ABSTRACT: The introduction of genically enhanced breeding values (GEBV) in The Netherlands and Flanders has led to huge changes in breeding program management, due to improved reliabilities of young breeding stock and the decreasing need for progeny-testing schemes for young bulls. Moreover, the availability of GEBV has also led to a multitude of industry and market opportunities, and has thus led to new developments in herdbook registration, genetic disorders, and on-farm genetic management, both in selecting breeding stock and bull choice. Challenges lie in the fields of 1) consistently maintaining the level of accuracy obtained for GEBV and genotypic information in general, 2) transparency to adopt this new technology in the market, and 3) the balance between costs and economic returns.

Keywords: dairy cattle genomics industry application

Introduction

CRV, a cooperative cattle improvement organization, started her genomic program in 2006, with an in-house genomic evaluation to select breeding stock for her breeding program. In 2010, genomic breeding values were officially introduced in the Dutch-Flemish national evaluation, and became widely available to the Dutch-Flemish market. Since then, the genomic evaluation has shown its use in multiple ways, and a wide variety of applications is currently in practice or in consideration. This paper describes the developments in industry application of genomics in The Netherlands and Flanders, with emphasis on those developments where CRV is actively involved.

Data & analysis

Genomic evaluation. Genotyping of all individuals is based on the Eurogenomics chip, developed by a consortium of European partners based on the Illumina technology. It consists of approximately 10,000 SNP. Bulls in the training population are (also) genotyped with the Illumina 50K SNP chip. All animals in the genomic evaluation are imputed to a 50K SNP set. The genomic evaluation is described by de Roos et al. (2009). Direct Genomic Values (DGV) are based on the Eurogenomics and CRV training population, which currently includes approximately 27,000 bulls with daughter-based EBV.

To estimate Genomically Enhanced Breeding Values (GEBV), the DGV are blended with conventional breeding values using a post-processing step (VanRaden et al. 2009).

Logistics. CRV has a policy to finish the process from genotype request until GEBV within 28 days. This includes processing the request, sending sample material (ID-labeled containers for hair, nose-swabs, or blood), sampling by herd owner, CRV technician or veterinarian, sending the sample tissue to a general collection point, and from there to the appointed laboratory for DNA extraction and chip analysis, and finally the processing of the raw genotypes and the genomic evaluation and blending procedure within CRV (Figure 1).

This tight logistic schedule has originally evolved around the male genotype requests, as in The Netherlands bulls have to be moved to slaughter herds within 30 days after birth. And thus CRV has to be able to buy or reject the bull within these 30 days. But this tight logistic setting is also used for female individuals.

Furthermore, around the logistic routing a track & trace system has been put in place, which follows a genotype request from the moment it is entered in the database, through the collection point for samples, the laboratory updates, and the CRV updates, right up to the point where the genotype requested individual receives its genomic breeding value, and output is send to the user who requested the sample. The track & trace system combines the update files from the several locations in a set of master files, tracking each individual. The track & trace system allows for monitoring of the process, updates reasons for delay, and allows for quick actions in case samples are rejected or have failed (e.g. lack of sample tissue, too low call rates, pedigree errors, etc.).

Weekly evaluation. Although the entire routing of a single sample takes 21 to 28 days, the collection and genotyping of these samples is a continuous process. Every Friday the new genotypes are sent to CRV, checked and a genomic evaluation and blending procedure is run. Every Monday, the new animals receive a GEBV, and decisions on bulls and bull dams are made.

Application of Genomic EBV

National evaluation. The most commonly known use of GEBV is within the national evaluation, where genotyped individuals receive a GEBV based on any conventional information available, blended with their respective DGV. As a consequence of genomics the youngest generation now dominates the breeding value top lists (de Roos 2013), and the former young bull testing system is largely replaced by a genomic testing system (Dür and Philipsson 2012), in which the only restriction to the use of the young top bulls on the female population is...
the biological onset of semen production. Constant monitoring of GEBV over the last years has shown that daughter EBV of these young bulls are comparable in level to their original GEBV, validating the genomic system to the general public (de Roos 2013).

**CRV breeding program.** As mentioned before, CRV started there genomic system already in 2006, and profits from the new genomic testing system by screening a much larger set of young bulls and potential bull dams, and buying/contracting only a fraction of them based on their GEBV. Due to the exquisite logistic routing, only a limited number of male calves fail to reach the 30-day deadline for a GEBV-based decision on buying or rejecting.

**DataPlus.** In 2012, CRV started with the DataPlus program. In this project, herds are contracted that fulfill a number of data requirements (a minimum use of young genomic bulls, data registration on testday production, conformation, and claw health), and in exchange receive GEBV for all their female stock for free, and for newborn calves against reduced prices. The advantages on national level, and CRV specifically, is firstly, that phenotypic information of traits is ensured and enhanced for young bulls, improving the information for the training population, as well as getting daughter EBV for young bulls without the former bull testing schemes. Secondly, the large number of genotyped females might at some point be used to enlarge the training population, thereby further increasing the added reliability of genomics (Schopen et al. 2014, Pryce et al. 2012). The advantage for the farmer is a more reliable breeding value for his female stock against economically attractive prices, management information, and more options for genetic management at herd level, e.g. a mating program with selected use of high quality or sexed semen, or appointing top females for flushing.

**InSire TalentScan.** Beside the DataPlus program, CRV also offers the testing of female individuals on a farmer-requested basis. These so-called InSire TalentScans are limited to female Holsteins, but have no other requirements as DataPlus has. It is an opportunity for farmers who quickly adopt to the new market changes and incorporate genomic information into their management system. TalentScans are typically used for pre-selection of (female) calves, selection of heifers for flushing, and the optimal use of sexed semen on genetic superior animals, combined with semen of beef breeds on the low end of the herd. Calus et al. (2013) studied the cost effectiveness of such management strategies, and concluded that the advantage of genomic testing was cost-effective on herd level, when the price of the genomic test does not exceed 55 €.

**Herdbook registrations.** Estimations have shown that about 4.5% of Dutch-Flemish herdbook registrations contain errors (Buiting 2014, personal communication based on year report of the Committee Supervision of Approved Data). These estimations are part of a Quality Control program of the herdbook, and consist of a compulsory aselect testing of herdbook registrations for parentage verification. This used to be based on a set of parentage markers, but will be replaced, in 2014, by a set of approximately 100 SNP, present on all commonly used SNP panels, and approved for ISAG (International Society for Animal Genetics) certification.

This change in procedure is beneficial for farmers appointed for aselect sampling of parentage verification, as they no longer run the risk to only lose herdbook registrations on an individual. Large-scale genotyping can now also be used to confirm parentage and lead to herdbook registration of non-registered animals, which is a pre for export. Furthermore, they will receive GEBV for the tested animals as well. As most bulls (and in case of a DataPlus herd, dams as well) are genotyped, even a failed parentage verification will often lead to confirmation of a different potential ancestor, which can subsequently be corrected in the herdbook.

**Genetic disorders.** The current Eurogenomics chip holds a number of SNP used to detect genetic disorders. This is extensively used within the breeding program on selection decisions and mating advice, but also holds important management information for active breeders, and DataPlus- and InSire TalentScan participants

**Mating advice.** Obviously, GEBV, with their improved reliability compared to daughter EBV or even parent average in case of young animals, can be used more effectively in mating advice programs, especially in combination with the DataPlus program, in which also all females are genotyped. Benefit is highest for (virgin) heifers, who, based on their genotype receive an improved breeding value based on genomics, resulting in an improved mating advice, compared to the advice based on a parent average.

**Challenges & Discussion**

**Accuracy.** A challenge in industry application of genomics is obviously the predictability of GEBV. Predictability is affected by size and population structure of the training population, but also by up-to-date phenotypes used for estimation. There is a relatively quick degeneration of predictability when training population are not regularly updated with new data, and new generation animals (Garrick 2011). More-over, predictability is typically assessed by cross-validation, in which the relatedness of the validation and training bulls affect the estimated predictability, which consequently implies that this predictability only holds if newly typed young animals have indeed a similar relatedness to the training population as the original validation group. Through international cooperation and exchange of genotypes, and the constant update of phenotypes (deregessed daughter proofs) within the training population, predictability of DGV has been on an ever increasing level.

**30-day Challenge.** A national challenge, to have GEBV for animals, is set by the 30-day deadline of young bulls entering slaughter herds. Although the logistic process is optimized in many ways, a single failure in the process (delay with posting, insufficient sample material, problems in DNA isolation or in call rate, observed pedigree errors) will quickly result in surpassing the 30 day threshold, resulting in fines.

**Acceptance.** Within the market, the dominance of young bulls in the top lists has caused a shift from the
traditional view on breeding values as being daughter-based predictions, to the new GEBV era with fastly moving markets where the genetic progress is higher and bulls are much faster replaced (Hayes et al. 2009). De Roos (2011, 2013) showed that of the top CRV bulls ranked on the Dutch Total Merit Index (NVI), approximately 95% were young genomic bulls, and only 5% were older proven bulls. However, acceptance in the market as reflected by semen sales is lacking behind, with market shares of young bull semen up to 40% in the Netherlands (de Roos 2013). Typically for a new technology introduced in the market, some innovators quickly adopt the new possibilities, whereas others lag behind (Diederen et al. 2003). Due to the speed of developments, it is important to keep your market involved.

**Cost effectiveness.** Relating to the above market acceptance of new technology, is the price at which the new technology is available. Two issues can be raised here. Firstly, the price at which the new technology is calculated to be economically effective for the farmer (Calus et al. 2013). Secondly, the price at which the farmer feels risk-free enough to test the new technology on his farm, which is usually considerably lower than the estimated economic return.

**Conclusion**

The introduction of genomic breeding values has led to huge changes in our view on breeding, decreasing generation interval and replacing top young bulls at higher rates. Furthermore, the availability of genotypic information and GEBV, has led to a multitude of industry applications and improvements, such as in herdbook registrations, parentage verification, and on-farm management. Challenges are the constant level of accuracy of information, both the GEBV reliabilities as well as the accuracy of SNP-based identification of genetic defects, a transparent and quick communication network to all involved, but not in the least directed at market acceptance, and that in a cost effective way.

**References**


De Roos (2013), Proc. 64th Annual Meeting of the EAAP, Nantes, France


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**Figure 1.** Schedule representing the 28-day process from genotype request to Genomically Enhanced Breeding Value (GEBV), including (in white arrows) the update moments within the Track &Trace system that follows each individual throughout the process.