern with the seasonal pattern of pasture growth (Butler, 2014). Poor herd fertility leads to inefficiencies, including wasted grass, increased feed costs, and shorter lactation periods. Genetic selection indexes to enhance productive and reproductive efficiency in dairy herds, such as the Economic Breeding Index (EBI) used in Ireland, integrate traits like milk yield, fertility, and beef production. The EBI's emphasis on fertility has helped improve phenotypic performance, boosting reproductive efficiency in pasture-based systems (Butler, 2013).

Welfare Concerns and the Role of Sex-Sorted Semen

A significant welfare concern in the dairy industry is the fate of surplus male dairy breed calves, which often hold little value due to their poor beef traits. This issue is exacerbated in seasonal-calving systems, where large numbers of male dairy calves are born within a short time frame, leading to market saturation and ethical concerns regarding their treatment (Crowe *et al.,* 2021). One potential solution is the use of sex-sorted semen, which allows dairy farmers to predetermine the sex of calves with approximately 90% reliability (Holden and Butler, 2018). By targeting the best genetic cows with sex-sorted semen, dairy farmers can focus on producing high-value dairy female replacements, while using beef semen on the rest of the herd to improve beef traits and hence calf marketability. The use of sex-sorted semen is not without challenges, however. Each sex-sorted semen straw contains fewer sperm cells (usually 2 or 4 million) compared with conventional semen straws (usually ~15 million), and the sperm cells in sex-sorted straws have been exposed to several potentially damaging steps during the sorting process (Vishwanath and Moreno, 2018).

Field trials evaluating sex-sorted semen

Large-scale controlled field trials have been conducted in Ireland to compare pregnancy per artificial insemination (P/AI) with sex-sorted semen compared with conventional semen. The first trial was conducted on dairy cows in 2018, and described in detail by Maicas *et al.* (2020). At that time, there was no sex-sorting lab in Ireland, but four bulls owned by Irish breeding companies had been moved to a stud at or near a sex-sorting lab in other countries. Also at that time, Irish breeding companies were interested in exploring the possibility of collecting ejaculates from bulls located at studs in Ireland, and sending only the ejaculate to the sex-sorting lab in a different country. Semen from both resident bulls (i.e., located at or near the sorting lab) and shipped ejaculates (i.e., bulls collected in Ireland, and ejaculates shipped to sorting lab within 6 to 7 h) were included in the study. Ejaculates were split and processed as either conventional semen (15 m sperm per straw) or sex-sorted (4 m sperm per straw). AI technicians and herd owners were blind to the experimental treatment, and straws were randomly allocated to cows after detected estrus. In total, 7,236 insemination events were available for analysis. The main findings are summarized as follows:

- Overall, pregnancy per AI (P/AI) was greater for cows inseminated with conventional semen than for those inseminated with sex-sorted semen (59.9% vs. 45.5%; 76.0% relative to conventional semen).
- The study was not designed to compare resident bulls vs. shipped ejaculates, but the magnitude of the difference between P/AI achieved by conventional semen and sex-sorted semen was apparently less for resident bulls (60.3% vs. 50.2%; 84% relative to conventional semen) than for shipped ejaculates

(58.6% vs. 40.7%; 70% relative to conventional semen). Based on this finding, sexed semen should only be generated using bulls resident close to a sorting lab.

- There was a treatment by bull interaction for shipped ejaculates (P/AI ranged from 45 to 86% relative to conventional semen) but not for the resident bulls (P/AI ranged from 81 to 87% relative to conventional semen).
- In 33.1% of the enrolled herds, the P/AI achieved with sex-sorted semen was ≥ 90% of the P/AI achieved with conventional semen; this was mainly explained by herds where sex-sorted semen performed exceptionally well, but conventional semen performed poorly.
- The findings highlighted large herd variation in both conception rates achieved, and also the relative difference versus conventional semen. This indicated that farm specific effects warranted further investigation. One possibility is that decision rules regarding timing of AI is better suited to sexed semen on some farms compared with others.

A second controlled field trial to evaluate the effect of timing of AI was conducted in 2019, and described in detail by Drake *et al.* (2020). Semen from 3 resident bulls was used. Ejaculates were split and processed as either conventional semen (15 m sperm per straw) or sex-sorted (4 m sperm per straw). Enrolled cows were synchronised using a 10-day P4-Ovsynch protocol. 24 herds participated in the study, and each provided cows that were parity ≤4 and ≥50 days in milk on the scheduled day of AI. After enrolment in the study, cows within each herd were stratified based on parity and days in milk, and randomly assigned to one of the following 3 treatments:

- Conventional semen at 16 h after the final injection of GnRH (CONT)
- Sexed semen at 16 h after the final injection of GnRH (SEXED-16)
- Sexed semen at 22 h after the final injection of GnRH (SEXED-22)

The total number of cows retained for analysis was 2,175. The average number of cows on each farm was 91 (range 62 to 100). The main findings are summarized as follows:

- Pregnancy per AI was less in both sexed semen treatments compared with conventional semen (49.0, 51.3 and 61.1% for SEXED-16, SEXED-22 and CONT, respectively). The relative P/AI was 80.3% and 84.0% for SEXED-16 and SEXED-22, respectively. The two sexed semen treatments did not differ statistically, suggesting that conducting inseminations anywhere between 16 to 22 h after GnRH likely encompasses the optimum window for timing of AI with sexed semen.
- To increase the reliability of the estimate for P/AI, both sexed semen treatments were combined to create a single sexed semen treatment. The relative P/AI (i.e., P/AI for sexed semen relative to P/AI for conventional semen) was calculated, and herds were ranked. A relative P/AI value of 100% indicates that the P/AI achieved with sexed semen was equal to the P/AI achieved with conventional semen. The best third of herds had a mean relative P/AI of 100% (range: 91% to 121%). Conversely, the poorest third of the herds had a mean relative P/AI of 67% (range: 48% to 77%).
- The herds with the poorest relative P/AI achieved good P/AI with conventional semen. This verifies that the cows were correctly treated during synchronisation to facilitate a high fertility ovulation event. As the cows in all treatments were balanced for parity and days in milk, and were exposed to the same nutritional and general herd management, the poor performance achieved with sexed semen was not due to an inherent fertility problem with the cows. There were three bulls used on the study, and every herd was allocated an equal proportion of conventional and sexed semen from each bull. Excellent fertility performance was achieved with sexed semen in the best third of herds, and acceptable performance with sexed semen was achieved in the best and middle third of herds combined (relative P/AI = 93%; range 78% to 121%). This indicates that sexed semen *per se* was not the primary cause of the compromised fertility performance in the poorest third of herds. This research highlighted the important effects of straw handling and insemination technique on P/AI when inseminating cows with sex-sorted semen.

Taking the findings from both studies, extension and advisory activities were undertaken with dairy farmers through open days and discussion groups highlighting the steps necessary to achieve acceptable P/AI with sex-sorted semen (summarized in Figure 1).

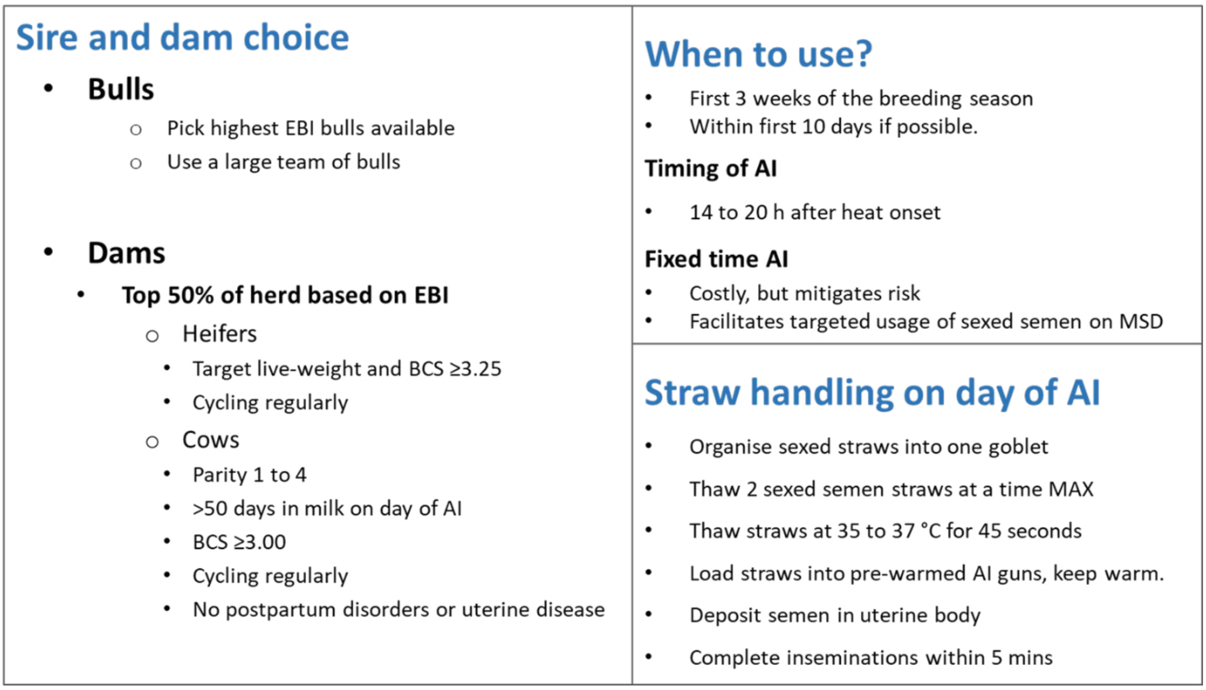

Figure 1. *Extension messages for dairy farmers outlining the key strategies to maximise pregnancy success when using sex-sorted semen*

Field fertility performance of sexed semen in dairy herds during the 2022 breeding season was examined by the Irish Cattle Breeding Federation (M. Kelleher, personal communication). The analysis compared P/AI with conventional semen (304,335 insemination events) versus sex-sorted semen (35,701 insemination events). Across all insemination events, the mean P/AI was approximately similar for AI events that used conventional and sex-sorted semen (57.4% vs 56.7%, respectively; relative P/AI = 98.8%). Of note, the use of sex-sorted semen was preferentially targeted on younger dams, dams with greater EBI and lactating cows with a longer interval from calving to AI. Adjusting for these effects in a statistical model, the mean P/AI remained similar (63.1% vs 60.2%, respectively; relative P/AI = 95.4%). This indicates that acceptable fertility performance is now being achieved with sex-sorted semen on commercial dairy farms in Ireland. The estimated total use of sex-sorted dairy semen has increased markedly in recent years, and this trend is expected to continue in the years ahead (Figure 2).

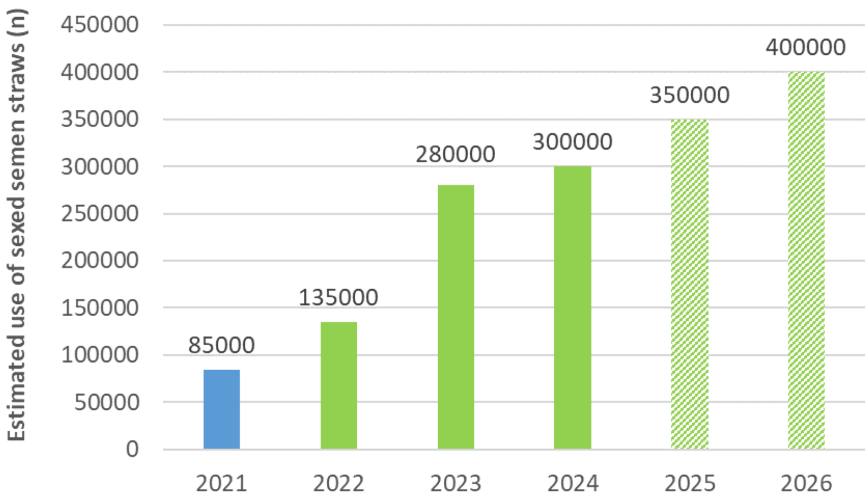

Figure 2. *Estimated use of sex-sorted semen in 2021 (blue), 2022 to 2024 (green) and projected use in 2025 and 2026 (green hatched)*

At the present time, sex-sorted semen must be used under optimal conditions, including strict adherence to insemination protocols (Drake *et al.*, 2020). As sorting technologies improve, it is expected that the fertility gap between sex-sorted and conventional semen will diminish, further increasing the appeal of this technology (Maicas *et al.*, 2020).

Enhancing the Dairy-Beef Sector

The integration of beef production into dairy herds is becoming an increasingly attractive option as more dairy farmers use sex-sorted semen to produce replacement heifers. With fewer dairy males born, there is an opportunity to use beef semen on all cows that are not required to generate replacement calves, improving the value of the calf crop. Dairy-beef crosses typically command higher prices and offer better beef characteristics, which makes them more desirable to beef farmers (Berry *et al.,* 2019). This approach not only increases the financial returns for dairy farmers but also addresses some of the welfare concerns associated with male dairy calves, as these crossbred calves are easier to market (Crowe *et al.,* 2021b).

Genetic Gain through Assisted Reproductive Technologies

Assisted reproductive technologies (ARTs), such as multiple ovulation embryo transfer (MOET) and in vitro embryo production (IVP), offer significant potential for accelerating genetic progress in both dairy and beef herds. The MOET method involves stimulating elite dams to ovulate multiple oocytes, which are then fertilized *in vivo* and allowed to develop for one week; the embryos are non-surgically collected seven days later and transferred to recipient dams. The IVP method involves transvaginal oocyte pick-up, in vitro maturation for 24 h, in vitro fertilization (IVF), and embryo culture *in vitro* for seven days and transfer to recipient dams. For both MOET and IVP, embryos can be frozen at the blastocyst stage for later on-farm thawing and transfer. Both methods enable the production of embryos from elite animals, offering flexible tools for breeding programs and allowing for the rapid dissemination of superior genetics (Sirard, 2018).

The widespread use of sex-sorted semen in dairy herds to generate replacement offspring could hinder the rate of genetic gain as a result of a marked reduction in the births of elite genetic merit male dairy calves. In addition, there will be a greater requirement for semen from beef breed bulls that are suitable for crossing with dairy dams to generate the non-replacement calves. The use of ARTs on elite genetic merit dams in both dairy and beef breeds can be harnessed to accelerate genetic gain for both dairy traits (replacement offspring) and beef traits (non-replacement offspring). Moreover, the ability to control the sex ratio of offspring through use of sex-sorted semen allows breeding companies and elite breeders to target specific production goals in both dairy and beef cattle.

The results of a large controlled field trial to compare pregnancy success and pregnancy losses in cows that received timed AI or timed embryo transfer (ET) was recently reported (Crowe *et al.,* 2024). The study aimed to compare fertility outcomes in seasonal-calving, pasture-based lactating dairy cows following timed artificial insemination (AI) versus timed ET using fresh or frozen in vitro-produced (IVP) embryos from either dairy or beef breeds. A total of 1,106 cows were enrolled, with 863 receiving ET and 243 undergoing AI. Oocytes were collected from live elite dairy and beef donors weekly (without exogenous gonadotropin stimulation), as well as from commercial beef heifers (post-slaughter). The study reported that pregnancy rates on day 32 were similar between AI (48.8%) and ET (48.9%), but significantly less for cows receiving frozen embryos (41.6%) compared with fresh embryos (56.1%). Pregnancy loss between days 32 and 62 was significantly greater for ET (15.1%) than AI (4.7%). Of note, serum progesterone concentrations on day 7 (i.e., the day of ET or 7 days after AI) were positively associated with pregnancy success; the cows in the quartile with the greatest progesterone concentrations had the greatest pregnancy rates. Overall, the study concluded that while ET can achieve pregnancy rates comparable to AI, especially with fresh embryos. The increased incidence of embryonic loss with ET, particularly with frozen embryos, poses a challenge for maximizing reproductive efficiency in dairy herds.

Despite their promise, ARTs face several practical challenges in seasonal-calving systems. One key issue is seasonal calving systems is the restricted availability of recipient cows, as the timing of embryo transfer must align with the fixed breeding season. Additionally, there is still room for improvement in the success rates of frozen-thawed IVP embryos, as pregnancy loss was greater for embryos that were cryopreserved compared with embryos that were transferred fresh (Sanches *et al.,* 2016). Continued advances in these technologies are likely to drive greater adoption in the future, particularly as the economic benefits of using ARTs become more apparent.

Commercial Beef Embryos

One potential avenue to improve the beef traits and economic value of non-replacement dairy calves would involve the transfer of mass-produced IVP beef embryos (offspring ≥75% beef breed genetics) instead of using beef AI (offspring 50% beef breed genetics). By transferring beef embryos into dairy cows, farmers could produce high-quality beef calves while maintaining dairy production (Crowe *et al.,* 2021). Currently, however, there are several barriers to the uptake of this strategy:

- in seasonal calving systems, the embryos would need to be available at the start of the seasonal breeding season (mid-April to early May), which would necessitate stockpiling frozen IVP embryos to ensure sufficient supply (increased risk of poor fertility);
- ovaries collected post-slaughter from beef breed and dairy-beef cross dams could be used as an inexpensive and high-throughput source of donor oocytes. Current regulations regarding the use of oocytes and embryos in cattle reproduction in Ireland require veterinarian verification of both the herd health status during the previous 12 months (free of tuberculosis and infectious bovine rhinotracheitis) and absence of clinical signs of disease in the individual donor females on the day

of oocyte collection. It is not unusual for beef heifers to be located on more than one herd during the final year of their life, which may include a herd designated as a Controlled Finishing Unit (or "feed-lot" herd) during the final phase before slaughter. Hence, verification of the health status of beef heifer oocyte donors is a current barrier to this approach.

- the cost of an IVP embryo (even if mass produced) will be a multiple of the cost of an AI straw;
- embryo transfer requires more training and expertise than conducting AI and is also a slower process, resulting in greater cost to transfer an embryo compared with the cost of conducting AI.

Collectively, these problems will delay widespread uptake of commercial beef embryos, but it may be feasible in the future.

A role for a beef nucleus herd

A nucleus herd is essentially a closed population of genetically superior animals, maintained with the primary objective of accelerating genetic improvement and disseminating elite genetics to commercial herds. The use of advanced reproductive technologies such as IVP and MOET further enhances the genetic gain by increasing the number of offspring from the best animals (Crowe *et al.* 2021).

Concentration of Superior Genetics

One of the primary advantages of a nucleus herd is the concentration of superior genetics. By carefully selecting animals with desirable traits—such superior growth rate, carcass weight and carcass conformation—a nucleus herd allows intense focus on the most genetically valuable individuals. This concentrated selection is crucial for maximizing genetic gain, as it allows for more accurate identification and propagation of elite genes. The rate of genetic gain in nucleus herds can be significantly greater than in conventional breeding programs, owing to the focused selection pressure and controlled breeding environment.

Accelerated Genetic Progress through Assisted Reproductive Technologies

The integration of assisted reproductive technologies (ART), such as IVP and MOET, in nucleus herds plays a critical role in accelerating genetic progress. These technologies can be paired with sex-sorted semen (X or Y) to allow rapid multiplication of elite genetics, and enable breeders to produce a large number of offspring with the desired sex from a single dam (and potentially multiple sires) within a short period (Butler *et al.* 2023). The MOET and IVP techniques can be harnessed to increase the speed of genetic gain and allow rapid dissemination of these superior genetics.

Genetic Diversity and Risk Management

Another advantage of a nucleus herd is the potential to manage genetic diversity and reduce inbreeding. While the goal is to concentrate elite genetics, it is equally important to maintain genetic diversity to avoid inbreeding depression, which can lead to reduced fertility, lower productivity, and increased susceptibility to diseases. Nucleus herds facilitate controlled breeding and the strategic introduction of new genetics from outside the nucleus, thereby managing the risk of inbreeding. This balance between genetic gain and diversity ensures long-term sustainability of the breeding program.

Conclusion

Reproductive technologies, such as sex-sorted semen, MOET, and IVP, are transforming how seasonal-calving dairy herds manage both dairy and beef production. These technologies enable farmers to enhance genetic progress, improve the economic value of their calf crop, and address critical welfare concerns associated with male dairy calves. While challenges remain, particularly in the implementation of ARTs in seasonal-calving systems, ongoing research and technological advancements are likely to further improve the efficiency and sustainability of both dairy and beef sectors. In an era of increasing scrutiny on the environmental and ethical impacts of livestock farming, the use of these technologies represents a crucial step towards more sustainable and responsible animal production systems.

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References

Berry, D.P., Amer, P.R., Evans, R.D., Byrne, T., Cromie, A.R., Hely, F. (2019). A breeding index to rank beef bulls for use on dairy females to maximize profit. *Journal of Dairy Science,* **102**:10056–10072.

Butler S.T. (2013). Genetic control of reproduction in dairy cows. *Reproduction Fertility and Development* **26(1):**1-11.

Butler, S.T. (2014). Nutritional management to optimise fertility of dairy cows in pasture-based systems. *Animal* **8:**15–26.

Butler ST, Crowe AD, Moore SG, Lonergan P. Review: Use of assisted reproduction in seasonal-calving dairy herds. *Animal,* **17 Suppl 1**:100775.

Crowe, A.D., Lonergan, P., Butler, S.T. (2021). Invited review: Use of assisted reproduction techniques to accelerate genetic gain and increase value of beef production in dairy herds. *Journal of Dairy Science,* **104**:12189–12206.

Crowe AD, Sánchez JM, Moore SG, McDonald M, Rodrigues R, Morales MF, Orsi de Freitas L, Randi F, Furlong J, Browne JA, Rabaglino MB, Lonergan P, Butler ST. (2024). Fertility in seasonal-calving pasture-based lactating dairy cows following timed artificial insemination or timed embryo transfer with fresh or frozen in vitro-produced embryos. *Journal of Dairy Science,* **107(3):**1788-1804.

Drake, E., Holden, S.A., Aublet, V., Doyle, R.C., Millar, C., Moore, S.G., Maicas, C., Randi, F., Cromie, A.R., Lonergan, P., Butler, S.T. (2020). Evaluation of delayed timing of artificial insemination with sex-sorted sperm on pregnancy per artificial insemination in seasonal-calving, pasture-based lactating dairy cows. *Journal of Dairy Science,* **103:**12059–12068.

Haskell, M.J. (2020). What to do with surplus dairy calves? Welfare, economic, and ethical considerations. *Landbauforschung,* **70**:45–48.

Holden, S.A., Butler, S.T. (2018). Review: Applications and benefits of sexed semen in dairy and beef herds. *Animal* **12**, s97–s103.

Maicas, C., Holden, S., Drake, E., Cromie, A., Lonergan, P., Butler, S.T. (2020). Fertility of frozen sex-sorted sperm at 4×10^6 sperm per dose in lactating dairy cows in seasonal-calving pasture-based herds. *Journal of Dairy Science* 103, 929–939.

Roche, J.R., Berry, D.P., Delaby, L., Dillon, P.G., Horan, B., Macdonald, K.A., Neal, M. (2018). Review: New considerations to refine breeding objectives of dairy cows for increasing robustness and sustainability of grass-based milk production systems. *Animal* 12, s350–s362.

Ritter, C., Beaver, A., von Keyserlingk, M.A.G. (2019). The complex relationship between welfare and reproduction in cattle. *Reproduction in Domestic Animals* 54 Suppl **3:**29-37.

The Dairy Beef Gene Ireland programme as a driver of the Dairy Beef Index and Commercial Beef Value in the Irish Dairy Beef industry

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Summary

Genetic Improvement: the Dairy Beef Gene Ireland (DB GI) breeding programme was established in 2015. The programme focuses on progeny testing young genomic high Dairy Beef Index (DBI) sires on dairy cows. The use of these sires then contributes to the generation of calves that, on average, rank highly on the Commercial Beef Value (CBV). By selecting and testing young genomic bulls, the programme ensures that the most profitable genetics are used, leading to more efficient and profitable beef production without compromising calving difficulty and gestation length.

Sustainable Practices: The programme is designed to enhance sustainability within the dairy and beef sectors. It encourages the use of sires that contribute to heavier carcasses for age and improved feed efficiency while maintaining ease of calving and shorter gestation periods both of which are critical for dairy herd management.

Farmer Participation: Dairy farmers participating in the programme have access to a panel of forty carefully selected high DBI young bulls. This allows farmers to improve the beef output of their dairy herds, making the most of both dairy and beef production systems.

Collaboration and Data Collection: The programme involves collaboration among various industry stakeholders, including bull breeders, AI companies, meat processors and research institutes. Data collected all along the supply chain are used to refine breeding strategies and accelerate genetic gain of the national herd.

Introduction

The Dairy Beef Gene Ireland Programme (DB GI) is a pioneering initiative aimed at enhancing the genetic merit of beef cattle in Ireland, specifically targeting the intersection of dairy and beef production. Launched by the Irish Cattle Breeding Federation (ICBF) in 2015, this programme is designed to identify and promote the use of elite genetics through sires being mated to dairy cows. By focusing on balancing traits that improve carcass quality without a concomitant increase in calving difficulty, the programme plays a direct role in driving farmer engagement and subsequently boosting the profitability and sustainability of Ireland's dairy and beef sectors.

Dairy Beef Gene Ireland Breeding Programme (DB GI)

At the core of DB GI is the annual selection and progeny testing of a panel of young genomic AI sires that should excel genetically for beef production. These sires are carefully selected based on their genetic merit, with particular attention given to traits such as calving difficulty, gestation length and beef performance; these bulls are then purchased by participating AI companies.

The programme not only benefits dairy farmers looking to maximise the value of their dairy-beef calves, but also supports beef finishers and meat processors by ensuring a consistent production and supply of high Commercial Beef Value (CBV) beef animals. The CBV is a new tool which provides beef finishers an insight into the genetic merit of individual animals for beef characteristics. A key aspect of the DB GI programme is that participating dairy farmers are allocated a pack of straws typically containing four bulls with a minimum of ten straws per bull. This ensures that the subsequent calf crop are from a mixture of sires in each GI herd which is very important to ensure accurate and unbiased genetic evaluations once the sire is proven and returned to a full commercial AI service. The average pack size per herd is 35 straws.

Through deep collaboration with AI companies, farmers, meat processors and research institutes, the DB GI Programme continuously gathers data and refines its strategies, ensuring that it remains at the forefront of genetic advancement in the livestock industry. At the core of this collaboration is the ICBF database. Data collated and utilised includes insemination data, calving records, growth rate and subsequent carcass data including meat eating quality. A subset of the animals are also reared on programme partner research farms where they are assessed for methane production at grass and ultrasonically scanned to determine optimal age at finish. Finally, a cohort of these animals are sent to the ICBF Tully Test Centre each autumn to record data such as feed intake, water intake, methane emissions and meat eating quality, which are captured indoors on a finishing diet; 600 animals annually go through the Tully Test Centre. All this data is assembled in the ICBF database where some of it is currently used in the evaluations and some is assembled for use in future new traits or for index validation purposes.

The rapid return of the best of the Gene Ireland proven sires for wider AI usage ensures an increased rate of genetic gain since they are often used by bull breeders to produce the next generation of AI sires. Some key metrics relating to DB GI are in Table 1.

Table 1. Dairy Beef Gene Ireland Statistics

Description	Count
Years in operation	10
Progeny test herds 2024	600
Average cow herd size 2024	150
Straws distributed per year	21,000
Average straws per herd	35
Straws distributed per sire	500
Bull testing capacity per annum	40
Average number of calves per 500 straws	200
Total AI Sires tested to date	258
Total progeny of these AI sires	664,085
Total progeny of these AI sires in Tully	1,276

Dairy Beef Index

The dairy beef index (DBI) is a critical tool within DB GI. It is an index designed to rank beef bulls based on their suitability for use in dairy herds where the resulting progeny are intended for beef production. In order for a bull to be considered eligible for inclusion on the DB GI panel, he must be in the top 20% across breed on the DBI. The DBI includes several key traits that are essential for both dairy and beef production systems.

Listed below are the main traits within the DBI (relative emphasis in brackets):

- **Calving difficulty (18%)**: the expected incidence of direct calving difficulty. It is a crucial trait to minimise calving difficulties, especially important in dairy cows.
- **Gestation length (12%)**: Shorter gestation lengths are preferred as they can lead to more efficient reproductive cycles in dairy herds, allowing cows to return to milk production sooner.
- **Carcass weight (24%)**: This trait assesses the potential weight of the animals at slaughter (for a common age), which directly impacts the economic return for beef producers. Heavier carcasses for the same age (i.e., carcass growth) are generally more desirable.
- **Carcass conformation (7%)**: This trait measures the shape and conformation of the carcass which affects the market value. Better conformation typically leads to higher prices in the market.
- **Feed intake (16%)**: This trait evaluates the gross intake of feed in the animal in the finishing period. Lower feed intake coupled with better carcass growth rate is desirable to reduce costs and improve the sustainability of beef production.
- **Age at finish (7%)**: This trait reflects the relative number of days for an animal to be finished for slaughter. A shorter age at finish is beneficial as it, on average, improves farm efficiency and reduces the time and resources needed per animal.
- **Carbon (7%)**: This trait reflects the carbon cost associated with raising the animal. Lower carbon emissions are increasingly important as agriculture strives to meet environmental sustainability targets. Selecting for bulls that contribute to lower carbon outputs can help reduce the overall environmental impact of beef production.
- **Docility (2%)**: This trait reflects the temperament of the animal. Calmer animals are easier to manage and handle, reducing stress and improving welfare and safety on farms.

The use of the DBI allows dairy farmers to select sires that will produce offspring with a balanced mix of desirable characteristics for both calving and subsequent beef production, optimising overall farm profitability and sustainability. As with all breeding indexes, it is critical that farmers understand and focus on the individual traits within the overall index to achieve changes in the traits that they want to improve in the next generation. In the case of the DBI, where farmers want to produce a valuable beef calf with a high CBV, then they should focus on the beef traits within the overall DBI. The importance of this message is displayed in Table 2 below where two AI sires with similar DBIs but very different sub–indexes are compared to each other. Bull A is likely to produce calves with higher a CBV than Bull B but with only a slight increase in expected calving difficulty. However, Bull B still has a role potentially for use on cows with a history of calving problems or on maiden heifers.

Table 2. Comparison of two AI sires with similar DBI but different sub traits

Bull A – High DBI & High Beef Sub-Index	Trait	Bull B – High DBI & Low Beef Sub-Index
Angus	Breed	Angus
1,037	Progeny	2,349
€164	DBI	€165
€129	Beef Sub Index	€82
€33	Calving Sub Index	€72
3.4	Calving difficulty %	2.3

Commercial Beef Value

All genotyped commercial calves are assigned a CBV at birth. Through the National Genotyping Programme (NGP) and the Suckler Carbon Efficiency Programme (SCEP) over 700,000 calves have been genotyped so far in 2024. Beef finishers buying animals are now in a position to make more informed purchasing decisions. This will allow them to be more discerning in their purchasing price by using the CBV as the guide to future profit potential of a group of calves. This exciting new addition to the suite of information tools available to Irish herdowners will build real engagement with beef finishers who heretofore may have had little direct contact with ICBF as they were not in the business of breeding animals.

Listed below are the main traits within the CBV (relative emphasis in brackets):

- **Carcass weight (35%)**
- **Feed intake (24%)**
- **Factory spec (12%):** this trait predicts the percentage of progeny expected to meet market requirements in terms of carcass weight, age and conformation.
- **Carcass conformation (11%)**
- **Age at finish (10%)**
- **Carbon (7%)**
- **Docility (1%)**

In order to compare the performance of high CBV and low CBV animals, those slaughtered in 2023 from two large commercial farms were chosen. The purpose of choosing this time period was to allow a full year and retrospective analysis of these animals which were purchased, finished and slaughtered in a commercial setting with no prior sight of the CBV. In Herd A that finished 600 suckler bred bulls there was a difference in average factory price of €428 in favour of the top 10% when ranked on CBV (Table 3). The equivalent figure in Herd B which finished 1,016 Dairy Beef steers was €463 (Table 4).

Table 3. Herd A: Suckler bulls slaughtered in 2023

	CBV	Age at slaughter	Carc weight	€/kg	Income	Diff
Top 10% (n=60)	€357	14	423	5.80	€2,452	€428
Bottom 10% (n = 60)	€203	17.1	372	5.43	€2,024	

Table 4. Herd B: Dairy beef steers slaughtered in 2023

	CBV	Age at slaughter	Carc weight	€/kg	Income	Diff
Top 10% (n=108)	€165	24	353	5.31	€1,878	€463
Bottom 10% (n = 108)	€34	23.3	278	5.08	€1,415	

Using the DBI to breed profitable beef animals

Herdowners can access the ICBF indexes by logging into their account at www.icbf.com.

To effectively apply them to their herd, a herdowner must address the two questions below:

What are the strengths and weaknesses of my females?

Assess the genetic merit of your females on the traits of importance for your system. The ICBF HerdPlus Economic Breeding Index (EBI) profile (Figure 1) provides a snapshot of the herd average EBI, milk, fertility, beef and calving interval (fertility) estimates of genetic merit. Further investigation can easily break this down by parity or even the individual cow level. The report also shows the average EBI breakdown of their herd compared to the national herd. In the case of a herdowner trying to breed high CBV calves they should be aware of the beef merit of their cowherd.

Scorecard (Jul 2024)	My Herd	National Average	Top 10%	Herd % Rank	Star Rating
Herd EBI	€226	€180	€231	90%	★★★★★
Milk	€46	€53	€69	43%	★★★☆☆
Fertility	€118	€78	€111	96%	★★★★★
Carbon	€15	€7	€14	88%	★★★★★
Calving	€37	€32	€41	79%	★★★★☆
Beef	€-11	€-7	€0	29%	★★☆☆☆
Maintenance	€17	€13	€20	75%	★★★★☆
Management	€0	€1	€2	13%	★☆☆☆☆
Health	€5	€6	€9	27%	★★☆☆☆

Figure 1. *Example of the HerdPlus EBI herd profile*

Am I selecting sires that are going to improve the traits required?

In the case of dairy farmers trying to produce high CBV calves, they should look at the Beef Sub Index within the overall DBI. The example displayed below (Figure 2) is a beef AI bull with a high Beef Sub Index balanced with an acceptable level of calving difficulty as displayed on the Animal Search facility on the ICBF website.

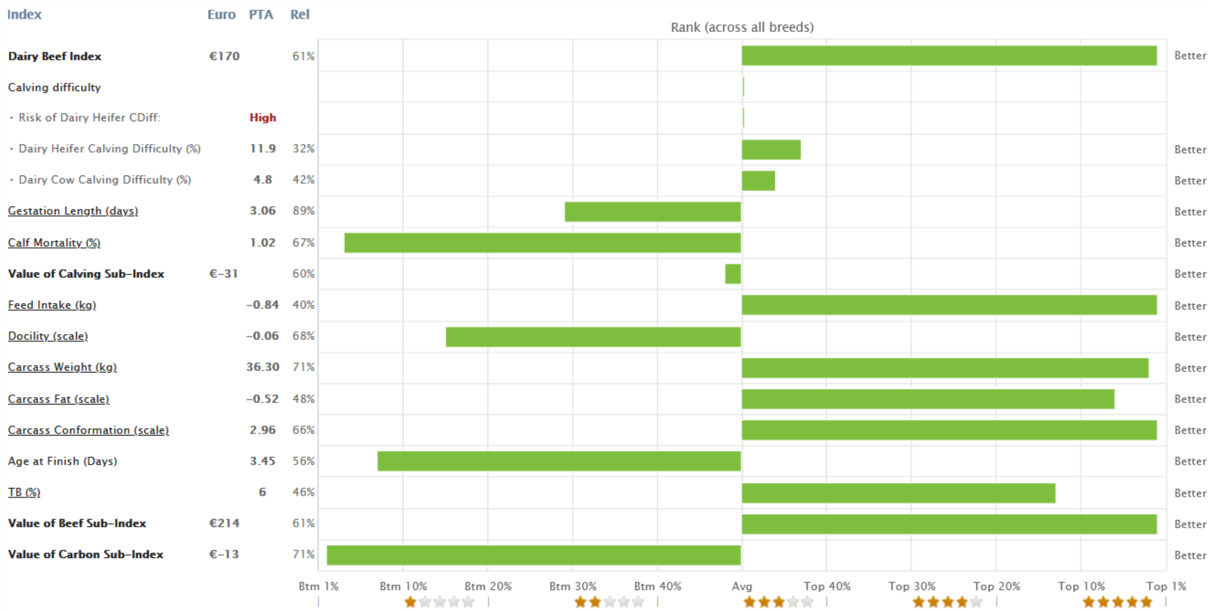

Figure 2. *Example of a high Beef Sub Index bull*

Using the CBV to identify profitable beef animals for finishing

The publication of a CBV on a large population of animals now enables herdowners to make more informed decisions on their beef finishing systems. These can be broadly broken down into two categories:

Herdowners making a decision on animals they own already

The significant costs and low margins associated with finishing beef animals means that any tool that can aid the decision to finish or sell live can have a significant impact on farm profitability. Herdowners that want to see the CBV of their own animals can log into their ICBF account and the profile as displayed below (Figure 3) will allow them to rank their animals on CBV and sort by animal type and sex.

Animal Details									Commercial Beef Value										
Jumbo	Animal Number	Breed	Birth Date	Sex	Dam	Sire	Geno Eval	Geno Sire Verified	Non-Geno Sire Pass	Breed Type	Value €	Star Ranking (Across Breed)	Star Ranking (Within Breed Type)	Carcass Weight (kg)	Carcass Conformation (1-15 scale)	Age at Finish (days)	Feed Intake (kg DM/ day)	Docility (1-5 scale)
2979	372214864132979	AA (50%), MO (34%)	23-FEB-24	F	IE301440280008	372224716621200	Y	Y		Dairy x Beef	148	★★★☆☆	★★★★★	4.0	0.55	-9	0.25	0.09
52989	372214864152989	AA (50%), HO (22%)	25-FEB-24	M	IE241435531628	372224716651178	Y	Y		Dairy x Beef	142	★★★☆☆	★★★★★	6.4	0.42	-10	0.09	0.11
2968	372214864192968	AA (72%), HO (19%)	17-FEB-24	F	372214864142600	372224716641292	Y	Y		Suckler	142	★★★☆☆	★☆☆☆☆	5.5	0.28	-7	0.27	0.16

Figure 3. *Example of the HerdPlus CBV herd profile*

Herdowners that wish to purchase animals for finishing

Approximately 1.8 million animals are traded in approximately 90 Irish marts annually. Historically buyers had no insight of the genetic merit of the animals and had to rely on limited data like date of birth and weight to make their purchasing decision. With the arrival of the CBV on the mart boards, as displayed in Figure 4, these critical actors in the beef industry now have a powerful tool at their disposal to enable them to identify the animals most likely to be profitable for their business.

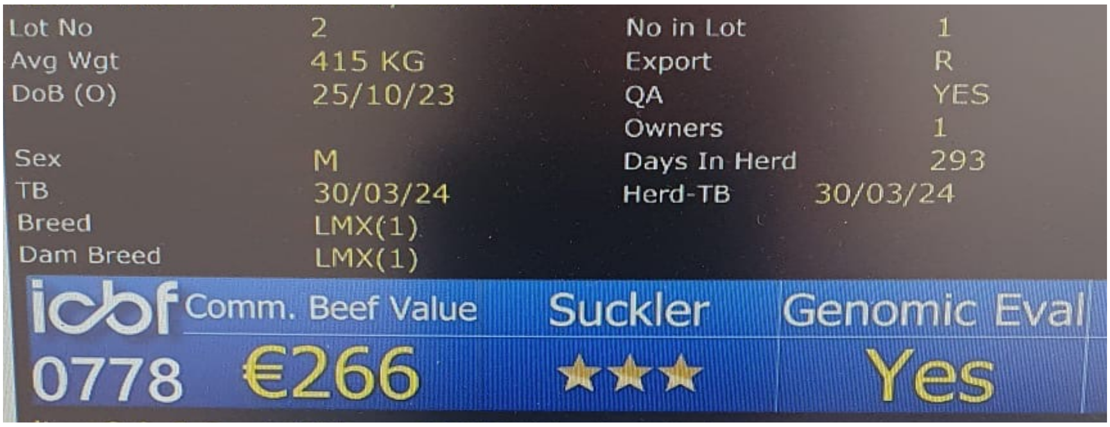

Figure 4. *Example of the CBV displayed on a mart board*

Conclusion

The DB GI programme has significantly advanced the genetic merit and efficiency of beef production within the Irish dairy industry. By utilizing the DBI and CBV, the programme has effectively balanced the improvement of beef traits with the maintenance of essential dairy characteristics, such as calving difficulty and gestation length. This targeted genetic approach has enabled dairy farmers to enhance the beef output of their herds while contributing to sustainability through improved feed efficiency and reduced carbon emissions.

The programme's success is rooted in its collaborative framework, involving farmers, AI companies, processors and research institutes. This ensures that breeding decisions are data-driven and validated. The introduction of the CBV has been particularly impactful, providing beef finishers with critical information to make informed purchasing and management decisions, thereby boosting profitability across the supply chain.

In conclusion, the DB GI programme exemplifies how a strategic breeding programme underpinned by comprehensive data collection and industry collaboration, can drive sustainable advancements in both dairy and beef production. As it continues to evolve, the programme is poised to play a vital role in maintaining the competitiveness and sustainability of Ireland's dairy and beef sectors in the face of ongoing industry challenges.

Experiences and future expectations for breeding programs targeting beef on dairy production systems

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Introduction

The increase in dairy cow numbers inseminated with semen of beef bulls is increasing because beef x dairy crossbred calves have a higher economic value than surplus dairy calves, and because the use of female sexed semen in dairy herds allows the remaining cows in the herd not producing replacement heifers to be inseminated with beef semen. Thus, there is a high demand for semen of beef bulls selected for a breeding goal targeted at beef x dairy performance. However, such a breeding goal might differentiate from a pure beef suckler production system and therefore require a specific breeding program tailored for beef on dairy production systems.

In addition, the beef sector and consumers are demanding meat with improved standards with respect to quality, production efficiency and climate footprint, which has to be included in the breeding decisions.

The aim of this paper is to give the current status and perspective at the Nordic level on the use of beef and dairy and to discuss the principles of building a strong breeding program targeting beef on dairy production systems.

Development in use of beef semen on dairy cows

During the last 10 years, the proportion of crossbred calves with a beef sire has increased from approximately 5% to between 35-45% dependent on breed. This development has been driven by an increased use of sexed female semen to produce replacement dairy heifers, which now in VikingGenetics is 35% across the dairy breeds. It is expected that beef semen can reach 50-60% of the market share if optimally combined with sexed semen in dairy herds to secure enough replacement heifers (Ettema *et al.,* 2017).

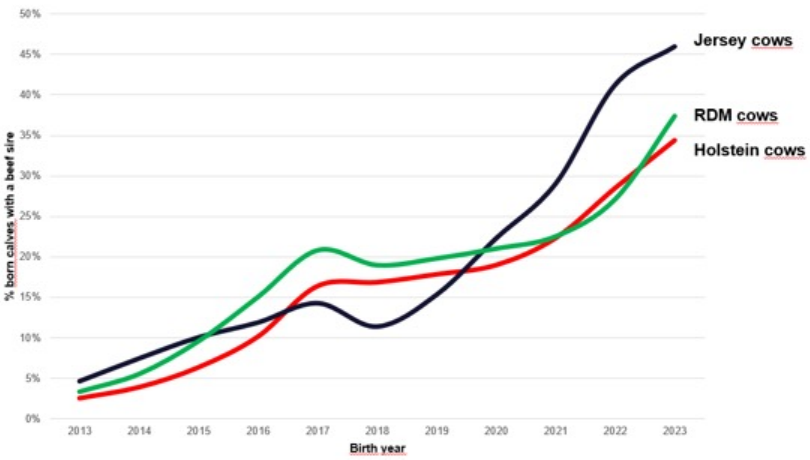

Figure 1. *Development in use of born calves with a beef sire on Jersey, Red Dairy Cattle (RDC) and Holstein cows in Denmark from 2013 to 2023*

Development of genetic evaluation for beef bulls used on dairy cows

The basis of genetic evaluation of beef bulls used for insemination of dairy cows, is the comprehensive registration and storing of crossbred data from all herds in the central Danish cattle database. It comprises data related to calving ease, calf survival at birth, health treatments and death during the rearing period reported by farmers, and carcass weight, carcass classification and carcass fat score from abattoirs. Further data on feed intake and methane emission are being recorded in large commercial herds (Byskov *et al.,* 2024). Marbling score is also expected to be recorded on a large scale in the future in Denmark.

Traditional breeding values for growth traits (net daily gain, carcass conformation and fat score), slaughter percentage, birth traits (calving ease and calf survival), young stock survival (early and late rearing period) and young stock health (pneumonia, diarrhea and claw abscess) are available to farmers and breed organizations. To make it easy to select beef bulls that sire slaughter calves with the highest economic potential, indices are weighted into a total merit index that optimizes economic output per index unit (see composition in total merit index in Figure 2). All indices are published on the internet and on printouts from the Danish Dairy Management system.

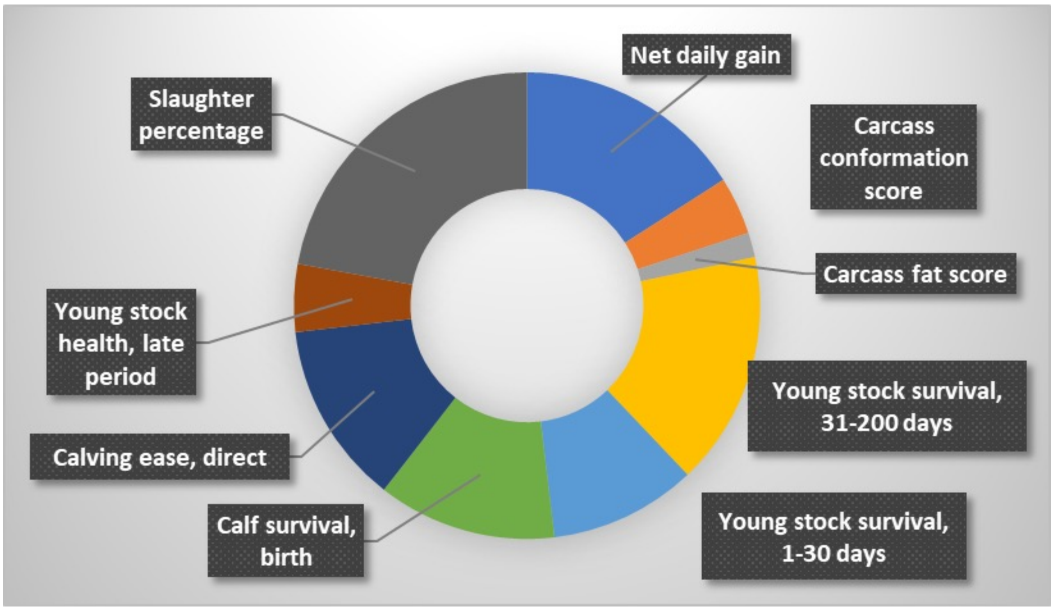

Figure 2. *Traits and weighting in x-indices*

Indices for feed efficiency, methane emission and eating quality (Følbæk *et al.*, 2024) are also calculated (Byskov *et al*, 2023) but are only used for selection purposes in the breeding program.

In 2025, it is expected that genomic breeding values will be introduced for beef bulls for crossbred performance. This is possible due to a comprehensive reference group containing more than 12.000 genotyped calves – mainly sired by Danish Blue bulls, but Angus and Charolais crosses are also included.

Fair pricing of calves from dairy farmer to slaughter calf producer

The pricing of crossbred calves is done in the usual management program of farmers (Dairy Management System) and it makes it easy for both specialized slaughter calf producers and dairy producers to trade crossbred calves in a fair way.

The pricing system is based on the national pricing of purebred Holstein bull calves. When calculating the price of a crossbred calf, there is a beef cattle bonus, a correction for the genetic level of the dam (beef traits) and a correction for the genetic level of the purebred beef sire.

The beef cattle bonus is calculated for all combinations of dam breed and calf sex based on production results in Denmark (net daily gain, carcass form, survival etc.). Assumptions are made about feed efficiency as well as current slaughter listing and feed prices. The beef cattle bonus is usually split 50:50 between the specialized slaughter calf producer and the dairy producer.

The correction for the sire genetic level depends on the bull status (proven or unproven). For proven bulls the correction is based on genetic potential. It is the part of the total merit index that is expressed at the specialized slaughter calf producer (slaughter percentage, net daily gain, carcass conformation, fat score, young stock survival, late period, young stock health, late period). In this way, the dairy producer is rewarded for using better beef bulls. For unproven beef sires, the beef cattle bonus depends on the average performance of the sire breed. On average unproven bulls do have a lower economic genetic level than proven bulls and the bonus for unproven bulls is therefore lower than for proven bulls.

Breeding scheme

In Denmark, Finland and Sweden, the breeding scheme for some of the beef cattle breeds (mainly Danish Blue, Angus and Blonde d'Aquitaine) is in a transition from a breeding scheme focusing only on purebred performance to two breeding schemes per breed focusing on either purebred performance or crossbred performance.

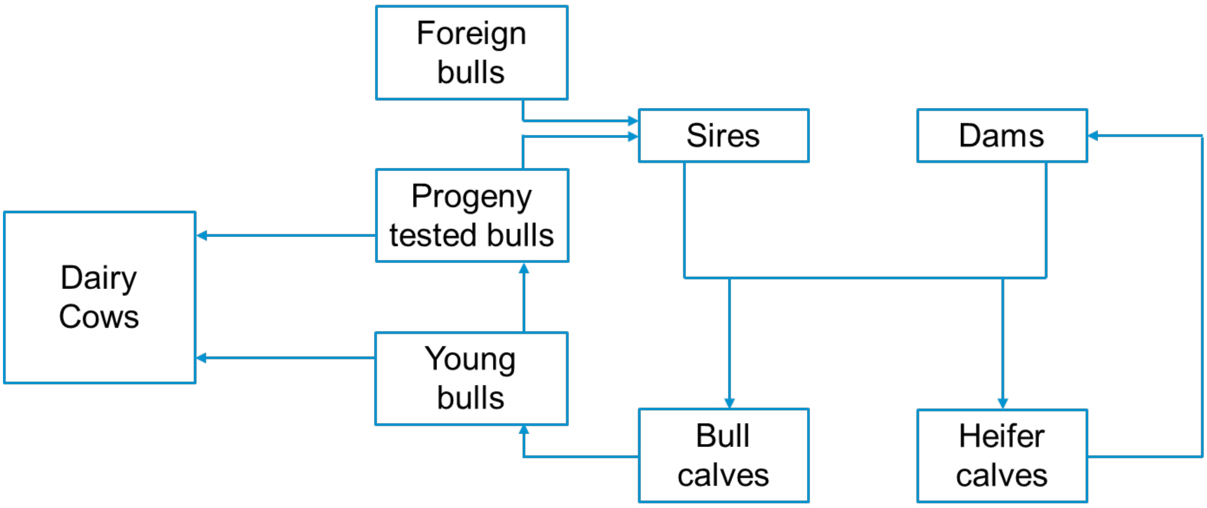

Figure 3. *Breeding scheme for beef cattle destined for use on dairy cows*

Over time, this approach will result in specialized populations of beef cattle that aim at improving Beef × Dairy calves. We expect the population size to be small in these specialized populations. Therefore, the breeding scheme should not only generate high genetic gain but also keep inbreeding at reasonable rates. Optimum-contribution selection maximizes genetic gain at a given rate of inbreeding (Wray and Goddard, 1994; Meuwissen, 1997). The other selection methods, e.g. truncation selection, do not take into account the relationship between the selection candidates. On that basis, we argue that optimum-contribution selection is a better selection method than truncation selection for a small, specialized population of beef cattle (Hjortø *et al.,* 2022).

Today, selection of young beef bulls for progeny testing and heifers for flushing is based on traditional estimated breeding value (EBV). The implementation of genomic breeding values described earlier will increase the accuracy of selection of young candidates and generate higher genetic gain.

It may be difficult to select the highest-ranking females for crossbred performance because beef cattle breeders want to improve purebred performance for suckling performance in their herds or the conformation of the animals for shows. Therefore, breeding companies may have to establish donor stations. Multiple ovulation and embryo transfer (MOET) offers the possibility to get more progeny from all selected heifers and thereby increase the selection intensity and genetic gain.

Conclusion

The growing use of sexed semen in dairy herds has generated a large potential in maximizing the use of beef on dairy crossbreeding for generating a more valuable and climate friendly beef production. To utilize this potential, it is important to establish effective breeding programs with a breeding goal focused on crossbred performance.

References

Beef on Dairy genomic evaluation for feed efficiency, methane emission and meat quality. Byskov K., Huiming Liu H., Johansen K., Shirali M., Interbull Open Session, Lyon 2023.

Beef-on-dairy: Meat quality of veal and prediction of intramuscular fat using the Q-FOM™ Beef camera at the 5th–6th thoracic vertebra. Drachmann, F. F., Christensen, M., Esberg, J., Lauridsen, T., Fogh, A., Young, J. F. & Therkildsen, M. 2024. Meat Science. **213:** 9.

Breeding schemes with optimum-contribution selection or truncation selection for beef cattle destined for use on dairy females. Hjortø L., Andersen T., Kargo K., Sørensen A. C. 2022. JDS: 105:5:4314-4323.

Economic opportunities for using sexed semen and semen of beef bulls in dairy herds. Ettema J. F., Thomasen J. R., Hjortø L., Kargo M., Østergaard S. and Sørensen A.C. 2017. JDS. 100:5: 4161-4171

Experiences from collection of feed and methane data from beef x dairy calves in Denmark. Byskov K., Nathansen L., Bjerring M., Dueholm B. and Fogh A. ICAR & INTERBULL May 19-24, Slovenia 2024.

Increasing long-term response to selection. Wray, N.R., Goddard, M.E. Genet. Sel. Evol. 1994; **26:**431-451.

Maximizing the response of selection with a predefined rate of inbreeding. Meuwissen, T.H.E. J. Anim. Sci. 1997; **75:**934-940.

Potential to increase the rate of gain for Irish beef sires on the dairy beef index

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Introduction

Interest is intensifying in the generation of more valuable calves from beef on dairy matings. This reflects the large and increasing proportion of beef output in Ireland that is currently sourced from the dairy herd (Berry, 2021). The Irish dairy-beef index (DBI) was developed for the identification of beef bulls with high genetic merit for traits underlining the breeding of high-quality beef calves from the dairy herd that are profitable to slaughter, but that also have minimal consequences on the calving difficultly and gestation length of dairy dams (Berry *et al.,* 2018). Moreover, the Irish Dairy Calf-to-Beef Ten-Point Action Plan has been developed in support of Food Vision 2030. A key action within this plan is to develop strategies to accelerate the rate of genetic progress within the DBI (Teagasc, 2024). The objectives of this study were to, firstly, determine the current rate of gain in the DBI, both at the sire- and calf-level, and, secondly, to assess the potential to increase the index's rate of gain into the future under different breeding program strategies.

Methodology

Trends in the DBI and in the associated beef and calving sub-indexes were generated from data sourced from the Irish Cattle Breeding Federation. The dataset included index and sub-index values for Angus sires with dairy-beef progeny, as well as Angus-sired dairy-beef calves, born since 2018.

To determine the potential to increase the rate of gain in the DBI under different breeding program strategies, selection index theory was employed (Dekkers, 2007; Van Vleck, 1970). The breeding program strategies of interest included a nucleus herd implementing early-in-life ovum pickup, increased progeny testing efforts, incentivisation of breeders, and contract mating. Selection index theory enables the prediction of annual response to selection in a breeding program at the index, sub-index and trait levels. In addition, cost-benefit analysis was conducted for the nucleus herd strategy to evaluate the marginal economic benefits to the overall agricultural industry generated from the proposed alteration to the breeding program. The calculation of cost-benefits factored in the predicted increase in DBI rate of gain from the nucleus herd, the expected cost of establishing and maintaining the herd, and the expected increase in beef-sired calves from the dairy herd in the coming years.

Results

Trend analysis of Angus sires determined that, on average, the DBI increased by €2.71 per year since 2018, with corresponding increases of €1.70 and €1.01 annually in the index's beef and calving sub-indexes, respectively. At the dairy-beef calf level (50% influenced by the dairy breed dam), the DBI was observed to have increased by €0.83 per year since 2018, with an observed annual decrease of €2.10 in the beef sub-index and an annual increase of €2.93 in the calving sub-index.

Modelling the various breeding program strategies established a potential to increase the DBI rate of gain to between €3.10/year and €5.83/year, depending on the strategy employed. Of all the strategies of interest, the nucleus herd presented the greatest increase in DBI rate of gain, while the contract mating scenario presented the lowest increase in DBI rate of gain (Figure 1).

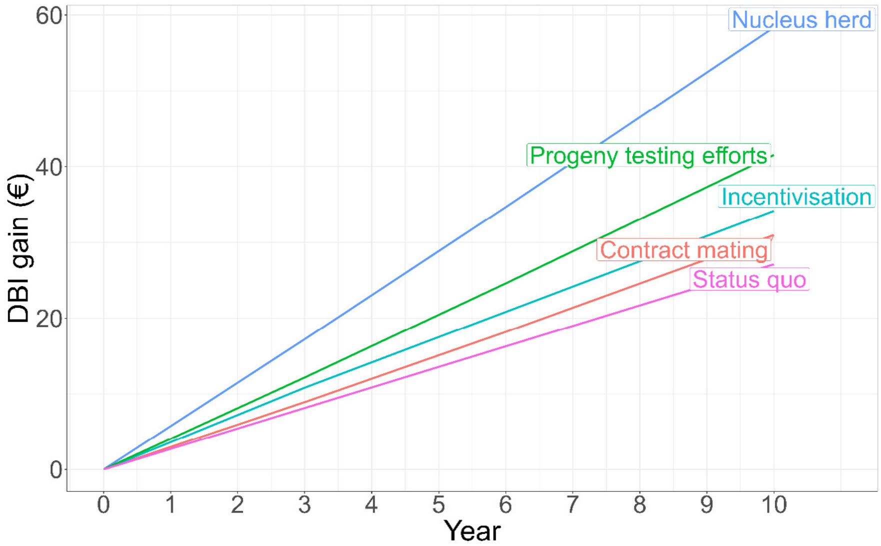

Figure 1. *Predicted rate of gain in the DBI for Angus sires based on the different breeding program strategies of interest*

From the conducted cost-benefit analysis it was calculated that a nucleus herd comprising 75 high-DBI donor heifers that utilised early-in-life ovum pickup would be expected to provide an annualised marginal benefit of €5.45 million to the Irish agricultural industry.

Discussion

Current DBI sire trends are comparatively low relative to other established breeding indexes (i.e., the dairy Economic Breeding Index; Berry *et al.*, 2022). Selection index modelling herein predicts the potential to increase the annual rate of gain in the DBI up to approximately 2.5 times the current rate of gain. An important assumption for the predicted benefits and increased rates of gain was buy-in from industry. Careful management of genetic relatedness and inbreeding, as well as ongoing outreach with industry stakeholders (i.e. AI companies and farmers) are likely to be fundamental to success.

References

Berry, D.P., Amer, P.R., Evans, R.D., Byrne, T., Cromie, A.R. and Hely, F. (2019). A breeding index to rank beef bulls for use on dairy females to maximize profit. *Journal of Dairy Science,* 10056-10072.

Berry, D.P. (2021). Invited review: Beef-on-dairy—The generation of crossbred beef× dairy cattle. *Journal of Dairy Science,* 3789-3819.

Berry, D.P., Dunne, F.L., McHugh, N., McParland, S., O'Brien, A.C. and Twomey, A.J. (2022). The development of effective ruminant breeding programmes in Ireland from science to practice. *Irish Journal of Agricultural and Food Research*, 38-54.

Dekkers J. C. M. (2007). Prediction of response to marker-assisted and genomic selection using selection index theory. *Journal of Animal Breeding & Genetics*, 331-341.

Teagasc (2024). Ten-point action plan on accelerating dairy calf to beef systems in Ireland.

Van Vleck L.D. (1970). Index Selection for Direct and Maternal Genetic Components of Economic Traits. *Biometrics*, 477-483.

Abstracts

Effect of pre and post-weaning plane of nutrition on development, performance and carcass characteristics of spring-born, dairy-bred bull calves

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Application

Offering calves a high plane of nutrition during either the pre-weaning or early post-weaning phases of development resulted in higher weight gain, with the advantage persisting to slaughter at 16 months of age.

Introduction

In dairy-beef cattle production systems, failure to meet daily liveweight gain targets results in older animals at slaughter leading to economic and environmental inefficiencies. During the early postnatal period, the animal is most efficient at converting feed-derived nutrients into muscle growth, and is therefore one approach to improving overall lifetime performance (Byrne *et al*., 2017; Rosadiuk *et al*., 2021). While increasing calves plane of nutrition typically results in higher liveweight gain, limited published results exist on whether such gains persist to later life and, particularly in terms of slaughter performance. Additionally, the latent impact of timing, amount, and interaction between pre and post-weaning dietary augmentation of artificially reared calves on lifetime performance and carcass characteristics is not clear. Thus, the objective of this study was to examine the impact of pre and post-weaning planes of nutrition on performance and carcass characteristics in dairy-bred male calves slaughtered at 16 months of age.

Materials and methods

Spring-born dairy-bred Angus and Holstein Friesian (n=56) bull calves were sourced from the same dairy research herd, Teagasc Moorepark, in 2023. Calves received differential pre and post-weaning planes of nutrition to 15 weeks of age, management thereafter was common to all treatment groups to slaughter as bulls at 16 months of age. At seven days of age calves were blocked by breed, calf liveweight and birth date, and assigned to one of two pre-weaning planes of nutrition: moderate (M PRE) or high (H PRE). Milk replacer (MR) and concentrate were offered individually using an electronic calf feeding system (Foster-Technik Vario; Engen, Germany). Calves on the M PRE treatment were offered: Stage I (7 days of age to arrival at Teagasc Grange Research Centre, d 0) 6L/day containing 750g MR , Stage II (d 0 – 36) the same as stage I, Stage III: (d 36- 50) 6L/day incrementally reduced to zero. Calves on H PRE treatment were offered: Stage I: (7 days of age to arrival at Teagasc Grange Research Centre, d 0) 8L/day containing 1200g MR , stage II: (d 0 – 24) 10L/day containing 1500g MR, stage III: (d 24 – 29) 10L/ day gradually reduced to 6L, stage IV: (d 29 – 36) 6L/day, stage V: (36 – 50 d) 6L/day incrementally reduced to zero. Calves were offered respective diets of reconstituted MR (containing 26% protein and 16% fat; Heiferlac, Volac,) and had *ad lib* access to a commercial calf rearing pelleted concentrate (18% CP) for the pre-weaning period. Post-weaning, calves were blocked by age and liveweight from within their respective pre-weaning treatment to one of two, four week long post-weaning diets, moderate (M POST) or high (H POST) where they received a daily concentrate allowance of either 1.5kg or *ad lib* access, respectively. Subsequently animals were managed in accordance with the standard Teagasc 16 month old dairy bull beef system blueprint. Carcass characteristics data were collected at slaughter.

All data were analysed, using Statistical Analysis Software (SAS v9.4). Data were tested for normality (UNIVARIATE procedure). Data were subsequently analysed using ANOVA (MIXED procedure). For performance data, block, pen, and plane of nutrition were included in the model. Animal was the experimental unit. Week was the repeated measure for intake analysis.

Results

A week x pre and post-weaning dietary treatment interaction was observed for both dry matter (DMI) and energy intake as per design. Pre-weaning, daily DMI MR was lower for M compared to H (0.63 vs 0.94 kg, respectively, $P < 0.0001$), as per design. Calves on the M diet had a greater concentrate DMI than H pre-weaning (1.06 vs 0.94kg, respectively, $P = 0.015$), with no difference in total DMI of milk and concentrate pre-weaning ($P = 0.13$). However, H consumed more total energy pre-weaning than M ($P = 0.0003$). Post-weaning concentrate DMI and energy consumption was lower in M than H, as per design ($P < 0.0001$). There were no interactions for liveweight gain between pre and post-weaning diets. Calves on H PRE diet had greater liveweight at weaning compared to M PRE ($P = 0.0002$, Table 1). Calves on H POST had greater liveweight at the end of the post-weaning period, compared to M POST ($P < .0001$). Differences in liveweight between treatments at the end of both the pre and the post-weaning periods were retained to housing (Table 1). At slaughter, both liveweight and carcass weight were greater for animals offered H compared with M post-weaning. There was no effect of pre-weaning plane of nutrition on either liveweight or carcass at slaughter. There was a tendency for pre but not post-weaning diet to affect both carcass conformation and fat scores, M PRE having a higher conformation and fat score than H PRE, but no significant difference observed (Table 1).

Table 1. Effect of pre and post-weaning plane of nutrition (M or H) on performance of dairy-bred bull calves slaughtered at 16 months of age

Plane of nutrition	Pre weaning		Pre weaning		SEM	Significance*	
	M PRE	H PRE	M POST	H POST		Pre weaning	Post weaning
Liveweight (kg)							
Birthweight	35.3	36.9	36.4	35.9	1.07	0.229	0.697
Arrival (3 Weeks)	46.8	52.0	49.9	48.9	1.20	0.001	0.513
Weaning (11 Weeks)	83.7	92.0	87.9	87.8	1.70	0.0002	0.957
Turnout (15 Weeks)	108.8	114.5	102.0	121.3	2.00	0.024	<.0001
Housing (9 months)	188.2	199.5	183.8	203.8	4.72	0.050	0.001
Liveweight at slaughter (16 months)	522.0	531.3	512.0	541.2	9.27	0.263	0.001
Carcass weight	270.1	273.8	263.8	280.1	5.40	0.443	0.001
Conformation	5.4	4.9	5.0	5.4	0.32	0.097	0.135
Fat score	7.2	6.6	7.1	6.7	0.45	0.094	0.286
Average daily gain (kg)							
Pre-weaning period (11 weeks)	0.71	0.81	0.73	0.76	0.024	0.015	0.306
Post-weaning period (4 weeks)	0.91	0.84	0.55	1.20	0.040	0.179	<.0001
Grazing period (5 months)	0.57	0.61	0.59	0.59	0.030	0.265	0.919
Housing to Slaughter (7 months)	1.34	1.32	1.32	1.35	0.035	0.584	0.318

**Non-significant (P>0.05) pre-weaning x post-weaning diet interaction was observed*

Conclusions

Pre and post-weaning energy intake increased performance of artificially reared dairy-beef calves, subsequently influencing slaughter performance within the context of a calf to 16 month old bull beef system. The magnitude of growth response to increased energy input in early life is greater post-weaning than pre-weaning. Further investigation is required into optimisation of post-weaning plane of nutrition and its impact on the economic and environmental efficiency of dairy calf-to-beef production systems.

Acknowledgements

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References

Byrne, C. J., Fair, S., English, A. M., Johnston, D., Lonergan, P. and Kenny, D. A. (2017) 'Effect of milk replacer and concentrate intake on growth rate, feeding behaviour and systemic metabolite concentrations of pre-weaned bull calves of two dairy breeds', *Animal*, **11(9):** 1531-1538.

Rosadiuk, J. P., Bruinjé, T. C., Moslemipur, F., Fischer-Tlustos, A. J., Renaud, D. L., Ambrose, D. J., Steele, M. A., Bruinje, T. C., Moslemipur, F., Fischer-Tlustos, A. J., Renaud, D. L., Ambrose, D. J. and Steele, M. A. (2021) 'Differing planes of pre- and postweaning phase nutrition in Holstein heifers: I. Effects on feed intake, growth efficiency, and metabolic and development indicators', *Journal of Dairy Science*, **104(1):** 1136-1152.

Tripl'Scotch: Beef from dairy cows managed within a compact spring calving grass-based system in Western France

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Application

This project will help dairy farmers to develop an original beef co-product, with the aim of making better use of marginal and remote grasslands and adding attractive economic value to calves born from dairy cows.

Introduction

Traditionally, in dairy systems, little attention is paid to male or surplus calves. The availability of sexed semen opens up new possibilities for selecting the best dairy cows to breed replacements from early in the breeding season and, complemented by the use of beef bulls or beef AI later in the breeding season to produce beef crossbred animals for dairy-beef production. This idea was implemented as part of the Tripl'XL experiment being carried out on the INRAE experimental farm at Le Pin in Normandy (Delaby *et al.,* 2024). The objective of this summary is to detail the management of the crossbred cattle and to present the initial results obtained from birth to slaughter from three cohorts born between 2020 and 2022.

Materials and methods

The main objective of the Tripl'XL experiment is to describe the effect of allocating a small quantity of concentrate (3 to 4 kg/cow/day over 100 days) at different periods of the lactation of Holstein (Ho), Normande (No) and Jersey (Je) dairy cows. The 3-breed dairy herd (168 cows) is managed within a compact spring calving grass-based system (1.80 cows/ha). The breeding period (21/04 to 21/07) is divided into two sub-periods: the first with pure dairy breed sexed semen until the end of May, and the second with Angus bulls used according to observed heats. The Angus breed is preferred for their calving traits (gestation length and calving ease), hornless, early-maturity, suitability for grass-based production and meat quality. Such dairy beef progeny provide interesting advantages for farmers and is in accordance with consumer demands. The calves born from Angus bulls are reared on the farm finished at 2-years of age, without concentrate use. March and April born crossbred calves are milk fed to 10 weeks of age, and reared with the replacement dairy heifers until they are 5 months old. After chirurgical castration for the males, the group is separated and grazed together for about two months in autumn. The 1st winter period occurred between Nov to mid-March, and the indoor feeding is based on grass silage or big-bale haylage (5 to 6 kg DM/animal/day). A long grazing period takes place from mid-March to Nov (240 to 280 d – from 0.15 to 0.30 ha/animal), on grasslands which are too far away to integrate as part of the dairy platform. The last period of 4 months is dedicated for fattening with excellent grass silage (10 to 12 kg DM/animal/day). All animals are slaughtered in one group at ~700 days of age.

The animals are weighed fortnightly and the bodyweight (BW) is calculated by linearization at a fixed age (Table 1). The GLM model applied (SAS 9.4, SAS Institute Inc., Cary, NC) on the individual BW, carcass weight and growth for key measurement dates includes the effect of the year of birth (n=3), sex (n=2), dam breed (n=3) and the interaction between sex and dam breed.

Results

After three experimental years, 62 animals (24 Ho, 20 No and 18 Je / 34 castrated male and 28 females) aged between 635 and 753 days were slaughtered. The interactions between dam breed and sex were non-significant for all dependant variables tested. At all key ages, the JeX weighs significantly less than HoX and NoX, which were similar throughout and do not significantly differ. At birth, the JeX BW is 73% of the two others crossbreds. This difference declines at weaning (85%) and during the 1st winter (90%), and at slaughter 86%. In terms of carcass weights, the HoX and NoX are similar at 310 and 320 kg, respectively, and significantly higher than the JeX (261 kg). For the three crossbreds, the carcass kill-out percentage is similar, ranging between 48% (JeX), 49% (HoX) and 50% (NoX). The growth does not differ significantly between crossbreds during the milk phase (765 g/d), during the 1st autumn (710 g/d) and 1st winter period (837 g/d). A difference appears during the 2nd long grazing period, with a significant advantage to the HoX and NoX (770 g /d) compared to the JeX (655 g/d). During the finishing period, the BW gain is always significantly higher for the HoX and NoX with a gain of 1040 g/d, and less for the JeX (833 g/d).

All the animals slaughtered met the carcass specifications defined for slaughter, in terms of carcass weight (min-max), conformation (O= or O+) and fatness (3- to 4=).

Table 1. Body and carcass weights of Angus x dairy cattle at key periods from birth to slaughter

Dairy breed [n]	Holstein [24]	Normande [20]	Jersey [18]	RSE
At birth (kg)	45.5 ^{a}	46.1 ^{a}	33.6 ^{b}	6.2
At weaning - 75 d (kg)	100 ^{a}	101 ^{a}	86 ^{b}	10.4
1st back indoor - 240 d (kg)	230 ^{a}	226 ^{a}	206 ^{b}	22.4
2nd turnout - 330 d (kg)	313 ^{a}	312 ^{a}	280 ^{b}	34.4
2nd back indoor - 600 d (kg)	523 ^{a}	519 ^{a}	457 ^{b}	41.1
At slaughtering - 700 d (kg)	625 ^{a}	636 ^{a}	544 ^{b}	48.8
Carcass (kg)	310 ^{a}	320 ^{a}	261 ^{b}	23.8

On the same row, two results without common letter are significantly different.

Conclusion

These first results confirm the possibility to develop beef from dairy production, which is interesting for farmers as a co-product with only forage utilisation, maximising grass grazed, with little additional workload and in according with the industry and consumer demands.

Acknowledgements

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References

Delaby, L., Gaborit, M., Leloup, L., Launay,F., 2024. *Grassland Science in Europe,* **29:**428.

The potential of strategic concentrate supplementation, and beef sire genetic merit in reducing age at slaughter within Irish pasture-based dairy-beef systems

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Application

The results of this study show that using beef sires of superior genetic merit and strategic concentrate supplementation can improve beef-on-dairy progeny growth performance.

Introduction

The contribution of dairy-beef to the total number of cattle slaughtered in Ireland now stands at approximately 60%, and is increasing. A stable and fertile national dairy herd allows for greater opportunity to increase sex sorted semen usage on dairy farms, and also increase the number of dairy cows bred to a beef sire. The Commercial beef value, or CBV, is a purchasing selection index for an animal destined for beef production (Dunne *et al.*, 2021). Developed in Ireland, it provides beef farmers with information on the potential profitability of beef cattle, allowing them to make informed purchasing decisions. The first objective of the current study was to investigate the potential of the CBV in predicting increased animal and economic performance of dairy-beef steers.

Reducing slaughter age, while still meeting minimum carcass specification, will improve the sustainability of dairy-beef production systems. The second objective of this study was to investigate the effect of strategic use of concentrate feed within the context of pasture-based dairy-beef steer systems, on the potential to reduce slaughter age across different genotypes.

Materials and methods

An investigation into dairy-beef steer systems was conducted from 2020-2023 at Teagasc, Animal & Grassland Research and Innovation Centre, Grange, Co. Meath, Ireland. This was set up as a three-by-two factorial design. The first factor involved three dairy-beef genotypes: high beef genetic merit Angus X Holstein-Friesian (High CBV), low beef genetic merit Angus X Holstein-Friesian (Low CBV) and Holstein-Friesian (HF). The CBV of High CBV, Low CBV and HF steers was €95, €64 and €-1, respectively. Across the three genotypes, steers were managed under two contrasting pasture supplementation strategies, Grass-only and Supplemented, with steers assigned to each treatment as calves post-weaning, balanced for genotype, sire, live-weight and age. Grass-only calves received no concentrate supplement over the first summer grazing season (June-September), with Supplemented calves offered 0.75 kg DM concentrate/day per calf. All calves were offered high quality grass silage (dry matter digestibility =756 g/kg DM) ad-libitum, and 1.25 kg DM/day of concentrate over the first winter. Post-turnout for a second grazing season, grass-only steers rotationally grazed pasture only, and received no concentrate supplement outdoors. Grass-only steers were housed for a conventional finishing period of grass silage *ad-libitum* (dry matter digestibility =725 g/kg DM) plus 4.2 kg DM/day of concentrate. Supplemented steers grazed pasture only post-turnout and from July 1st received 3.7 kg DM concentrate/day per steer until being deemed finished at pasture. Steers were deemed finished upon reaching a body condition score of ≥ 3.75 (on a 1-5 scale, with 1 being emaciated and 5 being morbidly obese), deemed to be equivalent of a EUROP carcass fat score of 3+. Bio-economic analysis was conducted using the Grange Dairy Beef Systems Model (Ashfield *et al.*, 2014). Statistical analysis was completed using a linear mixed model in SAS (version 9.4; SAS Institute Inc., Cary NC), with genotype, feed treatment, dam beef genetic merit, parity and day of birth within year as fixed effects, sire was included as a random effect for all traits.

Results

There was an interaction between genotype and feed treatment for age at slaughter and carcass weight. Beef × dairy steers supplemented during the second grazing season were younger at slaughter than grass-only beef × dairy steers ($P < 0.05$), but slaughter ages were similar for supplemented and grass-only HF steers ($P > 0.05$). Low CBV, grass only, Angus steers produced a heavier carcass ($P < 0.05$) than supplemented Low CBV Angus steers, albeit at an older age. Supplemented HF steers produced a heavier carcass than grass-only HF steers ($P < 0.05$), but consumed more finishing concentrate as they were unable to meet the prerequisite BCS to allow slaughter from pasture, and required a conventional finishing period indoors. HIGH CBV steers produced a similar carcass weight ($P > 0.05$) in each feed treatment.

Table 1. Slaughter performance per genotype (Geno) and pasture supplementation strategy (FT)

	Grass-only			Supplemented			SEM	P-Value	
	High CBV	Low CBV	HF	High CBV	Low CBV	HF		Geno	FT
Finishing age (days)	639[b]	650[b]	719[c]	602[a]	602[a]	714[c]	4.3	***	***
Carcass wt. (kg)	315[b]	306[b]	311[b]	311[b]	282[c]	328[a]	5.5	***	NS
Carcass conf. (1-15)	5.4[a]	5.1[a]	3.6[b]	5.7[a]	5.1[a]	3.9[b]	0.18	***	NS
Carcass Conf. (EUROP)	O=/O+	O=	P+/O-	O+	O=	O-	-	-	-
Carcass fat (1-15)	9.5[ab]	9.3[bc]	9.0[c]	10.0[a]	9.2[bc]	9.5[ab]	0.19	*	***
Carcass fat (EUROP)	3+/4-	3+	3+	4-	2+	3+/4-	-	-	-
Lifetime conc. (kg DM)	520	592	877	754	732	1,245	-	-	-
Lifetime[1] ADG (kg/day)	0.91[a]	0.88[b]	0.82[c]	0.92[a]	0.86[bc]	0.85[bc]	0.018	***	NS
Profit per head (€)	456	382	269	389	280	187	-	-	-

[a-e] *Least square means within rows with different superscripts differ (P< 0.05) from each other*
[1]*Lifetime ADG= (arrival body weight - final pre-slaughter bodyweight)/(age at slaughter - age at arrival).*

Conclusions

In conclusion the results of this study show that High CBV steers have a greater lifetime ADG and generate a greater profit/head than Low beef merit and HF steers. Additionally, supplementation at pasture reduced the slaughter age of Angus steers, with High CBV steers achieving a heavier (19 kg) carcass and greater profit per head (€109) than Low CBV steers when finished outdoors before a second winter. The slaughter age of HF steers was unaffected by concentrate supplementation, despite the greater carcass weight (17 kg) of supplemented HF steers coming at the expense of 368 kg DM more concentrate than Grass-only HF steers reducing profit per head by €82.

Acknowledgements

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References

Ashfield, A., M. Wallace, R. Prendiville, and P. Crosson. 2014. Bioeconomic modelling of male Holstein-Friesian dairy calf-to-beef production systems on Irish farms. Irish *Journal of Agricultural and Food Research*:133-147.

Dunne, F., R. Evans, M. Kelleher, S. Walsh, and D. Berry. 2021. Formulation of a decision support tool incorporating both genetic and non-genetic effects to rank young growing cattle on expected market value. *Animal,* **15(2):**100077.

Investigating the grazing behaviour and dry matter intake of dairy-beef steers, with or without concentrate supplementation

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Application

Understanding the grazing behaviours which lead to greater growth rates of beef steers at pasture will identify optimum genotypes and feed managements to optimise animal phenotypic performance from grass-based production systems.

Introduction

Grazed herbage is widely acknowledged as the cheapest feed source in ruminant production systems (Finneran *et al.*, 2012), and with feed accounting for 75% of variable costs in dairy-beef systems, maximising the quantity in the diet is an integral component of maximising profit (Ashfield *et al.*, 2014). Previous studies have shown the weakness of predicting pasture dry matter intake (DMI) from measurements recorded while animals are indoors, due to the low repeatability in feed intake measured during the grazing season and the indoor period (Clarke *et al.*, 2009). Therefore, the objective of this study was to determine the grazing behaviour and DMI of dairy-beef steers of divergent beef genetic merit, managed under two contrasting pasture based concentrate supplementation strategies.

Materials and methods

A grazing behaviour and DMI measurement study was completed as part of a wider study investigating dairy beef systems in 2021 at Teagasc, Animal & Grassland Research and Innovation Centre, Grange, Co. Meath, Ireland. The experiment was set up as a three-by-two factorial design, in which three dairy-beef genotypes: high beef genetic merit Angus X Holstein-Friesian (High AA) (n = 40), low beef genetic merit Angus X Holstein-Friesian (Low AA) (n = 40), and Holstein-Friesian (HF) (n = 40) were managed under two contrasting pasture supplementation strategies, Grass-only (GO) and Pasture-concentrate (PC), with steers assigned to each treatment as calves post-weaning, balanced for genotype, sire, live-weight and age. Pasture-concentrate steers received 2.7 kg DM concentrate per head from July 1st. Dry matter intake was estimated using the n-alkane technique (Dillon, 1993), on two occasions (mid-May and mid-July) in 2021, at approximately 15 and 17 months of age, respectively. Steers received a paper bolus (Carl Roth, Gmbh, Karlsruhe, Germany) containing C32-alkane (n-dotriacontane) for 11 days. Representative herbage samples from each pasture allocation were taken from day 6 to 11. Faecal samples from each steer were collected from day 7 to 11 in the morning and afternoon, faecal samples were mainly collected during field observations, with rectal grab sample taken from steers not seen to defecate at pasture.

Grazing behaviour was measured concurrently with DMI on all genotypes in the PC group using the RumiWatch noseband sensor (Iten & Hoch Gmbh, Liestal, Switzerland). Data collected was converted into 1 hour summaries using the RumiWatch convertor V 0.7.3.36, validated by Norbu *et al.* (2021) for use in grazing studies. Statistical analysis was completed using a linear mixed model in SAS (version 9.4; SAS Institute Inc., Cary NC), with genotype and concentrate supplementation treatment as fixed effects.

Results

There were no interactions between genotype and concentrate supplementation treatments ($P > 0.05$). During the early grazing season (May), HF steers had a greater DMI than both High and Low AA ($P < 0.001$) (Table 1) Accordingly, total DMI (TDMI) 100 kg^{-1} was greater for HF steers than both AA genotypes. This difference did not persist throughout the grazing season, with all genotypes having a similar ($P > 0.05$) DMI by July (Table 1). Mean substitution rates of concentrate for pasture DM for each genotype were 0.68, 0.79 and 0.84 for HF, High AA and Low AA, respectively. When management was similar (May), no difference ($P > 0.05$) was observed for DMI between management groups, however, once concentrate supplementation was introduced, DMI and TDMI 100 kg^{-1} increased ($P < 0.001$) for PC compared to GO (Table 1) In May, High AA grazing bout duration was longer ($P < 0.05$) than Low AA, with HF similar to both AA genotypes. Low AA displayed a shorter bout duration, and lower DMI $bout^{-1}$ than both High AA and HF, no other statistical differences were noted in grazing behaviour in May ($P > 0.05$). In July, no significant differences were observed in key grazing behaviour characteristics.

Table 1. Effect of genotype and treatment on steer DMI and growth

	Genotype			SEM	Treatment		SEM	Significance	
	HF	High AA	Low AA		GO	PC		Geno	FT
May DMI kg day^{-1}	9.03[a]	7.99[b]	8.03[b]	0.211	8.40	8.30	0.172	***	NS
May TDMI[1] 100 kg^{-1}	2.29[a]	2.02[b]	2.05[b]	0.053	2.13	2.11	0.043	***	NS
May Bodyweight	393	398	392	8.1	400	388	6.5	NS	NS
July DMI kg day^{-1}	9.10	8.96	9.30	0.317	8.80[a]	9.44[b]	0.231	NS	**
July TDMI 100 kg^{-1}	1.97	1.93	2.05	0.064	1.91[a]	2.06[b]	0.046	NS	***
July Bodyweight (kg)	461	465	456	9.2	461	460	6.4	NS	NS
ADG (May-Sept) kg day^{-1}	1.17	1.18	1.15	0.033	0.96[b]	1.36[a]	0.027	NS	***

[a-b] Least square means within rows with different superscripts differ ($P< 0.05$) from each other
[1] TDMI= total dry matter intake

Conclusion

In May, despite having a similar ADG, HF steers had a higher DMI than AA steers, with Low AA steers having a less aggressive grazing behaviour than High AA and HF animals, by July no differences existed between genotypes for DMI or grazing behaviour across pasture treatments. Concentrate supplementation late in the grazing season increased DMI significantly and contributed to increased ADG for each genotype. This allowed PC steers to maintain early season growth rates into the late season despite declining pasture quality.

Acknowledgements

Funding from the Irish Department of Agriculture, Food and Marine Research STIMULUS research grant DAIRY4BEEF is gratefully acknowledged.

References

Ashfield, A., M. Wallace, M. McGee, and P. Crosson. 2014. Bioeconomic modelling of compensatory growth for grass-based dairy calf-to-beef production systems. The *Journal of Agricultural Science,* **152(5):**805-816.

Clarke, A. M., M. J. Drennan, M. McGee, D. A. Kenny, R. Evans, and D. Berry. 2009. Intake, growth and carcass traits in male progeny of sires differing in genetic merit for beef production. *Animal,* **3(6):**791-801.

Finneran, E., P. Crosson, P. O'kiely, L. Shalloo, D. Forristal, and M. Wallace. 2012. Stochastic simulation of the cost of home-produced feeds for ruminant livestock systems. *The Journal of Agricultural Science,* **150(1):**123-139.

Norbu, N., P. Alvarez-Hess, B. Leury, M. Wright, M. Douglas, P. Moate, S. Williams, L. Marett, J. Garner, and W. Wales. 2021. Assessment of RumiWatch noseband sensors for the quantification of ingestive behaviors of dairy cows at grazing or fed in stalls. *Animal Feed Science and Technology*, **280**:115076.

Developing a vertically integrated dairy-beef programme

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Application

Vertical integration between the dairy and beef sectors will be crucial in ensuring the sustainability of the agriculture industry in the future.

Introduction

The rapid expansion of the dairy industry and the greater numbers of dairy beef calves born on dairy farms requires increased dairy beef integration between the dairy and beef sectors. The number of mating's of beef sires to dairy dams not needed to generate replacements has increased exponentially in recent years with research showing greater carcass value from beef x dairy crosses compared with purebred dairy or dairy x dairy crosses (Berry *et al.*, 2018). The Dairy Calf-to-Beef Action Plan has been developed in alignment with Food Vision 2030 which aims to promote greater integration between the dairy and beef sectors, particularly the production of beef from the dairy industry. To address the need for new rearing models for dairy beef calves, Teagasc developed the EveryCalf project in conjunction with commercial rearing farms to monitor the performance and profitability of dairy calf to beef systems.

Materials and methods

In Spring of 2024 six contract rearers across Ireland (Meath, Cork, Kerry, Tipperary, Sligo and Donegal) opted to take part in the project which involved rearing spring born calves for approximately 18 months until the end of the second grazing season. Contract rearers received between 48 and 180 calves depending on farm capacity from five Teagasc dairy research farms (Moorepark, Dairygold, Clonakilty, Curtins and Solohead). All calves remained in the ownership of Teagasc but were transferred in to the contract rearers herd. The first load of calves was transported at the end of February with the last load transported by the second week of May. Calves were transported at a minimum of 3 weeks of age contingent to meeting set health, welfare and performance criteria. Calves were sired by Aberdeen Angus, Aubrac, Belgian Blue, Hereford, Holstein Friesian, Limousin and Simmental AI and Angus stock bulls. The aim of the present study was to assess the performance to date of 2024 born dairy beef calves across 6 contract rearer's. Mean birth weight of calves was 36kg, calves were moved at 32 days of age on average and at a transport weight of 54kg to the rearing farms. The mean commercial beef value of all 2024 calves, dairy calves and dairy beef calves was €74, €33 and €87 respectively. Calves were weighed by ICBF technicians on each farm at turnout (mean weigh date: 25/05) and during mid-summer (mean weigh date: 28/07). All farmers are paid per/kg of liveweight gain achieved following each weighing. Weight data was available for 679 calves at turnout and 616 calves at mid-summer across six farms. All statistical analyses were performed using SAS 9.4 software. Average daily gain (ADG) from transport to turnout and turnout to mid-summer were determined using the PROC Means procedure in SAS. Average daily gain values from birth values were checked for normality using the Shapiro Wilk statistic and graphical outputs obtained with PROC UNIVARIATE. Average daily gain values from birth were analysed using mixed models (PROC MIXED) with rearer farm, calf sex, calf breed and CBV category (least, intermediate, greatest) included in the model.

Results

In total 696 calves were enrolled in the project. The predominant calf breed enrolled in the project was AAX (n =379). The breed composition of the 2024 calves is 26% dairy (Holstein Friesian, Holstein Friesian cross (FRX), and Jersey Cross (JEX)) and 74% dairy beef crosses (primarily Aberdeen Angus (AAX), but also including Aubrac (AUX), Belgian Blue (BBX), Hereford (HEX), Limousin (LMX), and Simmental (SIX). Calves were weaned on the contract rearers farm at approximately nine weeks of age or 85kg whereupon each calf was eating 1kg of concentrates daily. Average daily gain for male and female calves was similar at turnout (0.57 vs 0.56kg) and during mid-summer (0.60 vs 0.57kg). Overall mortality rates to date for 2024 born calves is 4.3%. Average daily gain from transport to turnout and from turnout to mid-summer ranged from 0.44 to 0.70kg and 0.37 to 0.89kg across the 6 farms. Average daily gain based on sire breed range from 0.42 to 0.70 at turnout and 0.32 to 0.71 kg during mid-summer (Table 1). Average daily gain from birth was not affected by CBV Category ($P = 0.62$) and calf breed ($P = 0.54$). A significant effect of calf sex ($P = 0.003$) on ADG was observed, male calves had slightly higher ADG than female calves (0.61kg vs 0.57kg). Average daily gain was significantly affected by rearer farm ($P < 0.0001$) with a range of 0.42 to 0.74kg from birth observed across the six farms (Figure 1).

Table 1. Range in ADG based on sire breed at turnout and during mid-summer

Sire Breed	ADG from transport to turnout(kg/day)	ADG from turnout to Mid-Summer (kg/day)
AA	0.54	0.52
AU	0.65	0.60
BB	0.50	0.32
FR	0.66	0.71
HE	0.63	0.45
HF	0.46	0.54
JE	0.70	0.56
LM	0.55	0.41
NR	0.42	0.57
SI	0.54	0.62

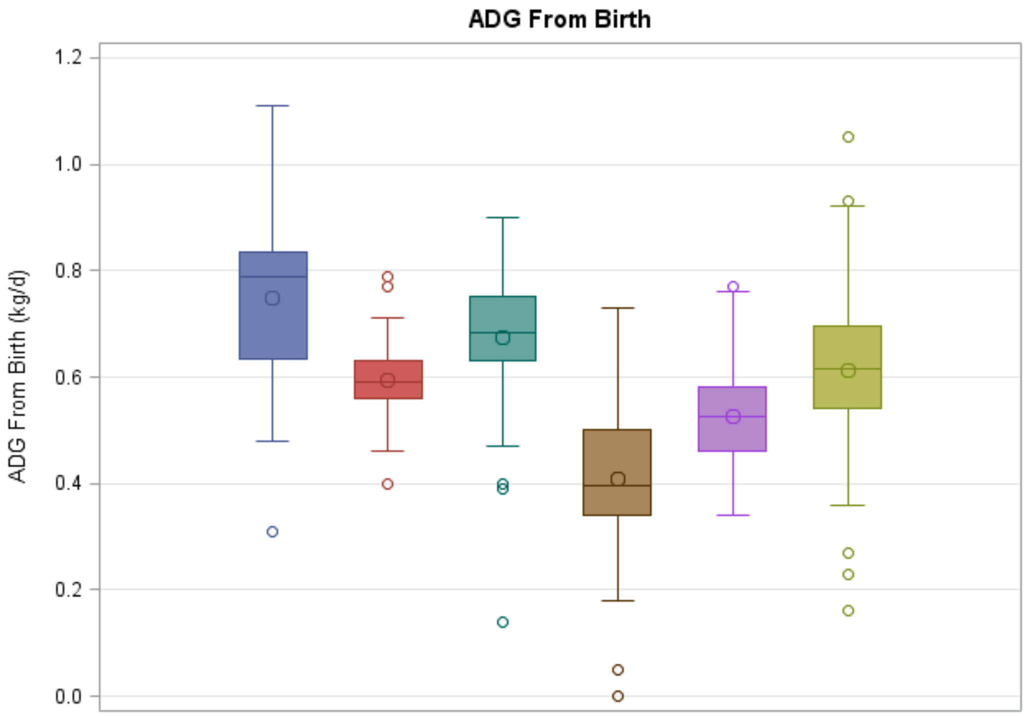

Figure 1. *ADG from birth across the six contract rearing farms*

Conclusions

The 2024 calves will continue to be monitored through the winter and until the end of next year's grazing season when all animal will be moved to a finishing unit. Contract rearing offers non-dairy farmers the opportunity to implement an alternative farming system, with the assurance of receiving a fixed payment for their land, labour, and management efforts, tied to their performance. For dairy farmers contract rearing reduces the need for additional infrastructure and labour by moving animals off site at a young age allowing them to focus on managing the main herd while also generating cash flow. The program will help optimise dairy beef calf performance and welfare while also improving the profitability of this system of production and will highlight the impact of CBV on animal performance. The preliminary results from 2024 highlight the importance of grassland management, health and welfare on commercial farms in order to deliver optimum animal performance. The program will also improve integration between the dairy and beef sectors by establishing a framework to create connections between dairy and beef farms.

Acknowledgements

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References

Berry, D.P., Judge, M.J., Evans, R.D., Buckley, F. and Cromie, A.R., 2018. Carcass characteristics of cattle differing in Jersey proportion. *Journal of Dairy Science*, **101(12):** 11052-11060.

Effect of conserved forage type and animal maturity on dry matter intake and growth of dairy-beef heifers during the first winter indoor period

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Application

The results of this study demonstrate that across all sward types early maturing genotypes achieved higher dry matter intakes (DMI) and daily growth rates, than their late maturing counterparts. Swards of increased diversity increased DMI but not necessarily animal growth during the indoor period. Feed intake and bodyweight gain differences contribute to the feed and environmental cost of dairy-beef production.

Introduction

The contribution of dairy-beef to the total number of cattle slaughtered in Ireland now stands at approximately 60%, and is increasing. An increasing percentage (>50%) of dairy calf registrations are now to a beef sire facilitated by the increasing use of sexed semen on the dairy herd. However, there continues to be a decline in the beef merit of the dairy cow herd (Mulhall *et al.*, 2023), and that of dairy and beef x progeny destined for beef production (Kelleher *et al.*, 2024). Beef x dairy animals are more feed efficient than dairy x dairy animals, and within beef breeds late maturing animals offer greater feed efficiency than early maturing (McGee, 2015). Animals of higher feed efficiency have been established to have lower methane emissions and a lower carbon footprint and the use of more efficient breed types can contributed to reduced agricultural emissions (Fitzsimons *et al.*, 2013). This has led to increased interest in late maturing breeds for use in the dairy herd to counteract this reduction in traits of significance for beef production. This study looked at the impact of offering three contrasting conserved forages over the first winter indoors, on the dry matter intake (DMI) and bodyweight (BW) performance of early and late maturing dairy-beef heifers.

Materials and methods

One hundred and twenty six dairy-beef heifers sired by high carcass merit early or late maturing beef sires and bred from Holstein Friesian dams were enrolled in this study. Calves were sired by Angus and Hereford (Early maturing) or Limousin and Belgian Blue (Late maturing) AI sires. All calves were purchased from commercial dairy farms at ~21 days of age and were reared commercially before being assigned to one of three sward types for the first grazing season (June – October). The three sward types were (i) perennial ryegrass only (PRG); (ii) PRG + clover (CL) and (iii) multispecies sward consisting of PRG, clover, plantain and chicory (MSS). Post-arrival calves were rotationally grazed on a pasture only diet over most of their first grazing season receiving 1 kg of concentrate from mid-September to housing in mid-October. Forage was harvested and conserved from each of the three sward types. At housing calves were offered silage *ad libitum* from their respective sward treatments in addition to 1.5 kg fresh weight of concentrate.

This study was conducted over 72 days from November 2023 until February 2024 at Teagasc Johnstown Castle. Upon housing, calves were assigned to pens which were balanced by sward type and sire breed type, three replicates per sward type and sire breed type (maturity) combination (3 x 2 factorial design), with pen being the experimental unit. Seven animals were accommodated in each pen on a concrete slatted floor surface. Silage was offered fresh daily to 110% of animals expected intake, with refusals weighed twice weekly and disposed of once weekly. Concentrates were offered once daily at 1.5 kg fresh weight. Samples of forage were taken twice weekly for dry matter (DM) and chemical composition analysis. Animals were weighed fortnightly to measure average daily gain (ADG). Statistical analysis was conducted using a linear mixed model in SAS (version 9.4; SAS Institute Inc., Cary NC), with sward type and sire breed type as fixed effects.

Results

There was an interaction between sward type and sire breed type for ADG during the measurement period. While Early maturing heifers performed similarly on all forages produced, Late maturing heifers fed CL had an increased ADG (+0.08 kg), compared to PRG and MSS, which was similar to that of Early heifers across all forage types.

Forage type had an effect on total DMI, with animals offered both CL and MSS swards having a daily DMI 0.4 and 0.35 kg higher than PRG. Early maturing heifers had a higher DMI (0.6 kg DM/day) ADG (+0.08 kg) and BW (+8 kg) compared to Late maturing counterparts. Despite differences in DMI and BW, when DMI is expressed as a % of body weight a similar DMI was achieved for Early (2.45%) and Late (2.36%) maturing animals.

As well as higher DMI, Early heifers had higher ADG (+0.08 kg) and BW (+8 kg) compared to Late heifers who achieved an ADG of 0.81 kg, building on their BW advantage established over the first grazing season..

Table 1. Effect of sward type and sire breed type on dry matter intake and bodyweight (BW) gain

Sward type	PRG		CL		MSS		SE	Sward (S)	Sire breed type (B)	S*B
Sire breed type	Early	Late	Early	Late	Early	Late				
Start BW, kg	205	196	207	204	221	214	3.3	<0.001	0.036	0.558
DMI, kg DM	5.8	5.3	6.2	5.8	6.2	5.7	0.11	<0.001	<0.001	0.877
ADG, kg	0.89	0.78	0.89	0.87	0.90	0.79	0.022	0.143	<0.001	0.069
End BW, kg	278	267	280	279	295	282	2.4	<0.001	<0.001	0.046

Conclusions

From the data gathered over the first winter indoors, it can be seen that irrespective of sward type high ADG's were achieved. Sire breed type can influence the DMI and ADG from conserved forages fed indoors, which is likely to differences in the environmental footprint and cost of beef production. Future work will establish the grazed DMI of heifers at pasture, methane emissions and carcass performance at contrasting slaughter ages of these heifers.

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References

Fitzsimons, C., D. Kenny, M. Deighton, A. Fahey, and M. McGee. 2013. Methane emissions, body composition, and rumen fermentation traits of beef heifers differing in residual feed intake. *Journal of Animal Science* **91(12):**5789-5800.

Kelleher, M., J. McCarthy, K. Downing, and R. Evans. 2024. The Commercial Beef Value (CBV): Potential catalyst for change. In: M. McGee and P. Crosson, editors, BEEF 2024 "Securing Your Future". Teagasc. p. 184.

Fitzsimons, C., D. Kenny, M. Deighton, A. Fahey, and M. McGee. 2013. Methane emissions, body composition, and rumen fermentation traits of beef heifers differing in residual feed intake. *Journal of Animal Science,* **91(12):**5789-5800.

McGee, M. 2015. Feed efficiency in beef finishing systems. *Irish Grassland Association Journal*, **49:**97-105.

Mulhall, S., R. Sleator, R. Evans, and A. Twomey. 2023. Genetic and phenotypic trends for carcass traits in Irish beef cattle. *Irish Journal of Agricultural and Food Research,* 1-14. DOI: 10.15212.

Slaughter performance of dairy-beef offspring derived from artificial insemination or in vitro-produced beef breed embryos

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Application

Animals with a greater proportion of beef genetics have the potential to have greater performance at slaughter and result in greater return for the producer.

Introduction

The number of in vitro produced (IVP) embryos transferred worldwide has surpassed 1.2 million in recent years (Viana, 2023). Despite their widespread use, limited data have been collected to investigate phenotypic performance of animals derived from in vitro-produced embryos later in life. The objective of this pilot study was to compare the slaughter performance of cattle derived from IVP embryos that had ≥75% beef breed genetics with cattle derived from artificial insemination (AI) with 50% beef breed genetics

Materials and methods

The oocytes used to generate the IVP embryos were collected from the ovaries of beef-cross heifers immediately post slaughter. Heifer pedigree was known before slaughter and consisted of Angus x Holstein-Friesian heifers (n = 90), Limousin x Holstein-Friesian heifers (n = 18) and other beef x dairy crossbreeds (n = 11). Oocytes were matured in vitro for 24 hours and subsequently fertilized in vitro with frozen thawed semen from one of two proven high fertility beef bulls (Limousin, LM; n = 1; Angus, AA; n = 1). Presumptive zygotes were cultured in vitro for 7 days, and resulting blastocyst-stage embryos were transferred fresh to synchronized recipients or frozen for transfer at a later date. Recipient lactating dairy cows were located in two herds (n = 214), and were synchronized using a 10-day Progesterone-OvSynch protocol. Cows received timed AI (n = 46) at the time of synchronized ovulation on Day 0 or received embryo transfer (ET) with a single Grade 1 blastocyst (fresh, n=80 or frozen, n=88) on Day 7 (n = 168). Timed AI was carried out with frozen thawed semen using one of the two same beef breed bulls that were used to generate the IVP embryos. During January and February 2022, 86 calves were born and reared on the birth farm until they were transported to two separate rearing farms where they remained until slaughter. Slaughter took place between September and December 2023, at 22.5 ± 1 months of age (mean ± SD). Complete slaughter data and Commercial Beef Value (CBV) data were available for 66 animals. Carcass grade and fat scores were converted to 15-point numeric scales. Slaughter data were analysed separately for AA and LM to determine the effect of treatment (AI vs ET) on slaughter weight, carcass weight, carcass grade and fat score.

Results

Treatment effects on slaughter weight and carcass weight were determined using generalised linear mixed models in SAS, with treatment, farm and sex included as fixed effects. The effect of treatment on carcass grade and fat score was analysed using a one way non-parametric test. The AA and LM dataset comprised of animals derived from AI (AA; n = 8, LM; n = 14) and ET (AA; n = 41, LM; n = 3). The CBV was less for animals derived from AI compared with animals derived from ET (AA: €105 vs €161, respectively P < 0.0001; LM: €149 vs. €185, respectively P = 0.02). Slaughter weight was not different between animals derived from AI or ET (AA: 523 kg vs 542 kg, respectively, P = 0.39; LM: 571 kg and 594 kg, respectively, P = 0.69). Carcass weight was not different between animals derived from AI or ET (AA: 261 kg vs 275 kg, respectively, P = 0.25; LM: 295 kg vs 306 kg, P = 0.74). Carcass grade was greater for AA animals derived from ET compared to those derived from AI (6.5 vs 5.5, P = 0.02) but was not different for LM animals derived from AI or ET (6.5 vs 7.0, P = 0.81). Mean fat score was not different for animals derived from AI or ET (AA: 8.3 vs 7.8, respectively, P = 0.25; LM: 7.2 vs 8.0, respectively, P = 0.51). Meat factory specifications for beef carcasses include minimum criteria for grade (minimum O=), fat score (2+ to 4=) and weight (≥280 kg). 61.3 % of ET derived animals (AA: 58.5%, LM: 100%) and 40.9% of AI derived animals (AA: 12.5%, LM: 57.1%) were within the specifications set out by processors

Conclusions

In conclusion, CBV was greater for animals derived from ET compared with animals derived from AI for both AA and LM breeds. At slaughter, carcass grade was greater for AA cattle derived from ET compared with AA cattle derived from AI. Numerical improvements in carcass weight, carcass grade, carcass fat score and percentage of animals 'in-spec' were observed, but statistical differences were not detected due to inadequate statistical power. Additional research with a more diverse panel of sires (for IVF and AI) and greater numbers of animals reared to slaughter is warranted.

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References

Viana, J. 2023. Statistics of embryo productoin and transfer in domestic farm animals. Embryo Technology Newsletter **41 (4):**20 -39.

Notes

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