Why Haven't We Seen an Improvement in Quality Grade? A Genetic Improvement Perspective

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Perhaps one of the most perplexing questions facing the U.S. beef industry is "Given the amount of perceived emphasis placed on genetic selection for carcass traits, why has the percentage of carcasses grading choice not increased over that period?" Like any complex question, this one has a complex answer, where a number of genetic and environmental factors interact to determine the distribution of quality grades. While the accompanying paper and presentation will address the environmental factors, a number of genetic considerations merit consideration as the industry examines how greater genetic improvement of beef quality might be created in the future.

Rate of Genetic Change. Bourdon (2000) explains the factors affecting the rate of genetic change with the following equation:

$$\Delta_{BV} / t = \frac{r_{BV,EBV}\, i\sigma_{BV}}{L}$$

where $\Delta_{BV} / t =$ rate of genetic change per unit of time (t)

$r_{BV,EBV} =$ accuracy of selection

$i =$ selection intensity

$\sigma_{BV} =$ genetic variation

$L =$ generation interval

Each of these four factors impact the rate at which genetic improvement of beef quality is occurring, and each is a result of decisions made by breeders and their organizations. Let's examine each of factors more closely, discuss their current status with regard to beef quality, and evaluate how breeders might alter them to result in more rapid genetic improvement.

Genetic Variation. While our industry is often scolded for the great diversity of genotypes that exist within its population, animal breeders view that variation as an asset, not a liability.

> *"Variation – differences between individuals – is the raw material on which the breeder works,"*
> *Lush, 1945*

Indeed, greater genetic variation does result in greater genetic change through selection, because the "best" animals have greater advantage over the average of the population. But highly effective directional selection typically results in loss of genetic variation, as only the most desirable animals contribute genes to the next generation. Selection for increased milk production in Holsteins is a classic example, and the amount of genetic diversity that remains in that population is minimal, leaving the breeder with limited opportunities for further genetic change. While the beef industry still enjoys both a relatively large number of significant breeds, and a reasonable amount of variation within those breeds, Cundiff and others at the U.S. Meat Animal Research Center (MARC) report that the major beef breeds are less divergent than they once were, with British breeds increasing in growth rate and mature size similar to that found previously in continental breeds. From the standpoint of beef quality improvement, it is fortunate that the most prevalent breed at the current time is superior for this attribute. Still, greater change would be possible if other breeds would more aggressively develop superior meat quality lines, enabling commercial producers to emphasize quality when selecting sires of multiple breeds for crossbreeding systems.

Other than black Angus, most beef breeds show a relatively flat genetic trend for marbling score over the last two decades, and even black Angus cattle of the current day under perform those of the 1970's with regard to marbling score. While genetic variation increases and decreases with aggregate breeder selection decisions, this factor is largely out of the control of the individual breeder.

Selection Intensity. While genetic variation describes the potential advantage that could be realized through selection of superior genetics, selection intensity describes how much of that potential has been realized. Selection intensity is the superiority of the animals selected to be parents of the next generation, compared to the average of population from which they were chosen. Maximum selection intensity occurs with single trait selection, but the greater the number of other traits selected for, the less intensity and less change resulting for each trait. This is one reason that the rate of genetic change for any trait in beef cattle is relatively slow. With the non-integrated, independent structure of the beef seedstock industry, many individual breeders make different selection decisions. Marbling score is but one of a large number of economically relevant traits, and breeders have differing opinions as to the true economic reward of increased marbling, especially if feed conversion suffers or cow maintenance costs increase as a result. While grid marketing provides economic rewards to those selling high marbling cattle, ownership of fed cattle is retained by a relatively small proportion of cow/calf producers. Our feeder cattle marketing system insufficiently values calves with superior genetic potential for quality grade, although progress is being made in this area. If market signals more clearly indicated significant increases in profit associated with higher marbling scores, more intense selection would likely occur. Selection intensity is also limited when genetic correlations with other traits are unfavorable, but in the case of marbling score, there is little evidence that serious unfavorable correlations exist.

Accuracy of Selection and Generation Interval. This juxtaposition of these factors is to illustrate how they interact to have a significant impact on the rate of genetic change. High accuracy of selection can almost always be achieved for a highly heritable trait like marbling, but accumulating the necessary data takes time, lengthening generation interval. Likewise, generation interval can be shortened by the use of younger, less proven sires, but accuracy suffers under that scenario. The greatest opportunity for the beef industry to enhance the rate of genetic improvement for marbling lies in technologies and techniques that provide more accurate information on sires at an earlier age.

Traditional selection using EPD calculated from progeny carcass data, while accurate, is far from timely. A sire must be at least four years of age by the time progeny carcass data is included in EPD calculations. The premise of ultrasound estimation of marbling score and other carcass attributes of live breeding animals is that by scanning the potential sire at a year of age, a more precise estimate of that animal's genetic merit can be made at that time, allowing relatively accurate selection with a dramatic reduction in generation interval. Also, ultrasound scanning should identify the most promising animals for progeny testing. However, the implementation of ultrasound evaluation has been less than optimum, and some changes might make this an even more useful tool for genetic enhancement of beef quality.

One misuse of ultrasound information that limits genetic progress is the use of actual or adjusted scan data in selection and marketing, rather than EPD. While centralized processing of ultrasound images should reduce technician bias and make scan measurements seem more comparable across herds, environmental influences still exist that significantly bias the actual scan measurement as an indicator of genetic merit. Furthermore, like any prediction equation, those equations used to predict intramuscular fat (IMF) from ultrasound images are most accurate on animals are near the center of the distribution. In contrast, the animals sought in selection are the most extreme, highest IMF animals, thus their predictions are subject to the greatest error. Use of IMF EPD for selection tempers that error, by including pedigree information in addition to the animal's own evaluation. But because of this, the resulting interim EPD tend to remain closer to the breed average than the actual scan measurements, so the more extreme actual values may command more interest when used in marketing, despite the fact that they are poorer predictors of true genetic merit.

Ultrasound measures of IMF are also useful tools in evaluating a young sire's first calf crop, and a sire's first groups of scanned yearlings are often the best indicators of what his marbling EPD will ultimately be. Still, the timeliness of information transfer is somewhat limited by our traditions. Most breeds conduct two complete genetic evaluations (BLUP runs) per year. Usually one is done in late fall, after spring-calving herds have submitted weaning weights, and fall calving herds have submitted birth weights, yearling weights, and scan data. Sometime in the summer, a second run is conducted, including new weaning data from fall calving herds and new birth, yearling and scan data from spring calving herds. Since most U.S. herds are predominately spring calving, the bulk of the scan data is collected in January through March, and is first fully analyzed in the summer. If a spring-born sire's first yearling progeny are scanned when he is three years of age, his IMF EPD will reach a relatively high accuracy level in time for use when he is four years of age, similar to a carcass data evaluation. Interim EPD are provided on the progeny that are scanned, but their sire's EPD is not updated until the next full run of the evaluation. If an additional run could be conducted in March, a significant amount of new scan data would be included compared to what was available in November or December, yet results could be communicated before breeding for the next year's spring calf crop. No doubt this additional run would require additional coordination and communication on the part of breed associations and artificial insemination organizations, but the full-year reduction in generation interval could be well worth it. If merited, a fourth run could be conducted in mid-fall for the benefit of fall matings. Eventually, beef genetic evaluations might be run weekly or even nightly, rather than semi-annually.

Another issue with ultrasound data arises from the way the resulting EPD are presented. Most beef breeds combine carcass and ultrasound data into one marbling EPD, as well as one EPD for ribeye area and one for fat thickness. But at least one major breed still publishes separate carcass and ultrasound EPD. A few breeds with a combined evaluation publish the ultrasound EPD for the indicator trait of IMF, instead of the marbling EPD on the economically relevant trait. Reasons for doing so may be legitimate, but accuracy of selection suffers. In fact, when EPD are presented for ultrasound IMF instead of carcass marbling score, the associated accuracy values are overestimated, because they reflect the accuracy of selecting for the correlated trait (IMF), not the true economically relevant trait of marbling.

Most estimates of the genetic correlation of IMF measured in breeding bulls and heifers with carcass marbling in fed steers and heifers hover around 0.70, although estimates are lower in some continental breeds. Some producers and scientists incorrectly interpret this correlation to imply that with infinite ultrasound IMF progeny data, the accuracy of selection for marbling is capped at 0.70. This would be true if U.S. beef genetic evaluations expressed accuracy values as the correlation between true breeding values and their estimates. But at a BIF meeting over

20 years ago, it was decided to use a more conservative accuracy number to create a greater range of accuracy values between young animals and proven sires. So our interpretation of this correlation's impact on indirect selection for marbling using ultrasound IMF needs to be adjusted to the BIF accuracy scale currently used. Examples follow in the table below, with the result being that selecting on an IMF EPD of 0.90 gives the same accuracy of selection for improving marbling as a carcass marbling EPD with accuracy of 0.28 on the BIF scale. In fact, an infinite amount of IMF progeny data, with IMF EPD accuracy approaching 1.0, would be equivalent to a carcass marbling EPD accuracy of 0.29.

Accuracy of IMF EPD, BIF Scale	0.900	0.700	0.500	0.300
Correlation of IMF EBV and IMF true BV	0.995	0.954	0.866	0.714
Genetic Correlation between IMF and Marbling	0.700	0.700	0.700	0.700
Correlation of IMF EBV and Marbling true BV	0.696	0.668	0.606	0.500
Accuracy of Selection on IMF EBV to improve marbling, BIF Scale	0.282	0.256	0.205	0.134

This isn't to say that ultrasound IMF measurements aren't useful, in fact, for young animals, they are likely the most powerful selection tools currently available. An EPD accuracy of nearly 0.30 conveys useful information, just less than a higher accuracy one. However, producers make more informed and correct selection decisions when carcass and ultrasound data are combined into a single set of EPD, with the EPD and accuracy values published for the carcass traits. A subcommittee of the BIF Genetic Prediction Committee made this very recommendation in 2006.

Whenever producers discuss calculation of carcass EPD, the endpoint used for adjustment of the data is often raised. In nearly every case, beef carcass genetic evaluations adjust data to a constant age. Yet, age is usually unknown and rarely a consideration when marketing decisions are made. Frequently, fat thickness, weight or marbling score are offered as more appropriate endpoints for carcass data.

Some of the early carcass EPD used a fat thickness endpoint, but when measurements are adjusted in this way, no fat EPD is calculated. Rather, selection for reduced fat would result from bulls with higher carcass weight EPD, so that their progeny would be leaner at a constant weight. Furthermore, rate of growth and age at finishing are economically important traits, and while some cattle are inherently younger or older at harvest due to the length of the backgrounding period, this variation should be consistent within contemporary group. Using a fat thickness endpoint would be somewhat risky, since fat thickness may be incorrectly measured due to hide removal, and that incorrect measurement would be used in adjusting all other traits.

Furthermore, there is good evidence that the results of genetic evaluation for carcass traits are consistent regardless of endpoint. Most studies have found that heritability does not change across endpoints. A recently published study by Rumph et al. (2007) found that rank correlations among most carcass EPD were high whether the endpoint used was age, fat, carcass weight, or ribeye area.

DNA tests are another category of tools that like ultrasound, aims to provide accurate information upon which to base selection early in the animal's lifetime. Since the first DNA test for marbling was announced at the 2000 BIF meetings, a number of competing products have entered the marketplace, most focused on meat quality attributes like marbling and tenderness. The primary DNA test for marbling, and the only to be validated by the National Beef Cattle Evaluation Consortium, is GeneSTAR Quality Grade. GeneSTAR Quality Grade is a panel of four single nucleotide polymorphisms, and evolved out of the original thyroglobulin SNP test introduced in 2000. Recently, MMI Genomics began marketing Tru-Marbling, a panel of 128 markers associated with marbling and quality grade.

While these tests have great potential, they also have limitations. Marbling is a complex trait likely influence by a large number of genes, as well as many environmental influences. While some of the current tests may include markers linked to some genes influencing marbling, researchers are unlikely to have markers for all marbling genes any time in the near future, and it is difficult to estimate exactly what proportion of the genetic variability is explained by these tests. Statistical significance of many of these tests in independent validations has appeared marginal, and cost is a significant barrier to widespread utilization. Gene frequency is also a consideration, especially when the proportion of certain favorable alleles is as low as four to six percent in some tested populations of major breeds.

While such tests have the potential to greatly add to the genetic information known on a young animal, they provide little new information for selection on proven sires with high accuracy marbling EPD. It would be a serious mistake to not use a highly proven sire with superior marbling EPD, just because his DNA tests were unfavorable. The favorable EPD indicates he must have a large number of desirable marbling genes, but perhaps not the ones identified by the DNA tests.

Lost in the discussion of new tools is the increased opportunity for greater collection of traditional carcass data. While a national animal identification system may be off the front burner, a large number of source-verified feeder cattle programs have been developed. These programs lend the ability to track animal and sire identify from ranch to cooler, greatly reducing the management required to obtain carcass data on the calves, and submit that data to the breed association. Automated grading and data collection systems are in place in several major packing plants. While these systems, like live animal ultrasound, are not perfect evaluators of marbling score, neither are USDA graders or carcass data collection services. All data collection is subject to some error, but the large amount of data that might be captured by these systems could greatly add to our genetic evaluations for marbling and other carcass traits.

A final consideration is likely both the least controversial and the most important. Cattle breeding is a long-term proposition, where generation interval averages five years or more. When you consider that we measure genetic change in seedstock populations, but evaluate phenotypic change in commercial cattle, it's not surprising that there is a time lag between genetic and phenotypic change. The combination of patience, a necessary but somewhat scarce ingredient for successful cattle breeding, coupled with critical evaluation of technologies old and new, should result in visible improvement of beef quality in the future.

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