Trends and Developments in Genetic Evaluation of Beef Cattle in the United States

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Summary

Structural changes in the servicing of EPDs for US beef cattle interests have been proposed since the advent of the federally-funded National Beef Cattle Evaluation Consortium (NBCEC) in 2001. In the future, breed associations will use a single entity for the provision of routine servicing of genetic evaluation rather than maintain separate relationships with Land Grant Universities. In the short- to medium-term, the Land Grant Universities will focus on the development of the next generation of evaluation software for transfer to the new entity. In the medium- to long-term, the universities, through the NBCEC, will have a much stronger research and development focus. The NBCEC has already developed evaluation tools for some new suites of economically-relevant traits for the cow-calf sector including heifer pregnancy, stayability, and mature cow maintenance energy requirements. Further developments are progressing on new traits for the postweaning phase. These include "value at finish" and "days to finish." Genetic markers have been incorporated along with pedigree and performance data to account for uncertain pedigree and to combine marker and phenotypic data in a single analysis. A national multi-breed evaluation for growth is being prototyped, along with a single database for storing pedigree and performance records prior to genetic evaluation and for the resultant EPDs. A prototype decision support tool for comparing the merits of alternative sires within a system context has been developed and will be linked to this single national EPD database.

Background – Some Brief History

Genetic evaluation of beef cattle in the US has had a different history from that of other livestock species. The poultry and swine industries developed around commercial nucleus breeding programs that undertook their own performance recording and evaluation. The dairy industry structure included centralized records processing laboratories, commercial AI companies and a federally-funded evaluation system researched and administered by USDA personnel in Beltsville, Maryland. In contrast, the seedstock component of the beef cattle industry was partitioned by breed associations, each of whom undertook their own pedigree and performance data collection and subsequent reporting on behalf of members. The level of complexity associated with analytical techniques for producing EPDs and the rapid rate of development in such approaches led various breed associations to become aligned with Land Grant Universities for the research and servicing associated with the methodology and

calculations used for ranking animals. By the 1980s, four universities were responsible for evaluating the national seedstock herd. These were Colorado State University, Cornell University, Iowa State University, and The University of Georgia.

The major developments in beef cattle evaluation in the 1970s and 80s were fundamentally of a statistical and computational nature and were dominated by contributions made at Cornell University, first by Dr. Henderson, and then by Drs. Quaas and Pollak. These included the development of Best Linear Unbiased Prediction (BLUP) theory, evidence that it was feasible to compute BLUP EPDs from mixed model equations, and rapid methods for computing the inverse of the numerator relationship matrix. During this time, the scope of EPDs was increased in terms of the animals that obtained evaluations (from sires, to sires & maternal grandsires and then to all animals) and in terms of the traits evaluated. Starting with growth traits, calving ease and carcass traits were progressively added to the list of traits for which EPDs were routinely provided. Statistical models became increasingly sophisticated, accounting for maternal effects, heterogeneous variance, threshold traits, genetic groups, heterosis and, more recently, external EPDs. Funding for these developments was principally provided through faculty support via the land grant system. Breed associations paid for some of the servicing costs associated with routine evaluations but typically did not contribute to equipment and to noncash expenses. Changes in accountability and increasing need for extramural funding at universities dictated that such a model for research and servicing of genetic evaluation was no longer sustainable as we moved in to the next millennium.

The solution was the National Beef Cattle Evaluation Consortium (NBCEC). Its task was to develop a vision for a sustainable system for research and servicing of genetic evaluations. Training graduate students in various aspects of livestock improvement was also recognized as an important aspect of the NBCEC activities as was the provision of extension/outreach related to developments in animal breeding. The consortium was established in 2001/02 with a federally-funded “umbrella” encompassing the four universities involved in genetic evaluation. The NBCEC heralded a new era in beef cattle evaluation in the US, with clear goals and objectives and some ambitious projects planned. The consortium works closely with its stakeholders, particularly breed associations and represents a much more unified research, development and delivery outlook for the US beef industry than had previously been the case. The remainder of this article outlines some of the philosophical aspects and research developments relating to genetic evaluation that have occurred during the NBCEC tenure.

Traits Assessed – Economically Relevant vs Indicator Traits

Growth traits were the first characteristics for which routine EPDs were derived. In practice, genetic improvement always involves a portfolio of traits encompassing a number of different activities, such as growth, end-product quality attributes, reproduction, longevity, and disease. The landmark exposition of multiple-trait improvement came out of Iowa more than 50 years ago. Hazel (1943) explained the concept of index selection whereby a new trait known variously as aggregate genetic

merit, overall merit or index merit is defined. Index merit represents the economic worth of an animal in the context of a production system. It summarizes the value of the favorable and unfavorable genetic attributes of a parent. It is obtained by first determining the list of traits that influence the goal of the production system. Second, the relative emphasis of each of the attributes in the list is determined. In the context of a profit-based goal, these are frequently referred to as relative economic values. They are the values of a unit change in that particular attribute, where all other attributes in the list held constant in the system. In Hazel's description, the outcome of multiple-trait genetic evaluation of so-called selection criteria would be the index values of aggregate merit.

Producing Hazel's index values were somewhat problematic. A major limitation was that the relative economic values for each of the traits influencing the goal had to be known in advance of the evaluation. Henderson (1951) demonstrated that the identical index values could be obtained in a two-step process. First, the EPDs for each of the traits in the list were obtained using the measured selection criteria. Second, these EPDs were weighted by their relative economic value and added together to give the index value. As a consequence of this alternative approach to index construction, animal breeders could focus on the problem of deriving EPDs for the component traits (influencing aggregate merit) from relevant pedigree and performance records. Although it was well-recognized that reproductive performance was a critical component of system profitability, this trait complex was hard to define and problematic to obtain EPDs from a statistical viewpoint (with categorical observations such as pregnant or not) and from a practical viewpoint (with observations only becoming available late in life after candidates have been selected to become parents). Initial EPDs therefore focused on easy to measure income traits, such as weights at various ages.

Over time, breed associations have built up considerable performance databases that include many attributes other than growth. Progressive associations introduced inventory or total herd recording and have been able to collect various measures of reproductive performance. Since data can be collected, it can be used to produce EPDs. Accordingly, an increasingly large list of EPDs has been generated, now spanning more than 50 different traits. Bull breeders, breed association personnel, and quantitative geneticists lost sight of Hazel's philosophical approach, overlooked the economic relevance of various traits and computed EPDs for many traits just because data existed.

In this regard, a foundation principle that the NBCEC has been using and communicating relates to the concept of economically relevant vs indicator traits (Golden et al, 2000). According to this philosophy, various performance attributes are either economically relevant or indicators of economically relevant traits. An economically relevant trait (ERT) is one that directly influences income or expenses and therefore profit. The EPDs for ERTs are what are required to construct Hazel's index using Henderson's two-step approach. An ERT will have a nonzero economic value, regardless of the other traits that are included in the selection objective. An indicator trait, in contrast, has no direct economic value – it does not itself influence income or expenses. However, it may be correlated with an ERT, and therefore data collection and analysis can be useful in

producing EPDs for ERTs. This distinction between indicators and ERTs is best illustrated by example.

The positive genetic correlation between scrotal circumference and female fertility implies that scrotal circumference would be a useful early indicator in males of reproductive merit in females. As a result, breed associations collected scrotal circumference (SC) records, and EPDs were produced. The interpretation of SC EPDs is problematic unless one knows the conversion of the circumference measure into some measure of reproductive performance such as calving rate. The trait is an indicator because it has no value if reproductive performance EPDs are included in the same index as an SC EPD. Consider two bulls with different SC EPDs but with the same high accuracy EPDs for reproductive performance. Provided the scrotal circumference data was included in the estimation of the reproductive EPD, these bulls will produce daughters with similar reproductive performance despite having different SC EPDs.

The value of a slaughter animal is influenced by quality attributes of the carcass such as marbling score. Bulls with different EPDs for marbling will have different value as sires. Carcass marbling measures are expensive to obtain and must be obtained on progeny or other relatives rather than on the individual of interest. One solution is to measure correlated indicator traits using ultrasound, such as intramuscular fat in the rib eye. Such measures can be used, along with carcass data, in multiple-trait prediction of carcass EPDs. The ultrasound EPD has no value if the corresponding carcass EPD is accounted for and the ultrasound data were used in the derivation of the carcass EPD.

Calving ease (or difficulty) is influenced by direct and maternal attributes. Producers have recognized that a disparity between the size of the calf and the pelvic dimensions of the cow can lead to calving difficulty. Accordingly, birth weight is a useful indicator of calving ease. Birth weights should be used in predicting calving difficulty. However, given EPDs for calving difficulty, knowledge of birth weight EPDs have no economic value. Two bulls with the same calving ease EPDs but different birth weight EPDs will not differ in value for calving ease.

The NBCEC, in a viewpoint shared by many breed associations, believes that the industry needs to focus on generating EPDs for ERTs. This includes collecting, recording, and analyzing records on indicator traits. However, publishing EPDs for indicator traits along with the corresponding EPD for the ERT is counterproductive. Many associations now use both carcass and ultrasound data in a multivariate analysis to produce carcass EPDs but do not publish the ultrasound EPDs.

Considering a cow-calf production system from the viewpoint of economically relevant traits indicated that some of the critical components from a system perspective did not have corresponding EPDs. These included heifer pregnancy (influencing replacement rates), stayability (reflecting reproductive and other causes of wastage that alter herd age structure and number of first calvers), and mature cow feed requirements. Colorado State University developed EPD systems for these three traits (Doyle et al, 2000; Snelling et al, 1995; Speidel et al, 2004), which are all available to the industry. The Red Angus

Association was the first to adopt these. The addition of these three traits makes the comparison of alternative sires in terms of system profitability much more straightforward and reliable than is the case when only growth and carcass attributes are available.

In the context of cattle finishing, many of the currently available EPDs are not particularly relevant to the income and expenses involved in feedlot enterprises. For example, carcass EPDs might be adjusted to a constant weight, adjusted to a constant age, or left unadjusted. A feedlotter needs to know what the value of the carcass will be at their particular endpoint. They also need to know how long the animals will take to reach that endpoint as time to finish is a major determinant of costs. Some future ERTs for finishing will be *days to finish* and *value at finish*. Delivering such ERTs in a paper system is problematic as different feedlotters my use different endpoints and this can alter rankings. Such ERTs will be delivered within the context of a web-based decision support system.

Revisiting Growth. Growth traits were the earliest to be used in producing EPDs and are the traits that have been the most widely collected. Typically, the weights recorded with breed associations have included birth, weaning, and yearling weights. To a lesser degree, mature cow weights have been collected. The usual approach to the analysis of weight traits has been to linearly standardize them by age (to 205 days for weaning weight and 365 days for yearling weight) prior to multitrait analysis. The standardization of these weights does not adequately remove the effect of age at measurement and further adjustments are usually included in the model used for calculating EPDs. This approach to weight traits has proven problematic in recent times for three reasons. First, in drought years there is a considerable management advantage associated with early weaning. However, only weaning weights collected from 160 to 250 days of age are acceptable for inclusion in the analysis according to Beef Improvement Federation Guidelines. Second, with the advent of electronic eartags and automated weighing systems, some producers are interested in weighing animals more frequently than simply on these three occasions. Such weights cannot currently be used. Third, many animals are sold or harvested at ages other than weaning or yearling age and accordingly an EPD at sale age is of interest. The University of Georgia has been investigating approaches including random regression for accounting for these three concerns (Bohmanova et al, 2005; Legarra et al, 2004; Robbins et al, 2005). The use of random regression would result in new EPDs to characterize the growth curve of each animal. A function of these EPDs could be used to form a sale weight ERT. There would be little merit in publishing the EPDs that describe the random regression coefficients, nor in publishing EPDs for weight at every possible sale age. Customized EPDs could readily be created in a decision support system to provide the flexibility required for different sale weights. The next generation of growth trait evaluations developed by the NBCEC is likely to use such new procedures.

Overall Merit - Monetary Indexes. In an effort to link the value of component trait EPDs to overall value, breed associations have shown increased interest in adopting Hazel's index approach. The problem with index construction is much the same as it was

in Hazel's day. How does one calculate the economic values? What assumptions should be made, what average level of performance should be assumed, what future price expectations are reasonable? Given these assumptions, economic weights can be constructed and index values generated. Some breed associations have constructed such indexes, but in most cases it is not clear exactly which traits are included in the index nor what assumptions have been made. Such an index is suggestive of "one size fits all" although this has sometimes been overcome by producing a portfolio of monetary indexes. Sadly, this contributes to the proliferation of EPDs and, in the worst case scenario, can actually make selection more difficult rather than more straightforward. Over the years, there have been many attempts to introduce indexes for beef cattle improvement, but few have been adopted by industry. The NBCEC prefers an approach that does not contribute to a proliferation of new monetary indexes and that can demonstrate to the user the productive and economic implications of using particular animals as sires. This could be described as "sire selection by simulation," but it is really an alternative more modern approach to index construction that will be covered later in this paper under the heading "Decision Support." It readily provides for index customization and readily enables simultaneous filtering of animals on many different criteria.

Adaptability. The performance of cattle in any environment is influenced by their response to stress. There are three major kinds of stressors that influence performance: heat, nutrition, and disease. Different environments can differ markedly for one or more of these stressors. There is a growing opinion among bull breeders and bull buyers that the ranking of their animals needs to take account of individual stress conditions. For example, an Angus breeder at high altitude (above 5,000 ft) expects the ranking of sires to differ from the ranking that is appropriate nearer sea level because of susceptibility to high-altitude disease, which is known to be heritable (Enns et al, 1992). Some cattle are "adapted" to a certain subset of environments, whereas others are not. There are a number of different approaches to handle the issue of adaptability which is really just a form of genotype-environment interaction. In some cases, breeds are adapted for certain conditions, and adaptability is automatically handled when one considers that breed on its own. Other breeds, such as Angus, are used in a wide range of environments and other approaches are more relevant. This might simply involve filtering the sire summary to animals whose performance records were collected in a "like" environment or partitioning of national records to facilitate multitrait analysis for different environments. Adaptability is a theme that NBCEC is currently exploring with its stakeholders.

Disease. A number of disease conditions are known to be heritable, but no such traits are yet routinely included in US national evaluations for beef cattle. The NBCEC has been investigating two disorders. Colorado State University routinely produces evaluations for a small number of herds prepared to invest in the costly measurements of pulmonary arterial pressure for high-altitude adaptability. Iowa State University undertook a major review of genetic disorders in beef cattle. Then, in conjunction with the American Angus Association, they began a major field project investigating the genetics of pink eye in cattle. It will take several years to collect information on a variety of sire families, but it is hoped the research may lead to techniques for routine genetic

evaluation of this economically important trait. Preliminary results regarding a genetic contribution to pink eye are encouraging.

Data Used – Multi-Country and Multi-Breed

The use of breed association data in genetic evaluation has tended to limit performance records primarily to those animals registered with a breed association. Due to the regular transfer of animals between the US and Canada, it has often been appropriate to combine the US and Canadian databases for multi-country genetic evaluations. Whereas in Europe the exchange of animals across borders is very common and a pan-European analysis makes considerable sense, the value of extending the analyses beyond the North American borders is not obvious. In contrast, the US industry has exploited crossbred and composite cattle at both commercial and seedstock levels. Some breed associations have actively sought to include records from crossbred animals into their databases. There is enormous interest at industry and seedstock level in multi-breed analysis that would produce EPDs for all contributing breeds on a single genetic base.

The first approach to multi-breed analyses used groups, heterosis, and "external" EPDs from the "external" breed association analysis in order to facilitate combined analysis (Pollak & Quaas, 1998). However, as interest in multi-breed analyses increases, it makes more sense to combine the entire data sets of collaborating associations. Accordingly, following the leadership of the Red Angus Association of America, the NBCEC is prototyping a multi-breed growth analysis that will include the pedigree and performance records of at least the Beefmaster, Braford, Brangus, Charolais, Chianina, Gelbvieh, Limousin, Maine Anjou, Red Angus, Red Brangus, Salers, Santa Gertrudis, Senepol, Shorthorn, Simmental, and South Devon breed associations in the US and some of their Canadian counterparts. The major technical issues of such an analysis relate to combining separate pedigree and performance information while recognizing those animals that are common to more than one breed association database. Some associations record the original association registration number of outside animals, but not all associations do this. In the long run, there is real promise for a combined analysis of many if not all breeds. It should be noted that popular sires in breeds that have not currently elected to participate (such as American Angus) will still be evaluated in the multi-breed run. This is by nature of the many crossbred offspring popular sires will have produced that are recorded by those breed associations that encourage the collection of crossbred records. Technical challenges aside, market forces will ultimately dictate the number and nature of separate evaluations in the same way that they have contributed to changing dynamics of breed associations over the last century.

Validation of Genetic Marker Tests

The availability of genetic markers in the research and commercial fields has matured to the extent that several companies now offer genotyping services. These include genotyping for the purpose of parentage determination in multiple sire pastures and

genotyping for the purposes of predicting genetic merit. The NBCEC, through the leadership of Cornell University, has been prototyping ranch-based systems for collecting performance information on multiple sire mating groups in order to combine records from unregistered (commercial) animals with the pedigree and performance records of seedstock animals. This has proven particularly appealing to large ranches, with or without their own breeding programs, as it allows them to validate sire performance in their environment and to obtain objective information comparing alternative sire sources. In the long term, such analyses might make use of external national EPDs, or alternatively the crossbred data might be directly included in multi-breed analyses. In either event, the use of DNA for parentage determination reintroduces some new technological issues as some fraction of the animals represented in the analysis will have uncertain parentage. Uncertain parentage occurs because DNA testing provides for the exclusion of candidate sires and dams as being the parent of any particular individual. Unless a very large number of DNA tests are undertaken, some offspring will have more than one candidate sire (or dam) that cannot be excluded.

Specific tests for marbling (thyroglobulin) and tenderness (mu-calpain and calpastatin) have been marketed in the US for some time. In response to industry requests to the NBCEC as to the role of these tests in genetic evaluation, an independent validation service has been offered. The NBCEC maintains a knowledge base of available performance data and makes DNA available to testing companies, at their expense, to generate "blind" genotypes. The NBCEC runs the analysis to demonstrate the utility of the test in the chosen population. Following the validation of mu-calpain, the genotyping data were combined with Warner-Bratzler shear force data to produce the first national evaluation that combined genotypic data with pedigree and performance data. Calpastatin data have not been included in the national evaluation because, to date, that test has not been independently validated. The use of marker genotypes in national evaluation is proving challenging because such data are not routinely captured by breed associations and the most readily available genotypic information is limited to those animals that were shown to have the favorable genotype. Consequently, the proportion of animals with genotypic data is likely to be low. Nevertheless, as increased number of marker tests become available, appropriate strategies will need to be routinely implemented.

Servicing – Moving Away from the Duplicated University Model

The servicing of genetic evaluations for breed associations uses land-grant funded resources, such as laboratory space and computers, in addition to faculty input. In the long run, this is not a sustainable option. Since the inception of the NBCEC, Iowa State University has seen the retirement of relevant faculty and a refocus more strongly in the molecular area. The evaluations for which they were responsible have been taken in-house by the American Angus Association. This leaves only three universities that are routinely involved in national beef cattle evaluation. The industry vision is that servicing should migrate to a new entity – some form of third-party organization. Land-grant resources should then be used to support research and development activities relating to

national evaluation procedures rather than servicing and running the evaluation itself. It is envisaged that such a migration from the three universities to a servicing entity be phased in over a period of several years.

Interpretation of EPDs – Decision Support

The value of EPDs is in allowing decision makers to predict the likely outcome of using particular animals as parents. The creation of the term EPD and its definition as half the breeding value or EBV was related to its ease of use from an interpretive viewpoint. Two bulls with high accuracy EPDs should produce the expected differences in progeny performance regardless of which herd or herds they are used in. More recent EPDs, such as those made available for threshold traits like calving ease, heifer pregnancy, and stayability, are not as easily interpreted. This is due to the fact that the phenotypic influence of a given change on the underlying scale is different according to the average level of performance. Suppose two bulls have given EPDs for a threshold trait like calving ease. These bulls may not exhibit much difference in calving ease in a herd with low incidence of calving difficulty, whereas there may be a large difference in performance among the bulls in a herd where a high level of calving assistance is required.

The value of particular EPDs also varies according to productive and economic circumstances. Consider mature cow size and sale (e.g., weaning) weight. Clearly, as weaning weight increases, the per head sale income increases. As mature cow weight increases, the feed requirements of the cow herd increase. Given an extensive pastoral setting as is the case for much of the cow-calf industry, the number of cows that can be run on a given range is dictated by their feed requirements. Accordingly, an increase in cow size would need to be associated with a decrease in the number of cows if the total feed consumption of the cows and their calves were going to be held constant. The tradeoff between cow size and sale weight determines the emphasis that should be applied to these two traits in an index setting. However, this tradeoff depends upon the value of extra sale weight less the opportunity cost of feed used for cow maintenance. The opportunity cost of feed changes according to the efficiency of the ranch system and could vary widely. The choice of one bull over another may lead to increased profitability in one ranch scenario and decreased profitability in another due to the varying value of grazed feed. Most ranchers in extensive circumstances are not well versed with the feed requirements of grazing cows or the opportunity cost of their feed. Such values can be readily calculated on a computer based on knowledge of the performance of ranch systems.

There are also interactions between various traits that influence system performance. Whereas an increase in sale weight EPD (such as weaning weight) is expected to be observed in heavier calves from, say, mixed age cows, an increase in actual sale weight might not be realized when other characteristics such as stayability are altered at the same time. Stayability, along with management factors, determines the age structure of the herd. If the age structure is reduced, perhaps as a result of reduced reproductive

performance, more female replacements are required. This increases the proportion of the herd that is calving for the first time and will reduce the average weaning weight of the herd since first calvers produce lighter calves than mixed age cows. Consider two bulls with different weaning weight direct EPDs. If the bull with genes for fast growth also has a lower stayability than the slower growing bull, it is possible that the total weight of sale animals will decrease as a result of using this bull, even though it produces heavier calves adjusted for age of dam.

All these factors argue for customized breeding objectives. Decision makers want to choose among available breeds and bulls, taking into account their assessment of future management, production, and economic circumstances. Customized breeding objectives are readily provided using web-based decision support systems. Furthermore, the advent of across-breed EPDs will require that heterosis values for all ERTs be used in the assessment of likely outcomes from using bulls of different breeds. Such values are not readily known to bull buyers, at least not for the entire suite of ERTs. The NBCEC has developed a prototype decision support system that is available via the web (http://ert.agsci.colostate.edu). This software will be developed in tandem with the development of new ERTs and the move to multi-breed evaluation.

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