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Commercially Available DNA Tests for Genetic Improvement of Beef Cattle

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

Misinterpreting DNA tests can cost the beef cattle producer both time and money. Use this NebGuide to learn more about 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. Terminology accompanying 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, 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 allows for knowledgeable culling and breeding decisions by determining which sire(s) are contributing the most (or least) to a particular breeding objective. In the case of correctly identifying whether the calf was a result of an AI mating, parentage testing

Terminology

Additive Genetic Effects — The portion of an animal's genotype that is transmitted from parent to progeny.

Allele — Alternate forms of a gene. It can also be thought of as variations of DNA. 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 has been associated 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, horned status, or disease status. These traits are generally controlled by a single gene.

Complex Traits — Traits such as reproduction characteristics, growth, and carcass that are controlled by numerous genes. These are also 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.

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.

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 ATGGTTA. Here the second 'A' is changed to a 'T'. Not every SNP causes a physical change in an animal.

allows for an animal to be registered with the correct breed association. Parentage testing utilizes 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 there is one marker with two alleles (A1 and A2). Using only one marker we can deduce that Sire 1 is the true sire of the calf. We know that 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 traits determining whether 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 they have 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 would be 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 for 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 that have tests available include Charolais, Gelbvieh, Hereford, Limousin, Saler, 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®, Bovigen GeneSTAR®, 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, and rib-eye area. The company Web site states that, "IGENITY® carcass composition is a tool designed for marker-assisted management. Results from this analysis are only relevant for procurement, management, and as a marketing tool for feeder calves intended for finishing and harvest. IGENITY® carcass composition results should not be used for selection or breeding decisions."

Bovigen GeneSTAR®

The GeneSTAR® DNA marker panel currently has tests for tenderness, quality grade, and feed efficiency. Net Feed Intake (NFI) measures the phenotype of feed efficiency in the case of Bovigen's test. NFI is the difference between what an animal actually consumes and what it is expected to consume. 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. Bovigen currently uses four markers for quality grade, three markers for tenderness and four markers for feed efficiency.

MetaMorphix, Inc. (MMI)

MMI Genomics offers DNA marker tests for marbling and tenderness (Tru-Marbling™ and Tru-Tenderness™). These two tests include more DNA markers than those tests previously discussed — 128 for marbling and 11 for tenderness.

Validation

This is the process by which the association between phenotypes and genetic tests are determined once the DNA markers have been discovered. It can be thought of as answering the following question "Do the DNA markers have an effect on a particular trait?" If the answer is yes, then the test is valid. Validation can occur internally or externally. Internal validation would include a commercial company validating its own DNA test. External, or independent, validation would include the work of a third party. This third party is generally a research institution such as a land-grant university or USDA research center.

Currently validation is performed by the National Beef Cattle Evaluation Consortium (NBCEC), comprised of researchers from various universities and the USDA. As of 08/31/2007, the only tests that have been validated by the NBCEC are IGENITY® Tenderness Profile, Bovigen's GeneSTAR® Tenderness and Bovigen's GeneSTAR® Quality Grade. Updated validation results will be placed on the NBCEC website once they are available at *http://www.ansci.cornell.edu/nbcec*.

Score	Genotype			WBSF Effect
	UoG-CAST1	CAPN316	CAPN4751	
10	CC	CC	CC	-2.27
9	CC	CG	CC	-1.95
8	CG	CC	CC	-1.85
7	CC	GG	CC	-1.63
7	CC	CC	CT	-1.55
7	CC	CG	CT	-1.55
7	CG	CG	CC	-1.53
7	GG	CC	CC	-1.44
6	CC	GG	CT	-1.23
6	CG	GG	CC	-1.21
5	CG	CC	CT	-1.13
5	CG	CG	CT	-1.13
5	GG	CG	CC	-1.11
4	CC	CC	TT	-0.83
4	CC	CG	TT	-0.83
4	CC	GG	TT	-0.83
4	CG	GG	CT	-0.81
4	GG	GG	CC	-0.79
4	GG	CC	CT	-0.72
4	GG	CG	CT	-0.72
3	CG	CC	TT	-0.42
3	CG	CG	TT	-0.42
3	CG	GG	TT	-0.42
3	GG	GG	CT	-0.40
1	GG	CC	TT	0.00
1	GG	CG	TT	0.00
1	GG	GG	TT	0.00

www.igenity.com

Figure 1. Relationship between IGENITY® score, Genotype, and Warner-Bratzler Shear Force (Lbs.)

Interpreting the Results

Unfortunately there is not a consistent method of representing the results of a DNA marker test from company to company. Some use a 1-10 scale (Merial IGENITY®), a scoring system using stars or a Genetic Progeny Difference (Bovigen GeneSTAR®), or the reporting of a Molecular Genetic Value (MMI). In the case of the IGENITY® 1-10 scale, genotypes are grouped together based on their effect on a particular phenotype. So a score of 7 for the IGENITY® Tenderness Profile, for instance, could include multiple genotypes that all have a similar effect on tenderness *(Figure 1)*. In Bovigen's system of reporting, each star represents one copy of a desirable allele. The example below shows four markers where the capital letter represents the desirable allele. In the Bovigen GeneSTAR system of scoring, each copy of the desirable allele would be equal to one star. Given the genotypes for the four markers below, this animal would have four stars for this particular trait.

Marker 1	*Marker 2*	*Marker 3*	*Marker 4*	*TOTAL*
Aa	BB	Cc	dd	
1 STAR	2 STAR	1 STAR	0 STAR	4 STARS

These tests include more than one DNA marker. In most cases the number of markers range from two to four per trait but in some more markers are included. It is likely that the number of markers per test will continue to increase allowing for more of the genetic variation to be explained by a single test.

How Do They Relate to EPDs?

EPDs estimate 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 their effect. While an EPD accounts for all the genetic variation, the specific sources of the variation (genes) are unknown. DNA marker tests reveal an animal's genotype for specific DNA markers for a particular trait but don't 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 because although the animal has the favorable form of one gene affecting marbling, it may have unfavorable alleles for numerous other unknown genes that affect marbling as well. To understand how this could occur we can use a simple example, such as quarterly scores of a football game.

	1st Quarter	*2nd Quarter*	*3rd Quarter*	*4th Quarter*	*FINAL*
Team A	14	7	0	3	24
Team B	0	3	14	7	24

If you only looked at the first quarter scores it would appear that Team A won by a considerable amount. Second quarter results alone would suggest Team A is still the better team, but by a narrower margin. Third and fourth quarter results suggest Team B is better. However, if you look at the final score (the sum of all four quarters) the two teams tied, or are equal. If you had tried to predict the winner by looking at only one quarter's scores, you would have been incorrect. The same is true when predicting the genetic merit of an animal based on information from a few markers versus an EPD.

Advantages and Disadvantages

Using DNA marker information can allow for early prediction of the genetic merit of an animal 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) or lowly heritable (stayability, heifer pregnancy). Thus, molecular information

can be of greater benefit. Benefits of Marker Assisted Selection (MAS) will be increased once this information is validated and combined with traditional EPDs. The use of this technology for Marker Assisted Mangement (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 with 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. Basing selection on DNA markers alone could have undesirable results if the DNA markers used don't explain a large portion of the genetic variation of a trait. 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. There is ongoing research to develop Genomic Selection, which could potentially include tens of thousands, perhaps hundreds of thousands, of DNA markers to be used for the accurate selection of superior animals before phenotypes are recorded. Because this technology is rapidly changing it's important to stay abreast of current genetic tools and their applications 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). Company Web sites are also listed below in order to provide information regarding sample collection and costs associated with specific tests. This technology is evolving, so tests for new traits, additional markers for current tests, and validation results are continually changing.

National Beef Cattle Evaluation Consortium
http://www.ansci.cornell.edu/nbcec/

University of California, Davis Animal Science
http://animalscience.ucdavis.edu/animalbiotech/Biotechnology/MAS/index.htm

Bovigen GeneSTAR®
http://www.bovigen.com

Merial IGENITY®
http://www.igenity.com

MMI Genomics
http://www.metamorphixinc.com

This publication has been peer reviewed.

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