Sustainable breeding — what are the options?

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Summary

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

Introduction

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

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

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

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

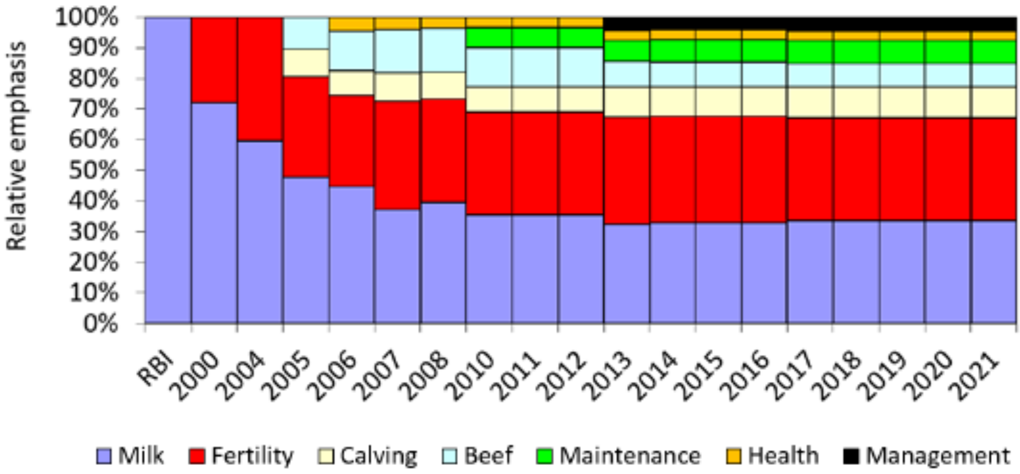

Figure 1. *Relative emphasis on different subindexes within the EBI as it evolved over the last 20 years since replacing the Relative Breeding Index (RBI)*

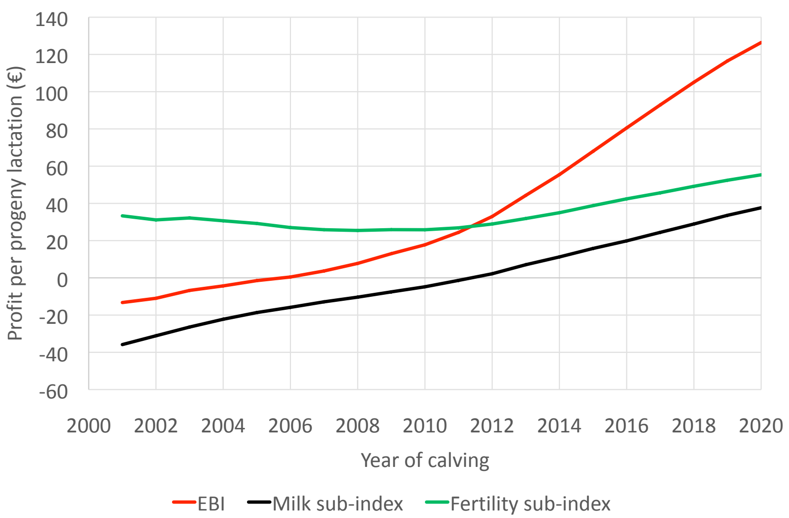

Figure 2. *Mean genetic merit of the Irish dairy cow population by year of calving for EBI and both the milk and fertility sub-indexes*

Selection for increased milk solids

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

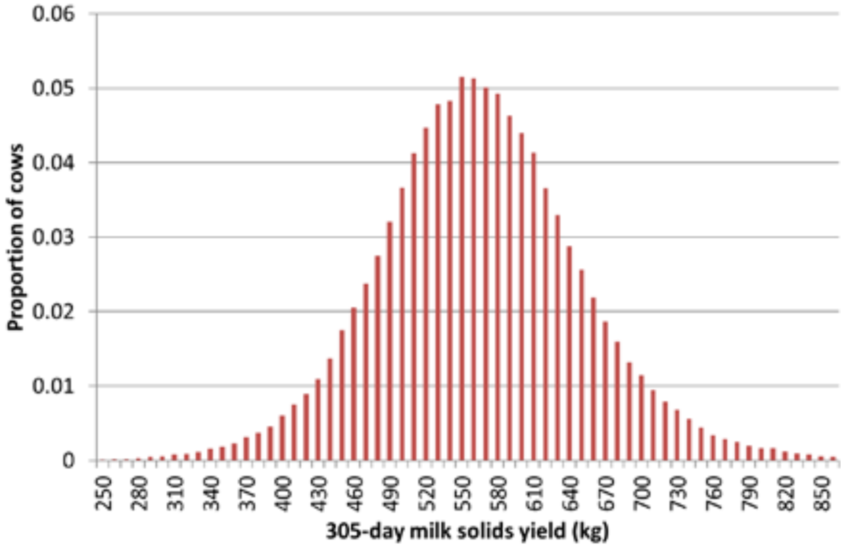

Figure 3. *Distribution of mature equivalent 305-day milk solids yield for cows with a genetic merit for milk solids yield of between 18 and 22 kg*

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

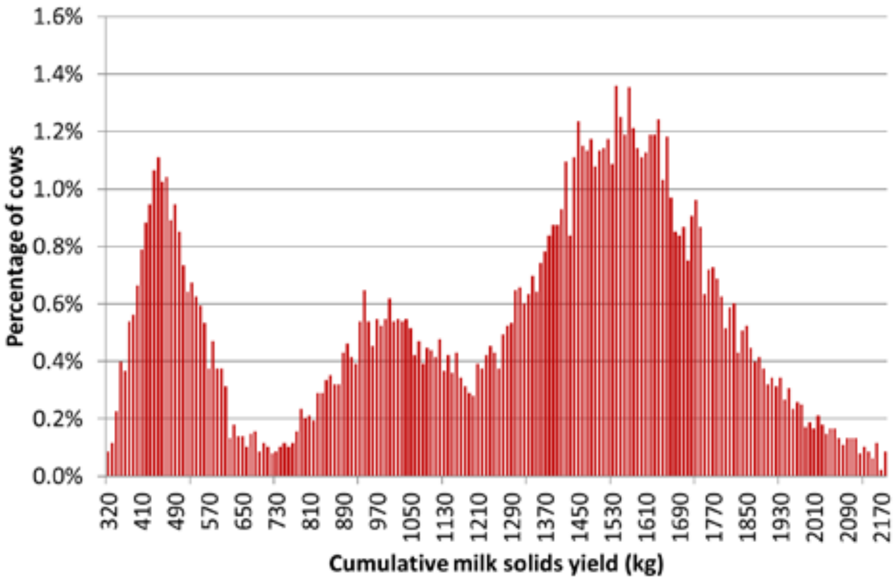

Figure 4. *Lifetime milk solids yield for cows with a genetic merit (i.e., PTA) for milk solids yield of ~20 kg all given the opportunity to produce for three lactations*

Crossbreeding with Jersey — is it still worthwhile?

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

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

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

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

Dairy-beef index

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

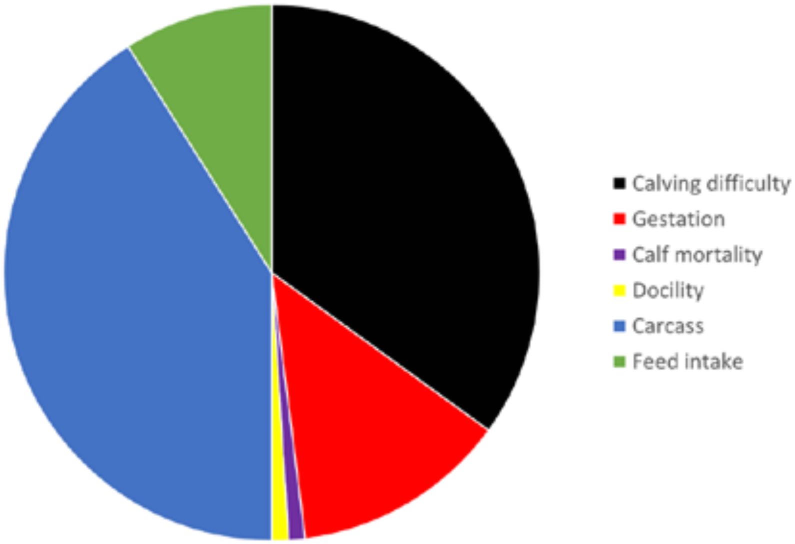

Figure 5. *Relative emphasis on the component traits of the dairy beef index*

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

Reproductive technologies to solve problems in the dairy industry

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

Sexed semen

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

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

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

In vitro produced embryos

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

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

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

Conclusion

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