Decision support tools to support a more sustainable beef -on-dairy industry

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Abstract
The global agri-industry is challenged with improving sector sustainability. Cattle production systems are not exempt, especially as dairy cow genetic merit becomes more specialized for dairy production, often to the determinant of beef value. Using national measures of genetic merit, the Irish industry has developed and deployed three interdependent strategies to complement the sustainable productivity and profitability of the dairy and beef sectors. The first tool, the Dairy Beef Index (**DBI**), was developed to identify genetically elite beef bulls for mating to dairy females with the goal of simultaneously improving calving performance and beef merit. Adoption of the DBI will be incentivized through 1) sire mating advice to aid in mating decisions and 2) a *Commercial Beef Value* per animal to aid beef producers in valuing cattle.

Introduction
Dairy cow reproductive performance in Ireland has progressively improved reducing the requirement for replacement dairy females and, in turn, create an opportunity to increase surplus calf value. Consequently, the frequency of mating beef sires with dairy females has increased 10% in the previous five years, a trend expected to continue. Beef sire selection by dairy producers has traditionally focussed on breed, easy expected calving, and short expected gestation length. The antagonistic genetic correlation between calving performance and beef merit will contribute to a progressive deterioration in beef merit of the beef sires available. Therefore, decision support tools are required to 1) identify suitable beef sires for mating with dairy females that possess both desirable calving and beef attributes, 2) recommend optimum matings of beef bulls with dairy females taking cognisance of genetic and phenotypic characteristics of the female, and 3) value surplus cattle destined for slaughter. These three tools must be inter-dependent in that suitable beef bulls must be available from which to suggest the recommended matings and the value of the resulting progeny must, on average, reflect the expected value at the time of mating. Combined, these decision support tools will help to improve the profitability and sustainability of the intrinsically linked dairy and beef systems. The objective here is to provide an overview of these decision support tools which can be relatively easily extended to other jurisdictions.

Materials & Methods
Measures of genetic merit for calving, beef, and docility performance traits (Evans, 2007, 2008, 2009, 2020) from the national multibreed genetic evaluations were available to construct each of decision support tools.

Dairy Beef Index. The DBI was derived to rank beef bulls for mating to dairy females (Berry et al., 2019) as:
DBI = direct dystocia + direct gestation + mortality + feed intake + carcass weight + carcass conformation + carcass fat + desirable carcass specification + docility + polledness

where each trait was a function of the sire's predicted transmitting ability (PTA) multiplied by the economic value and cumulative discounted genetic expression (Berry et al., 2019). The economic value applied to direct dystocia was non-linear (Berry et al., 2019) whereby bulls with a higher dystocia PTA were penalised more severely.

Mating Advice. The mating advice decision support tool ranks matings between each member of a team of beef bulls (selected by the dairy producer) to each dairy female in a herd where easier calving bulls are more favoured towards females more prone to calving difficulty while also considering the carcass merit of the bull to correct the deficiencies in carcass merit of the female (e.g., very light, poor conformation). Each sire x female mating receives an index based on the expected profit of the resulting progeny as:

$INDEX = CALVING + (1\text{-}Pred_{MORT\_BIRTH}) \times POLLED + (1\text{-}Pred_{MORT\_FINISH}) \times BEEF$

where $Pred_{MORT\_BIRTH}$ is the predicted calf mortality at birth based on the phenotypic mean of the base population plus the sum of the PTA for perinatal morality of both parents, $Pred_{MORT\_FINISH}$ is simply $Pred_{MORT\_BIRTH} + 0.03$ where the 0.03 is the mean mortality from birth until slaughter and POLLED is the economic value of whether or not the beef bull is polled. The CALVING and BEEF components of the index are described as:

$CALVING = Pred_{dystocia} \times COST_{dystocia} + Pred_{gestation} \times COST_{gestation}$

$BEEF = Pred_{CARCASS} \times PRICE_{CARCASS} + Pred_{docility} \times EW_{docility} + Pred_{feed\ intake} \times EW_{feed\ intake} + breed\_bonus$

The prediction of dystocia ($Pred_{dystocia}$) considers the direct PTA of the parents for dystocia plus twice the female's maternal PTA for dystocia all estimated from the national genetic evaluations. Non-linearity in the economic impact of calving difficulty is accounted for. Prediction of gestation length ($Pred_{gestation}$) is simply the sum of the parental direct PTAs. The prediction of carcass and carcass price per kg is a function of the expected EBV of the progeny for carcass weight, conformation and fat score individually but also includes a penalty if the resulting carcass does not adhere to abattoir carcass specifications for carcass weight and conformation. Predictions for docility and feed intake are based on the sum of the parental PTAs; a breed bonus was applied to Angus and Hereford bulls.

Commercial Beef Value. The Commercial Beef Value (**CBV**) values cattle for slaughter (Dunne et al., 2021) as:

$CBV = carcass\ weight + carcass\ conformation + carcass\ fat + docility + feed\ intake$

where each trait was a function of the animal's estimated breeding value multiplied by the economic value and cumulative discounted genetic expression; non-genetic effects are likely to be added to the CBV in later versions.

Results & Discussion

Growing consumer awareness of farming practices has strengthened the need to re-examine the inter-dependency between the dairy and beef sectors. Assuming 20-25% of calves born in the dairy herd are required as replacements, approximately 75-80% of calves are destined for slaughter; of the latter in Ireland, many are purchased <6 weeks old, weaned, and finished typically at 22-24 months of age by beef producers. Because dairy farmers are often not directly impacted by the sale value of the animal at slaughter, this can lead to a lack of consideration and appreciation of the importance of beef bull selection. In addition, the purchaser of the resulting calf <6 weeks of age cannot have any great knowledge of the carcass potential of the animal at such a young age. The decision support tools outlined here should incentivise stakeholders to work in unison towards the same common goal, a sustainably profitable dairy beef system. All data flowing into these tools originate from the one source, the ICBF database.

The ICBF database maintains and utilises data from an array of sources including farmers, abattoirs, marts etc.; all data used in these decision support tools are updated bi-monthly as additional phenotypes become available; decision support tools are also updated.
The DBI rewards bulls that produce a live calf with minimal calving assistance following a short gestation; docile, polled progeny that attain an acceptable carcass weight and both a desirable carcass conformation and fat grade are also favoured. The ability of this index to deliver phenotypically has been validated (Berry and Ring, 2020). The mean DBI for some beef breeds are provided in Figure 1. The Dairy Beef Index is comparable across beef breeds since the genetic evaluations used to develop the index are based on a multibreed population where all beef breeds are included in the same genetic evaluation. The DBI has highlighted the desirability of some breeds which would not traditionally have been used in dairy herds (e.g., Aubrac, Saler).

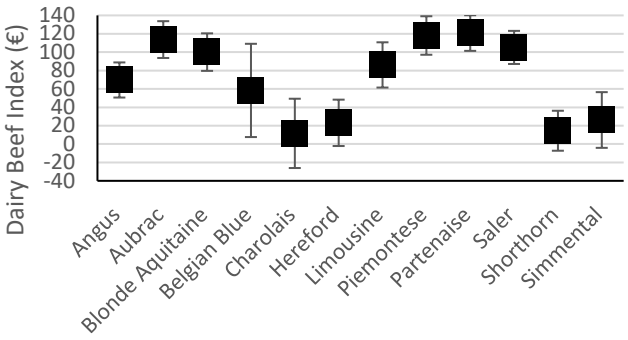

Figure 1. Mean and SD (at each side of SE bar) Dairy Beef Index value for the main beef breeds used in Ireland.

Although dairy producers remain cautious on selecting beef bulls that are acceptable on calving performance, the beef merit of beef bulls used in dairy herds has improved since the inception of the DBI, and this has also translated to a favourable change in CBV trends; trends in DBI and CBV pre and post the DBI launch are in Figure 2. Future versions of the DBI are likely to consider meat eating quality, animal health, age at slaughter and direct measures of methane.

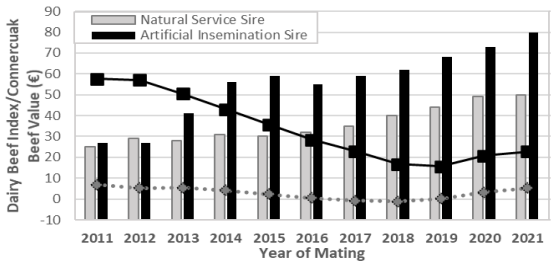

Figure 2. Trend in Dairy Beef Index (columns) and Commercial Beef Value (markers) for natural service sires and artificial insemination sires pre and post the availability of the Dairy Beef Index in 2019.

The framework of the sire mating advice algorithm is built on that of the DBI thus exploiting the gains in beef seedstock producing cattle of increasing DBI. Dairy producers must first select a team of beef bulls with a separate team selected for heifers and cows; the maximum usage per bulls is inputted. Future versions will recommend a bull team and usage. Using the sire advice, an older cow with good direct and maternal genetic merit for dystocia may be allocated the

more difficult of the bulls in the team in the pursuit of achieving a better calf value through improved carcass credentials. The producer decides which females are to be served to dairy bulls, beef bulls, and which females are to be culled (and not bred) based on the COW index (Kelleher et al., 2015); it is common practice in Irish dairy herds to use dairy semen for the first 6 weeks of the 15-week breeding season after which beef bulls are used. The sire mating advice program mates each bull in the team to each female; the three sub-herds are treated separately so that the intended proportional representative use of bulls should be close to the eventual usage in 1) heifers, 2) cows that the farmer has indicated should be served with a beef bull, and 3) all other cows which are not destined to be culled. An index value for each candidate bull x female combination is generated within a sub-population; then linear programming is used to maximise the expected index value of the resulting progeny within the constraints of the desired proportional representation of each bull. A check is also included to avoid some predefined matings like those which might result in very difficult calvings; this is at the discretion of the user. Some 8,000 dairy herds (out of a total of 17,000 nationally) already use sire mating advice to rank dairy bulls for use on dairy females; the user interface for the beef-on-dairy mating system is close to a mirror representation of the dairy-on-dairy sire advice. The output to the farmer is a user-friendly report which identifies the female and the three highest ranked bulls on the index. Users can save the results for their own use as well as onto their AI technicians handheld, enabling the immediate identification of preferred bull by technicians on the day of service.

Potential purchases need a reliable method of identifying profitable progeny from the beef-on-dairy matings. Assuming no/minimal market failure, this should logically facilitate higher market demand for the seller thus encouraging the dairy producer to use more elite beef bulls and closing the loop. The Commercial Beef Value was developed to support decisions on how much to pay for a calf destined for prime beef production. Dunne et al. (2021) validated that knowledge of the breed and Commercial Beef Value of the animal was a better indication of than knowledge of the animal breed alone. Each of these decision support tools should have a substantial impact on the future sustainability of both dairy and beef sectors alike; methods applied in the present study can be replicated in other jurisdictions to improve the profitability of beef progeny originating from the dairy herd.

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