CSIRO PUBLISHING

Animal Production Science, 2012, **52**, 172–179
http://dx.doi.org/10.1071/AN11166

Invited Perspective

Industrial perspective: capturing the benefits of genomics to Irish cattle breeding

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Abstract. Genomics is a technology for increasing the accuracy with which the genetic merit of young potential breeding animals can be determined. It enables earlier selection decisions, thus reducing generation intervals and gives rise to more rapid annual rates of genetic gain. Recently, the cost of genomics has reduced to the point where it enables breeding-program costs to be reduced substantially. Ireland has been a rapid adopter of genomics technology in its dairy-cattle breeding program, with 40% of dairy-cow artificial inseminations in 2010 being from bulls evaluated using genomic information. This rapid adoption has been facilitated by a comprehensive database of phenotypes and genotypes, strong public funding support for applied genomics research, an international network of collaborators, a short path between research and implementation, an overall selection index which farmers use in making breeding decisions, and a motivated and informed breeding industry. The shorter generation interval possible with genomic selection strategies also allows exploitation of the already accelerating rate of genetic progress in Ireland, because elite young dairy bulls are considerably superior to the small numbers of bulls that entered progeny test 6 years ago. In addition, genomics is having a dramatic impact on the artificial-insemination industry by substantially reducing the cost of entry, the cost of operation, and shifting the focus of breeding from bulls to cows. We believe that the current industry structures must evolve substantially if Irish cattle farmers are to realise the full benefits of genomics and be protected from related risks. Our model for future dairy breeding envisages a small number of 'next generation research herds', 1000 'bull breeder herds' and an artificial-insemination sector using 30 new genomically selected bulls per year to breed the bulk of replacements in commercial milk-producing herds. Accurate imputation from a low-density to a higher-density chip is a key element of our strategy to enable dairy farmers to afford access to genomics. This model is capable of delivering high rates of genetic gain, realising cost savings, and protecting against the risks of increased inbreeding and suboptimal breeding goals. Our strategy for exploiting genomic selection for beef breeding is currently focussed on genotyping, using a high-density chip, a training population of greater than 2000 progeny-tested bulls representing all the main beef breeds in Ireland. We recognise the need for a larger training population and are seeking collaboration with organisations in other countries and populations.

Received 5 August 2011, accepted 7 February 2012, published online 6 March 2012

Introduction

Over the past 13 years, Ireland has established a new infrastructure to facilitate the genetic improvement of both dairy and beef cattle. Prime responsibility for leading the development rests with the Irish Cattle Breeding Federation Society Ltd (ICBF), Shinagh, Bandon, County Cork, Ireland, established in 1997 with the objective of achieving the greatest possible genetic improvement in the national cattle herd for the benefit of Irish farmers, the dairy and beef industries, and members. This development has been funded by a unique partnership involving farmers, breeders, service providers and government.

In the present paper, we outline our strategy for ensuring the Irish dairy and beef cattle-breeding industry is able to benefit to the greatest possible extent from developing genomic technologies. The present paper deals with our research strategy, our implementation strategy, progress made so far, and how our industry needs to change in the future if it is to fully benefit from current and future developments in genomic technologies.

Irish cattle industry

The Irish cattle industry is based on 2 million calvings per year, with 1.1 million in dairy herds, from predominately Holstein–Friesian cows, and 0.9 million in beef suckler herds. The industry involves a large amount of cross-breeding, with 38% of dairy-cow calvings to beef-sire breeds, mainly Angus and Hereford, and 61% of calvings of suckler cows being to a

beef breed different from the breed of the cow. The five main beef breeds are Charolais, Limousin, Simmental, Angus and Hereford.

Dairy and beef production systems in Ireland are seasonal (Berry *et al*. 2006*a*; Mc Hugh *et al*. 2010). Some 80% of the milk and meat products of the Irish cattle industry are exported into a wide range of international markets.

Industry structure – the formation of ICBF

ICBF was established in 1997 and commenced operations in 1998, with its current structure being finalised in 2000. Its main activities are those associated with developing the cattle-breeding infrastructure in Ireland, operating the cattle breeding database, providing genetic evaluation services, and providing information useful for cattle-breeding decisions.

ICBF is owned by the cattle industry, with 18% of shares held by each of the artificial-insemination (AI), milk-recording (MR) and herd-book (HB) sectors and the remaining 46% held by the organisations representing farmers. The ICBF board of 16 comprises 15 persons appointed by the shareholders and one appointed by the Irish Department of Agriculture Fisheries and Food.

Since its inception, much of ICBF's work has been focussed on improving the quantity and quality of data available for cattle breeding. New technologies have been adopted (Berry *et al*. 2006*b*; Pabiou *et al*. 2011) and business arrangements established with both shareholders and industry stakeholders. The overall goal has been to ensure that Irish farmers have access to high-quality information for use in breeding more profitable cattle.

Since 2008, ICBF and its research partners have made a major commitment to researching and implementing genomic selection in dairy-cattle breeding and are currently extending this effort to beef-cattle breeding.

Breeding and selection criteria

A widespread industry consultation supported by extensive research resulted in an agreed breeding objective and selection criteria for dairy cattle (Veerkamp *et al*. 2000) and beef cattle (Amer *et al*. 2001) in Ireland. The objective in both cases is farm-level profitability by accounting for the most significant sources of income and cost. An overall index, the economic breeding index (EBI), and suckler-beef value, both expressed in economic terms (€), are the selection criteria for dairy and beef, respectively. These overall indexes are built up from several sub-indexes, also expressed in economic terms. Examples are readily available on the ICBF website (www.icbf.com, verified 1 May 2011). A recent well powered study (Ramsbottom *et al*. 2011) relating herd EBI to overall herd profitability across 1131 herd-years on Irish dairy farms clearly showed that profit per lactation was within expectations based on differences in EBI.

ICBF provides the genetic evaluation system for both dairy- and beef-cattle breeding in Ireland. This genetic evaluation system operates in close association with the ICBF database. ICBF is a full participant in the activities of Interbull, the international dairy genetic evaluation organisation and is currently providing leadership for the establishment of Interbeef.

The genetic evaluation system used by ICBF is an across-breed system with a single base for each set of traits. It covers all breeds and crosses of cattle in Ireland and the full range of traits. For some traits (e.g. calving and carcass), the evaluation system uses data from dairy and suckler herds, and the resulting evaluations, in these cases, are comparable across dairy and beef breeds. Strong emphasis is placed on obtaining peer review of the procedures and statistical models used (Olori *et al*. 2002; Crowley *et al*. 2010; Berry *et al*. 2011; Mc Hugh *et al*. 2011; Pabiou *et al*. 2012).

Phenotypes – the ICBF cattle-breeding database

At the time ICBF was formed, there were a large number of separate computer systems. Each had its own data-collection system and supported the information needs of one or other aspects of the cattle-breeding industry. For example, each pedigree breed society HB, of which there were 18 at that time, had its own system, and each MR organisation, of which there were eight in 1998, had its own system. At that time, the Irish Department of Agriculture Fisheries and Food also operated separate systems for genetic evaluations and the official calf-registration and cattle-movement monitoring. These systems used several different animal identifications and held limited cross-references.

ICBF established its cattle-breeding database using a software system from a Dutch cattle-breeding organisation. Creating the database involved an enormous effort to negotiate agreements for the sharing of data, to establish shared-data collection systems and to consolidate the existing computer files into a single shared database. The key principles underpinning the agreement among organisations to share data are summarised in Table 1.

ICBF established a team of information-technology developers, supported by several contractors, to customise the Dutch system to meet the needs of the Irish breeding industry. This customisation has now reached the point where the ICBF database requires no support from suppliers of the Dutch system.

The ICBF cattle-breeding database supports, through the use of a range of new technologies (Cromie *et al*. 2008) the information needs of MR, HB, AI organisations and cattle farmers. Farmers are able to access their own data in the database through the web, or on paper, via a service known as HerdPlus (www.icbf.com, verified 15 February 2012).

This database has and is playing a fundamental role in facilitating the research and implementation of genomic selection in Irish cattle breeding. In all, 90% of all dairy and beef cattle in Ireland are recorded in this database. Table 2 provides a summary of data and data sources included in this system. The database now also stores 13 739 genotyped animals (Table 3), consisting of >2 billion single-nucleotide polymorphisms.

Potential contribution of genomics

Ideally, to locate the most profitable cattle for use in Ireland, we would like to rank all potential selection candidates on the merit of future progeny, irrespective of breed. That is, to rank them on the Irish selection criteria. For an Irish breeder, the

Table 1. Principles of data- and information-sharing agreement underpinning the Irish Cattle Breeding Federation Society Ltd (ICBF) database

No.	Principle
1	Contributors of data to the creation of the database retain 'ownership' and can obtain a copy of their data at any time.
2	All data originating on farm, and known first to the farmer, is captured through a system controlled by ICBF.
3	ICBF operates an industry wide network of systems to facilitate the electronic sharing of relevant data collected for other purposes. Examples include; inseminations, slaughter data and sale data.
4	All data in the database are available for research subject to a minimal set of conditions.
5	Genetic evaluations are an integral element of the database.
6	Herd owners control service provider access to herd and animal data.
7	Service providers have access to data and information systems needed by their particular businesses for those herds that have granted access.
8	HerdPlus® is a service provided by ICBF to the herd owner. This service facilitates access to all data and information relevant to the herd in the database.
9	Service fees are set on the basis of *user pays* and *full cost recovery*.

Table 2. Sources and types of data captured by Irish Cattle Breeding Federation Society Ltd (ICBF) database for dairy and beef cattle in Ireland

DAFF, Irish Department of Agriculture Fisheries and Food

Source of data	Type of data
Farms	Animal events – birth, calving, weights, docility, calf quality
DAFF – official system	Registrations, movements, deaths, exports . . .
Meat factories	Slaughter (date, weight, grade . . .), images
Marts	Sale (date, weight, price . . .)
Artificial insemination	Insemination (date, sire)
Milk recording	Milk weight
Laboratories and milk processors	Milk composition, disease test results, genotypes
Linear scoring	Weights, scores – beef and dairy
Genetic evaluations	Breeding values, reliabilities, economic indexes . . .

Table 3. Number of male and female genotypes in the Irish Cattle Breeding Federation Society Ltd (ICBF) database for the three different Illumina genotyping platforms

Gender	Genotype platform		
	3K chip	50K chip	800K chip
Male	1908	8872	1974
Female	364	621	

candidates for selection are currently bulls worldwide available through AI, natural mating bulls in Ireland, and cows and heifers mostly in the breeder's own herd. The availability of candidates is complicated by disease regulations and disease risks.

Genomics has the potential to help the Irish breeder, in the short term, through a combination of one or more of the following three factors:

(1) To increase the accuracy of the genetic evaluation of selection candidates, especially natural mating bulls and replacement females.
(2) To reduce the age at which accurate evaluations are available on selection candidates, especially for bulls available through AI.
(3) To increase the number of potentially available selection candidates, especially for bulls available through AI.

In the longer term, and providing the technology is used appropriately, we expect that genomics will give rise to more rapid annual rates of genetic change (Mc Hugh *et al*. 2011). Providing this change is for a combination of traits giving rise to more profitable commercial production of milk and meat, there will be substantial added benefits to farmers in Ireland.

Implementation

The implementation of genomic selection in Ireland has followed closely on the availability of research results, industry acceptance, and a decision to proceed. Developments since this initial decision to proceed have included the availability of a larger training population, accurate imputation from lower-density (3K) to higher-density (50K) chips (Berry and Kearney 2011), extending genomic evaluations to the traditional Friesian, and the inclusion of body-conformation traits. This has been achieved in a well coordinated and integrated manner, through a combination of research, systems, operations, and communications.

Research

Ireland's cattle genomics research program is part of a longer-term strategy to build a more profitable cattle-farming sector. The research was undertaken by both the ICBF and Teagasc, Fermoy, County Cork, Ireland. The research strategy comprises several elements and resources, as summarised in Table 4. Genomic selection in Ireland is undertaken using genomic best linear unbiased prediction (Van Raden 2008) and are described in detail by Berry *et al*. (2009). When originally launched in 2009, the input variables for the genomic predictions were de-regressed proofs from the domestic proof run on 985 Holstein–Friesian AI bulls. The Illumina Bovine50 beadchip (www.illumina.com, verified 15 February 2012) was the genotyping platform used. Following considerable sharing of genotypes with international collaborators, research showed a benefit of replacing the de-regressed domestic proofs with de-regressed multiple-across-country-evaluation proofs from Interbull on a larger number of animals. This resulted in a considerable increase in the training population size. The dependent variables are weighted by their respective reliability

Table 4. Irish genomics research resources
ICBF, Irish Cattle Breeding Federation Society Ltd

Resource	Strategy
Relationships	Open sharing with anybody willing and able.
	Teagasc does research, ICBF implements. Very open communication during all phases from research to operations.
Skills	PhD program mainly in quantitative genetics, with one new completion per year for the past 13 years.
	Funded mainly through fellowships.
	Core research team currently comprising three scientists.
	Gaps in knowledge filled through international collaboration.
Knowledge	Scientists encouraged to travel, spend time in collaborating organisations, present and participate in scientific, Interbull, and international meetings.
	Scientists regularly present to, and publish for, Irish cattle-farming audiences.
	Open breeding consultation meetings three or four times per year, involving breeding industry and covering research plans, research results and implementation plans.
Phenotypes	Researchers have access to all data in ICBF database.
	ICBF across breed genetic evaluations for full range of dairy and beef traits.
	Interbull dairy sire evaluations on Irish base and scale.
Genotypes	Dairy – 1100 bulls with Illumina 50K from Ireland, and some 6500 bulls with Illumina 50K from bilateral sharing with an increasing number of countries.
	Beef – 400 with Illumina 800K and expect to have 1000 by end of 2011. Seeking more from international sharing and Irish stock bulls.
	Prototype database for international sharing of cattle genotypes currently catering for Illumina 3K, 50K and 800K. Proposed that this be hosted by Interbull.
Tools	Software – freely sharing with whoever is interested.
	Participating in http://www.genomicselection.net (verified 29 February 2012), a portal for sharing software relevant to using genomic data in genetic evaluations.
Funding	ICBF – public and industry funding for semen purchase, blood sampling, genotyping, information system development, extension and education.
	Public and industry funding for genotyping.
	Data – 'free' for use in research.

less parental contribution. A restriction is imposed that the reliability of the training animals must be >40%. This, therefore leads to different-sized training populations for the different traits, depending on (1) the respective heritability and number of effective daughters, and (2) whether or not the trait is included in the suite of traits evaluated by Interbull. The number of animals currently included in the training population for the milk-production traits is 4550, whereas the number of animals currently included in training population for calving interval is 2315. Direct genomic values are blended, using selection index methodology, with traditional breeding values of the ungenotyped back-pedigree. In 2011, the average reliability of genomic estimated breeding values of young animals was 50%. Research is currently underway to expand genomic selection in non-Holstein animals, by acquiring genotypes on cross-bred and alternative-breed cows with phenotypes and also the limited number of bulls proven in Ireland.

Systems

The key systems that were developed to support the implementation of genomic selection for dairy cattle in early 2009 were those associated with genomic data storage and genetic evaluations. Initially, in 2009, flat file systems were

Table 5. Steps in operational genomic-evaluation service available to Irish dairy farmers and breeding companies
ICBF, Irish Cattle Breeding Federation Society Ltd

Step	Description
1	A list of recently registered male-calf births is provided weekly to artificial insemination companies.
2	Herd owners and breeding companies use the ICBF website to place orders for genomic evaluations of specific recently registered calves.
3	Each business day hair sampling kits bar-coded with the official identification of the calf are mailed to the herd owner for all calves for which a genomic evaluation has been ordered.
4	Hair samples are mailed by the herd owner to ICBF.
5	ICBF sends batches of hair samples to genotyping laboratory(s).
6	Genotyping laboratory electronically transmits genotypes with official identification of the calf in the Interbull format, to ICBF database, or files of genotypes, identified using Interbull identification format, are transmitted to ICBF database. This caters for breeding organisations who make their own genotyping arrangements and wish to obtain a genomic evaluation on the Irish base and scale.
7	Genetic evaluations computed on a monthly schedule.
8	Genetic evaluation incorporating genomic data distributed to the customer who placed the order.
	All results, for male calves, are made freely available on the ICBF public bull search after each major, four times per year, evaluation run.

Table 6. Key messages to farmers on the introduction of genomically selected dairy bulls in artificial insemination
EBI, economic breeding index; ICBF, Irish Cattle Breeding Federation Society Ltd

No.	Message
1	Select bulls from the ICBF 'Active Bull' list. Select on EBI, then refine choice. There is plenty of choice in terms of supplier, breed, balance among traits, and price.
2	Use teams of four or five bulls as a strategy to reduce the risk associated with lower reliability for individual genomically selected bulls.
3	Use sire advice for mate allocation to avoid inbreeding, to minimise trait variation and maximise genetic gain.
4	Use enough straws of semen – 1.5 straws for each cow and 1 for each heifer.
5	Target to breed 40 heifer replacements per 100 cows.

used to store the genotypes but these have been replaced by a genotype storage system integrated into the ICBF database. ICBF's genetic evaluation systems, web screens and active bull lists were upgraded to incorporate genomic data into the existing trait-based evaluations system and progress has been reported elsewhere (Kearney *et al*. 2009, 2010).

Table 7. Response of Irish breeding industry to availability of genomics for dairy breeding

Year	Key event
2009	Genotyped bulls in progeny test pipeline.
	Started genotyping bull calves before selection.
	Offered genomically selected bulls at lower price.
	Promoted teams of genomically selected bulls.
	Semen from young genomically selected bulls imported from NZ and other countries.
	Sharing of genotypes with international collaborators.
2010	Increased use and price of genomically selected bulls.
	Disease outbreak in young bulls at largest bull stud. Large percentage lost.
	Reduced number of bulls in progeny test.
	Increased price paid for genomically selected bull calves.
2011	Disease outbreak in largest bull stud. Many bulls lost.
	Increased number of young bulls genotyped.
	Reviewing breeding-scheme design.

Operations

A genomic evaluation service to farmers and breeding organisations has recently been launched in Ireland. This user-pays-service, €50, including tax per animal for Illumina 3K-based evaluation, is focussed on providing genomic evaluations of new-born dairy calves, males and females. This service is available to farmers and breeding companies (Irish or international) alike. It is a fully integrated service that makes extensive use of the ICBF database and associated systems to save costs, minimise errors and minimise turn-around times. The service involves eight main steps (Table 5).

Table 8. Response of Irish farmers to availability of genomically selected (GS) bulls
EBI, economic breeding index

Proof type	2009 %Use	2009 Bulls used per herd	2009 Average EBI (Rel)	2010 %Use	2010 Bulls used per herd	2010 Average EBI (Rel)
DP–IRL[A]	37	2.7	120 (86)	25	3	146 (76)
DP–INT[B]	29	3	133 (56)	34	3	155 (47)
GS	34	4	179 (55)	40	4	218 (56)

[A]Daughter proven in Ireland. [B]Daughter proven in another country.

Table 9. Indicators of genetic trends in the Irish dairy herd
Bold indicates that values have been influenced by availability of genomically selected bulls. EBI, economic breeding index; ICBF, Irish Cattle Breeding Federation Society Ltd; PTA, predicted transmitting ability; index average for bulls with progeny test inseminations in year is expressed in economic units for overall selection index, the EBI and sub-indexes for trait combinations

Year	Average PTA for heifer replacements for dairy herd by year of birth.						ICBF 'Active Bull' list average EBI (€)	Index average for bulls with progeny test inseminations in year			
	EBI (€)	Milk (kg)	Fat (kg)	Protein (kg)	Calving interval (days)	Survival (%)		EBI (€)	Milk (€)	Fert. (€)	Other (€)
2002	45	108	3.8	4.4	–1.1	0.4	64				
2003	47	105	3.6	4.3	–1.2	0.6	76				
2004	46	108	3.9	4.5	–1.1	0.5	100				
2005	53	107	4.4	4.8	–1.3	0.7	96	89	49	36	4
2006	57	98	4.6	4.6	–1.5	0.8	106	110	47	55	7
2007	62	97	4.9	4.8	–1.7	0.9	111	123	53	60	9
2008	65	101	5.2	5.0	–1.7	0.9	118	129	56	63	10
2009	73	108	5.8	5.4	–2.0	1.1	**147**	**154**	**62**	**80**	**12**
2010	**84**	**115**	**6.3**	**5.8**	**–2.3**	**1.4**	**196**	**166**	**59**	**87**	**20**
2011							**198**				

Communications

Communications with the Irish cattle-breeding industry, that is AI companies (including semen importers), breed associations, MR organisations and advisory services, are primarily focussed on three to four open public meetings annually – the cattle breeding consultation meetings. Copies of all presentations to these meetings are routinely placed in the publications section of the ICBF website (http://www.icbf.com, verified 1 May 2011), with meeting summaries and developments also reported in a weekly update, which is also available in the publications section of the ICBF website. The cattle-breeding consultation meetings operate on an annual cycle, with the meetings earlier in the year focussed on research plans and priorities, and those later in the year focusing on implementation plans. Most changes to evaluations are implemented later in the year, so as to ensure complete and stable information for the main spring breeding season in Ireland. Between these major meetings, the breeding industry has ready access to scientific staff, receives the results of periodic test runs and interacts with ICBF's operational team. The subject of genomics has been a routine part of this communication system since 2008.

Communication with farmers for the implementation of genomic selection in 2009 primarily focussed on a relatively small set of key messages, through a range of well established communication channels, as summarised in Table 6.

The communication channels include farmer discussion groups, national farming press (for a period of 16 weeks there was a full page feature titled 'Best Practice in Cattle Breeding' in the weekly Irish Farmers Journal), farm-walks, and a Discussion Group competition. The latter focuses on rewarding groups of farmers who have excelled in making sustainable genetic gain.

Table 10. Results of cost–benefit study exploring options for future breeding schemes for Ireland
The model now being pursued in Ireland (i.e. 10b) is shown in bold

Scheme	Description	Total costs (million €)	Total benefits – net-present-value over 20 years (million €)
1	30 bulls selected from 100 progeny tested	1568	854
2	30 bulls selected from 50 progeny tested	784	432
3	Scheme 1 with genomic pre-selection	1818	1232
4	Scheme 2 with genomic pre-selection	1034	953
5	15 bulls selected from 1000 genomic tested	326	657
6	30 bulls selected from 1000 genomic tested	541	516
7	30 bulls selected from 1000 genomic tested from elite herds	541	968
7a	60 bulls selected from 1000 genomic tested from elite herds	973	797
7b	30 bulls selected from 1000 genomic tested with contract mating	541	1866
8	30 bulls selected from 5000 genomic tested in elite herds	681	1121
9	30 bulls sel. from 1000 tested in elite herds and 200 tested in nucleus herds	563	1029
10	30 bulls selected from 5000 tested in elite herds and 200 tested in extreme nucleus herds	691	1286
10a	60 bulls selected from 5000 genomic in elite herds and 200 tested in extreme nucleus herds	1123	999
10b	**30 bulls from 5000 tested in elite herds and 200 tested in nucleus herds with contract mating**	**691**	**2184**

Table 11. Key attributes and roles of herds in the envisaged Irish dairy-breeding scheme that makes best use of genomic technologies
EBI, economic breeding index; ICBF, Irish Cattle Breeding Federation Society Ltd

Type of herd	Numbers	Objectives	Operations
Bull breeder	1000 herds 100 000 cows	Validation of genomic predictions. All females genotyped at birth. Full phenotype recording. Supply elite males for artificial insemination and natural service. Initial progeny test of genomically selected bulls.	Privately owned herds. Industry contribution to costs associated with research value of data collected in these herds. Targeted breeding advice from ICBF. Breeding companies provide semen. Breeding companies purchase elite bulls.
Commercial	All other herds 1 000 000 cows	Basis of profitable dairy industry. Collect data needed for best practice breeding, herd health and herd management.	Independent businesses. Service providers (artificial insemination, milk recording, herd book, advisory, veterinarians) use ICBF database to access relevant service data and comparative information.
Next-generation research	5 herds 1000 cows	Validate and develop traits in EBI. Conduct management research using relevant genetics. Supply elite animals for breeding program.	Owned by research organisations. Replacement females from bull-breeder herds.

Progress – so far

The use of genomically selected (GS) dairy bulls in AI is now in its third year in Ireland. The response of the Irish AI industry to the availability of genomic technology is summarised in Table 7 and that of farmers in Table 8. The AI industry has moved rapidly to the provision of younger GS dairy bulls, with higher EBIs selected using genomic information. These are known as GS bulls. In the past 2 years, the situation has been complicated by repeated outbreaks of infectious bovine rhinotracheitis in the bull stud of the largest AI company in Ireland, which will lead to an even greater use of young bulls in the future. Farmers have responded by using the higher-index GS bulls and have taken the advice to use teams of bulls to compensate for the lower reliability of individual bulls.

The impact of genomics on genetic trends is shown in Table 9. Genomic technology was first introduced early in 2009 and its impact can be immediately seen in the average EBI of the bulls available in AI – the 'Active Bull' list – and the bulls used in progeny testing. Further gains in these two indicators also occurred in 2010. The flow through to the birth of replacements for the dairy herd is seen in the dairy replacements born in 2010. The contribution of fertility to the bulls being selected on the basis of genomic information for progeny testing was observed in 2009 and 2010, where a large part of the EBI increase is explained by increases in the fertility sub-index of the EBI.

Future breeding-scheme design

Breeding-scheme design was a priority from the establishment of ICBF in 1997, and before adopting genomic selection, the implications of the breeding-scheme design were considered. An initial analysis conducted in 2008 (Sonesson *et al*. 2008) about the impact of genomics identified the potential for more rapid genetic gain and lower costs and was a key element in the decision to pursue the technology vigorously. The study of Sonesson *et al*. (2008) identified the risk of increased inbreeding if the use of genomic selection was not well implemented. It was on the basis of this finding, and the very large impact of one bull on the Active Bull List, that the practicality of guiding the mating of elite cows in the Irish dairy herd was tested (McParland *et al*. 2009). Further research included extensive simulation studies that identified the important potential role of females and the need to maintain some form of progeny test (Mc Hugh *et al*. 2011). An extensive industry consultation was conducted during 2010 and culminated with the completion of a cost–benefit evaluation of a range of future options (Amer 2010). The benefits and costs of these options are summarised in Table 10.

On the basis of the present results, the current focus for the future breeding scheme for Irish dairy cattle comprises three types of herds – commercial, bull breeder and next generation. Table 11 contains a summary of the key attributes and roles of these herds.

Summary

In the past 13 years, the Irish cattle-breeding industry has undergone a complete redevelopment of its data-gathering and genetic-evaluation infrastructure. The comparatively recent availability of genomic technologies has been quickly assimilated by this new infrastructure, through a combination of the following:

- research based on Irish phenotypes, Interbull evaluations and genotypes from Irish and international collaborations;
- rapid implementation of research findings into the Irish genetic evaluations systems for dairy cattle;
- deployment of an operational system for efficiently providing genomic evaluations to anybody for new-born male and female selection candidates;
- effective communications with both the breeding industry and farmers;
- research on breeding-scheme design and related cost–benefit studies; and
- plans for ensuring the Irish cattle-breeding industry is structured to enable the rapidly evolving genomics technology to be fully exploited for the benefit of Irish cattle farmers.

Irish farmers, research scientists, HBs and AI companies have responded by making good use of the information now available on the role that genomics can play in cattle breeding. As a result, Irish farmers are now able to better exploit the potential of genetics as a tool for improving the profitability of their enterprises.

References

Amer PR (2010) Implications of alternative breeding program structures for dairy cattle in Ireland. Available at http://www.icbf.com/publications/files/cost_benefit_analysis_final.pdf [Verified 13 February 2012]

Amer PR, Simm G, Keane MG, Diskin MG, Wickham BW (2001) Breeding objectives for beef cattle in Ireland. *Livestock Production Science* **67**, 223–239. doi:10.1016/S0301-6226(00)00201-3

Berry DP, Kearney JF (2011) Imputation of genotypes from low- to high-density genotyping platforms and implications for genomic selection. *Animal* **5**, 1162–1169. doi:10.1017/S1751731111000309

Berry DP, O'Brien B, O'Callaghan EJ, O'Sullivan K, Meaney WJ (2006*a*) Temporal trends in bulk tank somatic cell count and total bacterial count in Irish dairy herds during the past decade. *Journal of Dairy Science* **89**, 4083–4093. doi:10.3168/jds.S0022-0302(06)72453-5

Berry DP, Burke M, O'Keefe M, O'Connor P (2006*b*) Do-it-yourself milk recording as a viable alternative to supervised milk recording in Ireland. *Irish Journal of Agricultural and Food Research* **45**, 1–12.

Berry DP, Kearney JF, Harris BL (2009). Genomic selection in Ireland. Interbull Bulletin 39. Uppsala, Sweden, 26–29 January 2009.

Berry DP, Evans RD, McParland S (2011) Evaluation of bull fertility in dairy and beef cattle using cow field data. *Theriogenology* **75**, 172–181. doi:10.1016/j.theriogenology.2010.08.002

Cromie A, Wickham B, Coughlan S, Burke M (2008) The impact of new technologies on performance recording and genetic evaluation of dairy and beef cattle in Ireland. Proceedings ICAR biennial conference, Niagara, June 2008.

Crowley JJ, McGee M, Kenny DA, Crews DH Jr, Evans RD, Berry DP (2010) Phenotypic and genetic parameters for different measures of feed efficiency in different breeds of Irish performance tested beef bulls. *Journal of Animal Science* **88**, 885–894. doi:10.2527/jas.2009-1852

Kearney F, Cromie A, Berry D (2009) Implementation and uptake of genomic evaluations in dairy cattle in Ireland. Available at http://www.icbf.com/publications/files/itb_082009_FK.pdf [Verified 13 February 2012]

Kearney F, Cromie A, Berry D (2010) Implementation and uptake of genomic evaluations in dairy cattle in Ireland. Available at http://www.icbf.com/publications/files/wcgalp_fk.pdf [Verified 13 February 2012]

Mc Hugh N, Fahey AG, Evans RD, Berry DP (2010) Factors associated with selling price of cattle at livestock marts. *Animal* **4**(8), 1378–1389. doi:10.1017/S1751731110000297

Mc Hugh N, Meuwissen THE, Cromie AR, Sonesson AK (2011) Use of female information in dairy cattle genomic breeding programs. *Journal of Dairy Science* **94**, 4109–4118. doi:10.3168/jds.2010-4016

McParland S, Kearney JF, Lopez-Villalobos N, Berry DP (2009) Optimal system of contract matings for use in a commercial population. *Irish Journal of Agricultural and Food Research* **48**, 43–56.

Olori VE, Meuwissen THE, Veerkamp RF (2002) Calving interval and survival breeding values as measure of cow fertility in a pasture-based production system with seasonal calving. *Journal of Dairy Science* **85**, 689–696. doi:10.3168/jds.S0022-0302(02)74125-8

Pabiou T, Fikse WF, Cromie AR, Keane MG, Nasholm A, Berry DP (2011) Use of digital images to predict carcass cut yields in cattle. *Livestock Science* **137**, 130–140. doi:10.1016/j.livsci.2010.10.012

Pabiou T, Fikse WF, Am PR, Cromie AR, Näsholm A, Berry DP (2012) Genetic relationships between carcass cut weights predicted from video image analysis and other performance traits in cattle. *Animal*, in press.

Ramsbottom G, Cromie AR, Horan B, Berry DP (2011) Relationship between dairy cow genetic merit and profit on commercial spring calving dairy farms. *Animal.* doi:10.1017/S1751731111002503

Sonesson A, Meuwissen T, Cromie A (2008) Genomic selection in Irish dairy cattle breeding scheme. Available at http://www.icbf.com/publications/files/Genomic_Selection_in_Irish_dairy_cattle_breeding_Report_Dec_2008.pdf [Verified 13 February 2012]

Van Raden PM (2008) Efficient methods to compute genomic predictions. *Journal of Dairy Science* **91**, 4414–4423. doi:10.3168/jds.2007-0980

Veerkamp RF, Meuwissen THE, Dillon P, Olori V, Groen AF, van Arendonk JAM, Cromie AR (2000) Dairy breeding objective and programs for Ireland. Available at http://www.icbf.com/publications/files/Final_RBI_report_25_11_2000.pdf [Verified 13 February 2012]