Review of commercially available genomic technologies in cattle

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Abstract

Genetic testing can be a key component of a beef cattle management program. Available tests can help inform parentage, selection for simple traits like coat color or polled, management of genetic defects in breeding populations, and estimating the genetic merit of individual animals for economically relevant traits. Increasingly, comprehensive genotyping arrays that assess tens of thousands of genetic markers are being used to inform selection in cattle populations.

Key words: genomics, genetic testing, accuracy, breeding value, parent verification

Résumé

Le dépistage génétique peut être une composante clé du programme de régie des bovins de boucherie. Les tests disponibles peuvent aider à cibler l'origine, la sélection pour des traits simples comme la couleur du manteau ou l'absence de cornes, la régie des défauts génétiques dans les populations reproductives et l'estimation du mérite génétique d'individus pour des traits qui ont un impact économique. De plus en plus, des matrices complètes de génotypage qui évaluent des dizaines de milliers de marqueurs génétiques sont utilisées pour aider la sélection dans des populations bovines.

Introduction

Genetic tests have evolved considerably over the last 10 years and are now reasonably commonplace in many sectors of livestock production. Several cycles of evolution in genotyping platforms have passed, and in many respects the technology itself has now stabilized. As a result, current testing options are characterized less by the underlying genotype, and more by the manner in which the genotype is used. For simplicity, we will characterize available genetics tests in the following categories – parentage, single gene tests, and genomic tests.

Parentage Tests

Parent verification (PV) is 1 of the most basic applications of a genotype, and verification of recorded pedigree is imperative in driving accurate predictions of genetic merit in genetic evaluations. When performing a PV, the genotype between the offspring and alleged parent(s) is performed by comparing the genotypes of parent(s) and offspring to look for evidence of misassignment. The premise is that we know that each parent contributes 1 allele at each locus (i.e., position on a chromosome). Therefore, we know that a parent with a genotype of AA could not have produced an offspring with a genotype of BB at that locus; they would have had to inherit a B from each parent and this parent does not have any B alleles.

There are 2 common types of genetic markers used for parentage – single nucleotide polymorphisms (SNP) and short tandem repeats (STR; also referred to as microsatellites). In most instances, SNP genotypes have replaced the older STR technology, but some beef breeds still rely on STR genotypes for PV. Given that PV analyses are effectively a statistical process by which candidate parents are excluded on the basis of genotype, most PV are performed using multiple genetic markers. The International Society on Animal Genetics (ISAG) has established a recommended standard panel of specific SNP to be used for PV,[6] thus ensuring some degree of consistency among genotyping laboratories.

There are 2 primary applications of PV analysis in cattle. The first would be routine testing to confirm pedigree in the case of animals registered with breed societies. This is a critical step to ensure integrity of the associated herd book and any analysis thereof. Breed societies typically have regulations that require either all animals or specific subsets (e.g., calves derived from embryo transfer) as a condition of registration. The second application would be management of pedigree in non-registered calves born from breeding cohorts that contain multiple sires. This is quite common in commercial beef production, and particularly important in situations where combinations of artificial insemination (AI) and natural service are used for breeding. In this scenario, producers may prefer to keep replacement females from sires with superior genetics (e.g., the AI sires) and would use PV to identify AI-sired females in the cohort.

Single Gene Tests

Single gene tests are those where the genotype for a known genetic variant is used to inform breeding and marketing decisions. Common examples include tests for genes influencing coat color, polled, genetic defects, and genes like myostatin that have a distinct impact on phenotype. These tests are most commonly used to inform breeding decisions. For example, a bull that is homozygous for black coat color or polled may be more valuable as they will both produce offspring that are black or polled, respectively. In the case of recessive genetic defects, identifying animals that are carriers for the deleterious allele may be helpful in avoiding matings with other carrier animals that could produce an affected calf.

Genomic Tests

In this context, I will use the term Genomic Tests to describe the application of tests that utilize genotypes for many markers, often tens of thousands of markers, to estimate the genetic merit for multiple traits. Given that most economically relevant traits are polygenic (i.e., influenced by many genes), the use of many genetic markers can help to increase the accuracy of prediction. The genetic markers on these assays typically include a combination of markers that are associated with individual traits, presumably because they are in linkage disequilibrium with a specific gene associated with the trait of interest, and markers that broadly characterize genetic variation among animals. The latter are useful in identifying and describing genetic relatedness among animals in such a way as to help make an inference on the genetic merit of your animals on the basis of phenotypes that have been collected from other animals with similar genomic composition.

While the specific markers assembled in these assays may vary to some degree, the primary distinguishing feature of genomic tests is how they are used. In some instances, algorithms are developed that describe the relationship between the genotype at each marker and a given trait. Individual marker effects are then summed across all the available markers to produce a prediction for that trait. Separate algorithms are developed for each trait of interest, using the same set of markers for each trait. The predictions produced by these algorithms are referred to as molecular breeding values (MBV). It is most common for these tests to be applied in commercial animals for which no other data, such as pedigree or phenotypes, is available to inform the prediction.

Another potential application is to utilize the genotypes from genomic tests in a genetic evaluation. In this approach, the genotype is combined with available pedigree and phenotype information to estimate genetic merit for relevant traits. While the specific statistical methods used to combine these sources of data into a single prediction is beyond the scope of this paper,[1,3,4,7,8] this application is widely regarded as the gold standard for creating the most accurate predictions of genetic merit. These predictions are commonly referred to as genomically-enhanced expected progeny differences (GE-EPD) in North America or genomic breeding values (GBV) in other parts of the world.

One of the key features of genomic tests is the ability to estimate the accuracy of the prediction from an estimate of the prediction error variance.[5,9,10] In beef cattle genetics, accuracy is often expressed in terms of Beef Improvement Federation (BIF) accuracy.[2] Conceptually, the estimated accuracy represents the cumulative weight of evidence in support of the prediction. Adding a genotype or phenotypic record will increase accuracy. Further, an MBV will generally have a lower accuracy than a GE-EPD or GBV by virtue of the fact that an MBV is only informed by a genotype. The concept of accuracy does not apply to single gene tests as they deal with qualitative outcomes influenced by one gene.

Conclusions

Genetic testing is becoming increasing common in beef cattle production and is used extensively throughout breeding programs. A variety of tests are commercially available. Choosing the right genetic test is based upon knowledge of the decision to be made, and the information required to inform that decision.

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