

Commercially Available DNA Tests for Genetic Improvement of Beef Cattle

Matt L. Spangler, Beef Specialist, Beef Cattle Breeding and Genetics

Misinterpreting DNA tests can cost beef cattle producers time and money. This NebGuide discusses how to interpret commercial DNA marker tests.

Several companies now offer DNA marker tests for a wide range of traits in beef cattle. Unfortunately, the interpretation of the results has caused a great deal of confusion. Testing an animal is simple but determining exactly what to do after you get the results can be much more complex. The terminology that accompanies these DNA tests only adds to the confusion.

Parentage Testing

The identification of an animal's parents via DNA marker technology can be advantageous in several situations including multi-sire breeding pastures and ascertaining if a calf is the product of an artificial insemination (AI) mating or a clean-up bull. Genotyping to determine parentage allows a sire to be correctly linked to a corresponding calf. This promotes knowledgeable culling and breeding decisions by determining which sire(s) are contributing the most (or least) to a particular breeding objective. For example, to correctly identify if a calf is a result of an AI mating, parentage testing allows for the animal to be

Terminology

Additive Genetic Effects — Average individual gene effects that can be transmitted from parent to progeny.

Allele — Alternate form of a gene. It also can be thought of as variations of DNA sequence. For instance, if an animal has the genotype for a specific gene of Bb, then both B and b are alleles.

DNA Marker — A specific DNA variation that can be tested for association with a physical characteristic (marbling, tenderness, etc.).

Genotype — The genetic makeup of an animal.

Genotyping (DNA marker testing) — The process by which an animal is tested to determine the particular alleles it is carrying for a specific genetic test.

Simple Traits — Traits such as coat color and horned status, and some diseases. These traits are generally controlled by a single gene.

Complex Traits — Traits such as reproduction, growth, and carcass that are controlled by numerous genes. These also are referred to as Economically Relevant Traits (ERTs).

Homozygous — Having two copies of the same allele for a single gene such as BB.

Heterozygous — Having different copies of alleles for a single gene such as Bb.

Locus — Specific location of a marker or a gene.

Marker Assisted Selection (MAS) — The process by which DNA marker information is used along with phenotypic-based Expected Progeny Differences (EPDs) to select parents for the next generation.

Marker Assisted Management (MAM) — The process by which DNA marker information is used to assist in making management decisions, such as sorting cattle entering the feedlot based on their propensity to meet certain grid criteria as determined by a genetic test.

Marker Panel — A combination of two or more DNA markers that are associated with a particular trait.

Non-Additive Genetic Effects — Effects such as dominance and epistasis. Dominance is the interaction of alleles at the same locus, while epistasis is the interaction of alleles at different loci.

Nucleotide — A structural component of DNA that includes one of four base chemicals: adenine (A), thymine (T), guanine (G), and cytosine (C).

Phenotype — The outward appearance of an animal that can be measured. Phenotypes are influenced by the genetic makeup of an animal and the environment.

Single Nucleotide Polymorphism (SNP) — Pronounced "Snip." A SNP is a single nucleotide change in a DNA sequence. For instance, AAGGTTA is changed to ATG-GTTA. Here the second "A" is changed to a "T." Not every SNP causes a physical change in an animal. SNPs occur in the hundreds of thousands across the genome.

registered with the correct breed association. Parentage testing uses several DNA markers to compare two or more animals, based on their similarities for the markers tested.

Example

In the following example, two bulls are possible sires of a calf, given that the calf's dam is known.

Sire 1		Sire 2		Dam	
Marker A		Marker A		Marker A	
A1	A2	A1	A2	A1	A2
C	T	T	T	T	T

Calf

Marker A	
A1	A2
C	T

In this simple example, one marker has two alleles (A1 and A2). Using only one marker, we can deduce that Sire 1 is the calf's true sire. The dam had to pass on a T allele to her calf, and the only sire that could have provided the C allele is Sire 1. In practice, multiple DNA markers would be used to ascertain parentage.

Popular Tests for Simple Traits

Color, horned status, and carriers for genetic defects are among the genetic tests available for simply inherited traits. Color refers to determining if an animal is homozygous or heterozygous black. Because the allele for red coat color in cattle is recessive, it is possible that an animal will be black hided but still have a red allele to pass to his/her offspring. If an animal is red, then its genotype for color is known with 100 percent confidence, as it has to be homozygous for the red allele. In some marketing schemes, black hided cattle are more desirable because of the association among black hides, Angus cattle, and Certified Angus Beef (CAB). Breeds more commonly tested for color status include Simmental, Limousin, Gelbvieh, and composite or hybrid animals that may contain a combination of breeds that have both red and black ancestry.

Genetic tests for horned status allow a producer to determine if a polled animal is homozygous polled or heterozygous polled (carrier of the horned allele). All horned animals are homozygous for the horned allele, while animals that have a polled phenotype may be carriers of a horned allele and produce horned offspring if mated to females who are horned or heterozygous polled/horned. Different companies have validated tests for different breeds. Breeds with tests include Charolais, Gelbvieh, Hereford, Limousin, Salers, and Simmental.

Current Tests for Economically Relevant Traits (ERTs)

The tests for complex traits can be more challenging to understand. Several companies offer commercial tests for ERTs, including Merial IGENITY®, Pfizer Animal Genetics, and MetaMorphix, Inc.

Merial IGENITY

The IGENITY profile currently includes DNA marker tests for tenderness, marbling, quality grade, stayability (longevity), heifer pregnancy, calving ease, weaning weight, docility,

external fat, yield grade, carcass weight, feed efficiency, and ribeye area.

Pfizer Animal Genetics (Bovigen)

The GeneSTAR® DNA marker panel currently has tests for tenderness, marbling, and feed efficiency. Net Feed Intake (NFI) measures the phenotype of feed efficiency in Bovigen's test. NFI is the difference between an animal's actual consumption and what it is predicted to consume, based on size and performance. The assumption is that animals with a negative NFI are more efficient. Warner-Bratzler Shear Force (WBSF) measures the phenotype of tenderness in both the IGENITY and GeneSTAR tests. WBSF is simply the amount of force required to cut through a piece of meat. Consequently, a lower WBSF value would indicate meat that is more tender.

MetaMorphix, Inc. (MMI)

MMI Genomics offers DNA marker tests for marbling and tenderness (Tru-Marbling™ and Tru-Tenderness™).

Validation

This is the process by which the association between phenotypes and genetic tests is determined once the DNA markers have been discovered. It can be thought of as answering this question: Do the DNA markers have an effect on a particular trait?

Validation can occur internally or externally. Internal validation includes a commercial company validating its own DNA test. External validation includes the work of an independent party such as a land-grant university or USDA research center. Currently, validation is performed by the National Beef Cattle Evaluation Consortium (NBCEC), which comprises researchers from various universities and the USDA. Updated validation results are placed on the NBCEC Web site at <http://www.nbcec.org>.

Using Validation Results

How do you use validation results? Several key components should be evaluated before you decide to use a particular product (marker panel). First, it is important to determine if the genetic test is significantly associated with the trait of interest. Second, is the trait for which the test is significantly associated with the same as the name of the test would imply? For example, is a genetic test for marbling score really associated with marbling score or is it associated with quality grade or percentage of intramuscular fat (IMF) as measured by ultrasound? This might impact the rate of genetic change that could be made because IMF is an indicator trait and marbling score is the economically relevant trait.

Finally, look at the regression coefficient (b). The regression coefficient tells you the expected change in phenotype for every one unit change in the molecular score (genetic test score). For example, if two animals have molecular scores for tenderness of -1.5 and 1.0, respectively, the difference between those scores is 2.5. Normally, we would expect that, on average, these two animals' phenotypes would differ by 2.5 lb of shear force. However, if the regression coefficient is 0.4, we would expect their phenotypes to differ by 1 lb (2.5*0.4). This has relevance to MAM as well and can be used to determine if the differences in phenotypes that can be predicted by a genetic test are worth the cost of the test.

Interpreting the Results of a Genetic Test

Unfortunately, there is not a consistent method of representing the results of a DNA marker test from company to company. However, most companies are moving away from the use of a 1-10 scale or a system based on the assignment of one star per desirable allele. Most companies are reporting results based on Molecular Breeding Values (MBVs), although most have names that are unique to a specific company (e.g., Pfizer's Molecular Value Prediction). It is important to realize the difference between a breeding value (molecular or phenotypic based) and an EPD. A breeding value is equal to twice an EPD. A breeding value is the genetic potential of an animal while an EPD is the genetic potential of an animal as a parent given that only half of an animal's alleles will be passed to the next generation. Just like an EPD, these results are reported in units of the trait.

Some companies are publishing a value of accuracy to go along with these molecular breeding values. It is important to note that the accuracy (some companies call it a reliability) that is associated with the molecular breeding values is not calculated the same way as the accuracy associated with EPDs. Consequently, one cannot compare the accuracy values of an MBV and an EPD.

As an example, assume that two Angus bulls (denoted below as animals 1 and 2) both have been DNA-tested by company X for their marbling panel, and the test results have been provided in the form of a molecular breeding value and associated accuracy (or reliability). Also assume that these two bulls have an ultrasound record that has been included in their marbling EPD. If you just look at the MBVs, you would assume that animal 2 is superior. However, if you look at the EPDs, it appears that animal 1 is superior. Which bull is really more desirable for marbling can be confusing. First you must realize that one is reported as a breeding value and the other as an EPD.

Also, if we remember that the current DNA marker tests only account for a small fraction of the genes that impact marbling, and that an EPD accounts for all the gene effects, it is clear that animal 2 has the more desirable genotype for the genes accounted for by the DNA test. But when we consider all the genes that affect marbling, animal 1 is more desirable.

What about the accuracies? From the example, it looks like the MBVs are more accurate than the EPDs. Remember, at the current time the accuracies of the MBVs are not calculated the same way as the accuracies of the EPDs. The two are not comparable, and in many cases, even though the EPD accuracies are lower, they actually do a much better job of predicting the total genetic merit of an animal as a parent.

Animal	MBV	Accuracy (or Reliability)	EPD	Accuracy
1	0.10	.20	.30	.17
2	0.40	.22	.20	.15

How are DNA Marker Tests Related to EPDs?

EPDs provide an estimate of an animal's genetic potential as a parent based upon ancestral information, its own records, and the records of its progeny. With this in mind, an EPD accounts for all the genes that affect a particular trait, regardless of the magnitude of the effect. While an EPD accounts for all the genetic variation, the specific sources of the variation

(genes) are unknown. DNA marker tests reveal the genotype of an animal for specific DNA markers for a particular trait but do not account for all of the genetic variation.

It is critical to understand that a desirable genetic test result is not always associated with a desirable EPD. For instance, an animal could be homozygous for the favorable allele for a DNA marker for marbling but still have a marbling EPD that is below breed average. This could occur if the animal has the favorable form of one gene affecting marbling but has unfavorable alleles for numerous other unknown genes that affect marbling as well.

Accuracy

The accuracy associated with EPDs increases as more information becomes available. Initially, EPDs are derived from the average of the animals' parents (pedigree estimate). Once an animal has its own record, the accuracy of the EPD increases and continues to do so as the animal has recorded progeny. Unfortunately this takes time, and for some ERTs, it is not possible for an animal to have its own record or the record may occur very late in life (i.e., stayability).

In some countries, the accuracy of a genetic prediction (EPD in the U.S.) is determined by the correlation between the estimated value and the "true" value.

In the U.S., the beef industry uses accuracy standards recommended by the Beef Improvement Federation (BIF). BIF accuracies are more conservative, in that they require more progeny records to achieve high accuracy values (*Table 1*). The benefit of DNA tests lies in the fact that they can be done at birth and thus have the potential to increase the accuracy of genetic predictions on young animals. That being said, the benefit of this is determined by the genetic correlation between DNA test results and the trait of interest.

Table 1. Accuracies of estimated breeding values based on the correlation with true breeding values (r) and the BIF standard.

Genetic Correlation (r)	BIF accuracy
.1	.01
.2	.02
.3	.05
.4	.08
.5	.13
.6	.20
.7	.29
.8	.40
.9	.56
0.99	.93
0.995	.99

Example:

Assume that a DNA test has a genetic correlation of 0.8 with the trait of interest. This would equate to a BIF accuracy of 0.40. For traits that are hard to measure or measured late in life, this would be very beneficial. Seedstock producers could identify superior animals earlier in life, and commercial producers who purchase unproven sires could reduce the risk associated with low accuracy values. However, if the genetic correlation between the molecular test and the trait of interest is low (0.02), the value of using only the genetic test score for selection is dramatically decreased, especially in the context of having available EPDs for the trait of interest. The greatest

benefit in accuracy should come from the integration of DNA test scores along with phenotypic records in the calculation of EPDs.

What is the benefit of higher accuracy values on young sires? For the seedstock producer, it enables the selection of truly superior animals earlier in life and potentially decreases the number of animals to place on test. It also allows seedstock producers to supply clientele with a product that has less risk of change. The benefit to commercial producers lies in the ability to buy yearling bulls with more certainty surrounding their EPDs.

Example:

Assume a commercial producer wants to purchase a calving ease bull for use on heifers. If a bull does not have a record of calving ease, the BIF accuracy might be 0.20. Assume that the possible change* associated with this accuracy level is 6 and that the published EPD is +5 (breed average in this case). In this situation, we would be 68 percent confident that this bull's "true" EPD for calving ease is between -1 (5-6) and +11 (5+6), realizing that for calving ease a larger number is more desirable since it is interpreted as the percentage of unassisted births. However, if the accuracy were higher (0.5), this would mean a small possible change value (4), so we would then be 68 percent confident that his true EPD would be between +1 (5-4) and +9 (5+4).

Advantages and Disadvantages

Using DNA marker information can allow for early prediction of an animal's genetic merit before phenotypic records are collected, thus increasing the accuracy of young sires and decreasing the generation interval. In some instances, traits are expensive to measure (tenderness, feed intake) or lowly heritable (stayability, heifer pregnancy), which means molecular information can be of greater benefit. MAS benefits will increase once this information is validated and combined with traditional EPDs. Using this technology for MAM requires validation of the DNA marker tests and the technical ability to correctly identify cattle with differences in genetic potential for carcass traits (yield and quality grade) beyond what is possible by simple visual appraisal of breed differences. As with any new technology, the cost of DNA marker tests is decreasing over time. However, careful economic analysis must be performed prior to implementing MAM to determine if the end results justify the cost of the tests.

Summary

Given the current status of genetic testing for complex traits, the corresponding results from these tests are not substitutes for traditional phenotypic-based EPDs. Selection

*Possible change values are standard deviations and are a measure of risk associated with different accuracy values. Possible change values differ between breeds and between traits. Updated possible change values can be found on breed association Web sites.

based on DNA markers alone could have undesirable results if the DNA markers do not explain a large portion of a trait's genetic variation. If you decide to incorporate this information into a selection process, use it in conjunction with EPDs and Economic Indexes.

Molecular (DNA marker) tests are an evolving tool. More DNA markers are being discovered all the time and added to the genetic test panels. There is ongoing research to develop Genomic Selection, which could potentially include tens of thousands, perhaps hundreds of thousands, DNA markers for the accurate selection of superior animals before phenotypes are recorded. Because this technology is rapidly changing, it is important to stay abreast of current genetic tools and their application to specific breeding objectives.

Helpful Web Sites

These Web sites contain current information regarding available tests (University of California, Davis) and validation results (National Beef Cattle Evaluation Consortium). Also listed are company Web sites that provide information regarding sample collection and costs associated with specific tests. This technology is evolving, and tests for new traits, additional markers for current tests, and validation results are continually changing.

National Beef Cattle Evaluation Consortium

<http://www.nbcec.org>

University of California Davis Animal Science

<http://animalscience.ucdavis.edu/animalbiotech/Biotechnology/MAS/index.htm>

Pfizer Animal Genetics

<http://www.pfizeranimalgenetics.com>

Merial IGENITY®

<http://www.igenity.com>

MMI Genomics

<http://www.metamorphixinc.com>

This publication has been peer reviewed.

Disclaimer

Reference to commercial products or trade names is made with the understanding that no discrimination is intended of those not mentioned and no endorsement by University of Nebraska–Lincoln Extension is implied for those mentioned.

UNL Extension publications are available online at <http://extension.unl.edu/publications>.

**Index: Beef
Beef Management**

2008, Revised October 2009

Extension is a Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln cooperating with the Counties and the United States Department of Agriculture.

University of Nebraska–Lincoln Extension educational programs abide with the nondiscrimination policies of the University of Nebraska–Lincoln and the United States Department of Agriculture.