Sustainable and responsible breeding and reproductive programs

Stephen Butler[1], Siobhan Ring[2] and Donagh Berry[1]

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

Summary

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

Introduction

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

The Economic Breeding Index (EBI)

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

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

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

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

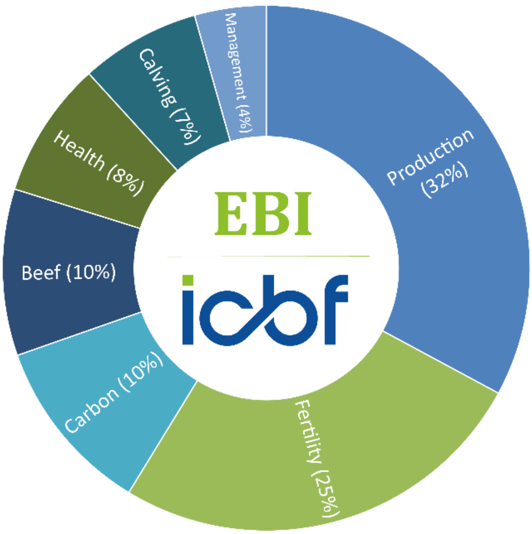

Figure 1. *Relative emphasis of each sub-index within the current EBI*

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

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

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

Beef-on-dairy breeding strategies

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

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

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

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

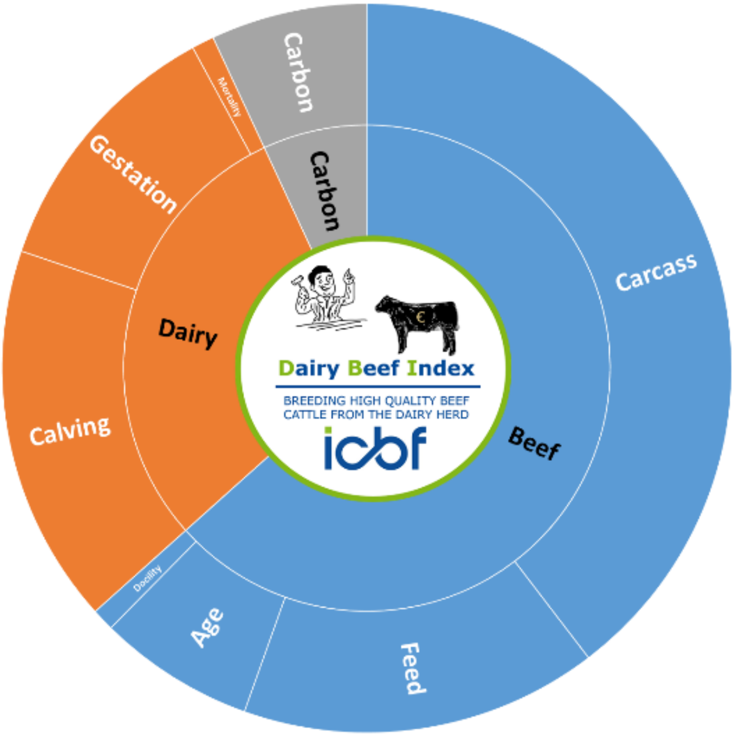

Figure 2. *Relative emphasis of the current DBI*

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

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

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

Sexed semen

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

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

Strategies for using sex-sorted semen

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

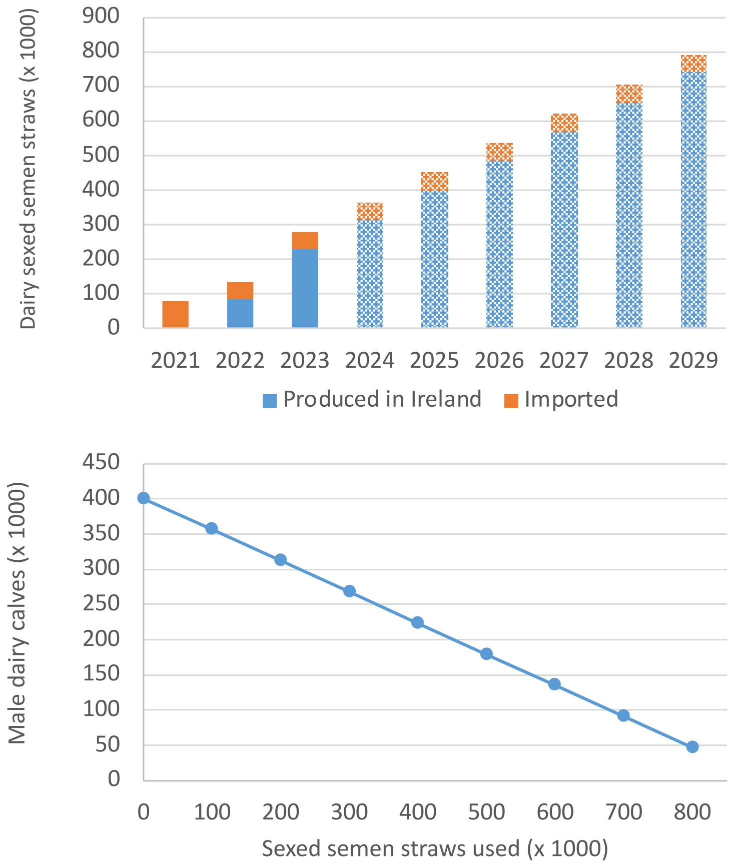

Figure 3. *Top panel: approximate figures for sexed semen source and usage during 2021 to 2023 (solid bars) and projection for potential usage in the years 2024 to 2029 (hatched bars). Bottom panel: relationship between the number of dairy sexed semen straws used and the number of male dairy calves born*

Sire and dam choice

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

When to use?

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

Timing of AI

- 14 to 20 h after heat onset

Fixed time AI

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

Straw handling on day of AI

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

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

Future innovations

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

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

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

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

Conclusions

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

Appendix 1 - Dairy Breeding Guidelines

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

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