DNA TESTING: WHAT WE KNOW, WHAT WE DON'T KNOW, AND HOW TO USE IT

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Introduction

Genetic selection tools have advanced substantially during the last decade. Ten years ago, DNA testing was not widely available. Today, several breed associations have started incorporating genomic information into their EPDs. Numerous DNA tests for genetic defects (e.g., fawn calf syndrome) are available. Beef producers can identify sire parentage of their calves when using multi-sire breeding pastures using DNA testing. Although many of the DNA tests on the market today are primarily applicable to improving accuracy of bull selection, DNA testing is also being used for heifer selection as well. It is becoming increasingly difficult for beef producers to keep abreast of the latest advances in genetic technology.

The purpose of this proceedings paper is to update beef producers on the different DNA testing technologies available to improve accuracy of genetic selection. We will begin at a very basic level; however, the reader is assumed to understand the definition of an EPD and how to use EPDs for genetic selection. The available DNA tests can be divided into three basic categories:

1) DNA tests for simply-inherited defects and traits (e.g., fawn calf syndrome, red/black coat color in Angus cattle)
2) DNA tests for determining sire parentage when using multi-sire breeding pastures
3) DNA tests for improving the accuracy of genetic selection (e.g., GeneMax, GeneSTAR, Igenity PROFILE)

This proceedings paper will focus on the third category (in bold).

Genetics Terminology

Before going further, we need to review genetics terminology. The DNA within cattle harbors roughly about 20,000 **genes**, many of which play important roles in reproduction, growth, development, metabolism, behavior, and immune response. These genes provide the blueprint for how a cow develops from an embryo into a calf, how the calf grows into an adult animal, the digestion and metabolism of nutrients, reproductive cycles in heifers and cows, and how an animal responds to pathogens in its environment. Each animal has two copies of each gene. Each of these two copies of a gene are called **alleles**. Thus, each animal will have two alleles for each gene.

The alleles for each gene are not always identical. For example, let's consider the Melanocortin-1 Receptor (*Mc1r)* gene. This gene is responsible for black/red coat color in Angus cattle. In Angus cattle, two alleles[1] at this gene exist: **B** and **r**. Cattle have two alleles at the *Mc1r* gene, and therefore each animal can have two copies of the **B** allele (**BB**), one **B**

[1] A third allele also can be present, but we will ignore this allele for the sake of simplicity.

allele and one **r** allele (**Br**), or two copies of the **r** allele (**rr**). Individuals who are **BB** or **Br** will have a black coat color and individuals who are **rr** will have a red coat color. Thus, whether an Angus animal has black or red coat color is almost completely determined by the alleles the animal carries at the *Mc1r* gene in its DNA.

Black/red coat color in Angus cattle is a **simply-inherited trait.** Many of the genetic defects seen in beef cattle (e.g., fawn calf syndrome, curly calf syndrome) are also simply-inherited trait. A simply-inherited trait is determined by alleles at only a few genes, and often only a single gene. Environmental influences often play a minor role in trait expression. In our black/red coat color example, coat color is determined by the alleles present at the *Mc1r* gene. No other genes or environmental factors influence coat color[2]. As a result, DNA testing available for genetic defects and coat color is close to 100% accurate.

Most of the economically important traits in beef production, however, are **polygenic traits**. A polygenic trait is determined by alleles at hundreds of genes. Environmental influences often play a major role in trait expression, too. A good example of a polygenic trait is weaning weight. Alleles at many genes in DNA determine the weight of a calf at weaning. Additionally, many environmental factors such as nutrition and feed resources, milking and mothering ability of the dam, stress, and weather also affect weaning weight. Because so many variables affect the weight of a calf at weaning, a DNA test can never predict with 100% accuracy weaning weight or any other polygenic trait. However, DNA testing can increase the accuracy of our genetic predictions for polygenic traits, which increases selection accuracy and the rate of genetic progress we can make when selecting for a trait.

What Do We Know and Don't Know About DNA Testing?

The most important two concepts to understand about DNA testing is its benefits and limitations. The major benefit to DNA testing is an increase in selection accuracy. If we can more accurately predict genetic merit for a trait, we will also make faster genetic progress when making selection decisions based on the more accurate data. Below is a list of bulls with weaning weight EPDs and associated accuracies for two herds. Both herds have bulls with exactly the same EPDs, but the second herd's EPDs have higher accuracies.

Table 1. Comparison of two herds with bulls that have identical weaning weight EPDs, but different accuracies associated with the EPDs. Which herd will make the fastest genetic progress for this trait, all else being equal?

	Herd One			Herd Two	
ID	WW EPD	EPD Acc.	ID	WW EPD	EPD Acc.
A	+ 62	0.39	F	+ 62	0.79
B	+ 59	0.42	G	+ 59	0.82
C	+ 47	0.40	H	+ 47	0.72
D	+ 43	0.40	I	+ 43	0.84
E	+ 39	0.43	J	+ 39	0.80

All else being equal, herd two will make the fastest genetic progress. The bulls in herd two have more accurate EPDs for weaning weight. We are more certain that bull F has an EPD of + 62 than bull A because bull F's EPD is more accurate. By using DNA testing, we are increasing the accuracy of our genetic predictions, which will help increase the rate of genetic change.

The major limitation to DNA testing is that not all DNA tests will substantially increase the accuracy of our genetic selections. All DNA tests are not equal. Some DNA tests will more accurately predict genetic merit than others. Even for tests offered by the same company, not all DNA tests are equal. For example, a DNA testing company could offer tests for marbling and feed efficiency, and the marbling DNA test could predict genetic merit for this trait better than the feed efficiency DNA test.

Producers can compare and contrast DNA tests by asking for the **percent genetic variation** explained by the DNA test. Higher percentages of genetic variation explained by the DNA test are better. To explain percent genetic variation, imagine we have three boxes filled with 10 marbles each. Each box represents a different DNA test for marbling, while each marble within a box represents one gene that affects marbling. If the DNA test could explain 100% of the genetic variation for marbling, then the DNA test would be able to "see" all 10 marbles (i.e., genes) in the box. However, to date no DNA test can explain 100% of the genetic variation for a polygenic trait. (Not even an EPD on a proven bull with thousands of progeny records can reach 100% accuracy for a trait.) The three DNA tests below can explain anywhere from 20% to 60% of the genetic variation for marbling.

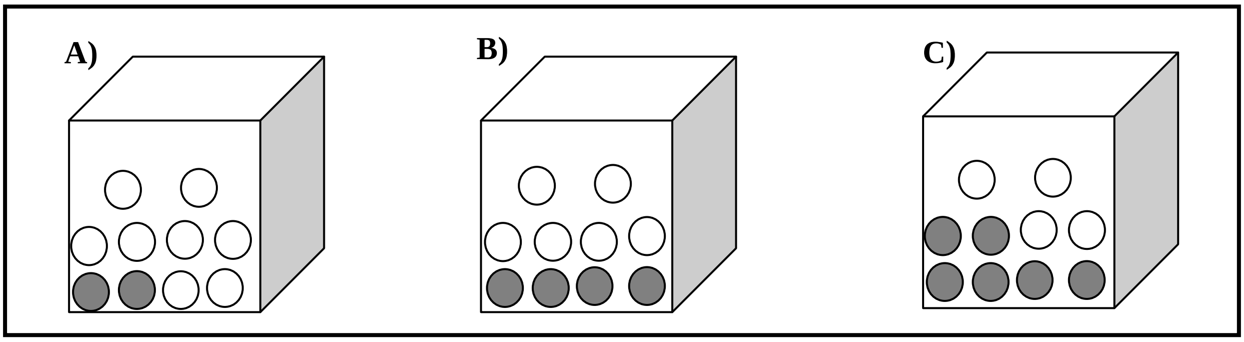

Figure 1. Examples of three DNA tests that explain 20% (A), 40% (B), and 60% (C) of the genetic variation for marbling. Each gray marble represents a gene that is "observed" by the DNA test.

Obviously, in the above example, the best DNA test is (C), which can explain 60% of the genetic variation for this trait. In reality, most DNA tests available to date can explain 10-50% of the genetic variation for the trait of interest. It's important to understand that although DNA testing increases accuracy of selection, it does not explain all of the genetic variation for a trait. An analogy is to compare DNA testing with progeny testing of bulls. A DNA test is equivalent to adding increased numbers of progeny to a genetic evaluation, with the exact number of progeny dependent upon the percent genetic variation explained by the DNA test and the trait itself. Including more progeny in an animal's genetic evaluation will increase the accuracy of the EPD, but will not explain all of the genetic variation for the trait (i.e., an accuracy of 100%). Similarly, DNA testing will improve accuracies of genetic prediction, but accuracy is not 100%.

Numerous companies and breed associations now offer DNA testing for polygenic traits. By the time you read this proceedings paper, this list will probably be out of date. Pfizer Animal Genetics, in partnership with the American Angus Association and Red Angus Association of America, now offers a 50K HD test for purebred Black and Red Angus cattle. The American

Hereford Association also has begun DNA testing for purebred Herefords. Igenity (now Neogen) is marketing a 50K HD test for purebred Black Angus and for commercial cattle. Pfizer Animal Genetics is still marketing GeneSTAR, which was one of the first DNA tests available to the beef industry. GeneSTAR predicts genetic merit for commercial cattle. Finally, Certified Angus Beef is offering a GeneMax DNA test for cattle with 75% or greater Black Angus genetics.

You may notice that some DNA tests are breed-specific, while others can be used on all cattle regardless of breed composition. The more accurate DNA tests are breed-specific. Animal geneticists have learned that many of the genes that are important for a trait in one breed of cattle are not as important in other breeds. Thus, right now, DNA tests are being developed that are breed-specific. Breed-specific DNA tests are available for Black Angus, Red Angus, and Herefords. A future goal would be to develop a highly accurate DNA test that could be used on all breed types of cattle.

How to Use DNA Test Results

Ideally, your DNA test results will be incorporated into traditional EPDs. A **genome enhanced EPD** is an EPD that includes DNA test, pedigree, and progeny information. Genome enhanced EPDs are the best way to utilize DNA test results because producers only need to evaluate one number when making selection decisions on a single trait. It's difficult for individual producers to judge whether more emphasis should be placed on the DNA test results or the traditional EPD (without DNA test information). Genome enhanced EPDs solve this problem by weighting the DNA test information relative to the accuracy of the DNA test and the number of progeny records available on an animal. The breed-specific Black Angus, Red Angus, and Hereford DNA tests are all used to calculate genome enhanced EPDs by their respective breed associations. Beef producers only need to submit DNA samples for these tests; the breed associations will automatically include the DNA test results when calculating genome enhanced EPDs.

Some DNA tests do not offer the option of inclusion in an EPD. These tests are usually available for all commercial cattle (i.e., not breed-specific), with the exception of Certified Angus Beef's GeneMax test. The DNA test results are reported to producers as either Molecular Breeding Values (e.g., Pfizer) or categorical 1-10 scores (e.g., Igenity). The Molecular Breeding Values (MBV) can be interpreted similarly, but not identically, to EPDs. For example, the following are two MBVs for tenderness (interpreted as lbs. of Warner-Bratzler Shear Force (WBSF), where lower MBVs are more desirable).

Animal "A"	0.37 lbs. MBV Tenderness
Animal "B"	0.13 lbs. MBV Tenderness
Difference A – B	0.24 lbs. MBV Tenderness

Thus, Animal "B" is expected to be 0.24 lbs. more tender (based on WBSF) than Animal "A". Because we are interested in selecting animals that will produce more tender progeny, it is more appropriate to compare the expected progeny difference between these animals based on the MBVs. In this case, we need to divide the difference by two.

Difference between progeny sired by Animal A and Animal B 0.24 / 2 = 0.12 lbs. MBV

Thus, Animal “B” is expected to produce progeny that are 0.12 lbs. more tender than progeny from Animal “A”. This last step is unnecessary when comparing EPDs between animals, but becomes necessary when comparing MBVs.

The categorical 1-10 or 1-5 scores are more difficult to interpret. At first glance, these numerical scores seem the easiest to understand: an individual with a numerical score of 10 for ribeye area, for example, has a larger ribeye area than an individual with a numerical score of 5. However, how do you define “larger”? Without quantifying how much better one animal is relative to other animals, it becomes difficult for beef producers to know how much importance to place on the DNA test results. Some companies do relate these numerical scores to effect sizes, but this step is an extra burden placed on beef producers who use these DNA tests.

Conclusion

DNA testing can increase accuracy of selection in a shorter amount of time than can be achieved by progeny testing. The improved accuracy of selection will result in faster genetic gains. Producers must also understand the limitations of these tests. No DNA test can explain all of the genetic variation for a trait, and not all DNA tests are equal. Some DNA tests explain a larger percentage of genetic variation for a trait than other tests. Further, the most powerful tests are breed-specific. Ideally, DNA test results should be incorporated into EPDs as genomic enhanced EPDs. This step provides only a single number that producers need to evaluate when making selection decisions, as opposed to trying to interpret DNA test results and traditional EPDs simultaneously.

Notes