1991 South Dakota Beef Seedstock Symposium,
December 13-14, 1991

Department of Animal and Range Sciences, South Dakota State University

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1991 SOUTH DAKOTA

Beef
Seedstock
Symposium

December 13-14, 1991

Department of Animal and Range Sciences
College of Agriculture and Biological Sciences
South Dakota State University, Brookings
FRIDAY, DECEMBER 13

ANIMAL SCIENCE ARENA  8:30 - 12:30
  Registration  8:30 - 9:00 am
  Ultrasound and Visual Evaluation of Live Cattle
  Impact of Frame Size on Feed and Market Requirements - Dr. Don Boggs, SDSU
  Which Cows Are the Most Efficient? - Dr. Don Marshall, SDSU
  How Big Should They Be? - panel discussion

HOLIDAY INN  1:15 - 5:00
  Nuts and Bolts of National Cattle Evaluation - Dr. Larry Benyshek, University of Georgia
  Turning Young Bulls into Proven Sires - Roy Wallace, Select Sires
  Milk EPD's - Dr. Larry Benyshek, University of Georgia
  Putting EPD's to Work - panel discussion
  Factors Affecting Birth Weight and Calving Difficulty - Dr. Terry Goehring, SDSU
  New Developments in Predicting Calving Ease - Dr. Larry Benyshek, University of Georgia
  Across Breed EPD's - Dr. Jim Gibb, American Gelbvieh Association

SDSU STUDENT UNION  6:30 - 10:00
  Impact of Biotechnology on the Beef Cattle Industry - Dr. Jim Kinder, University of Nebraska
  Bull Pen Sessions - Program speakers and others will be available for discussion.

SATURDAY, DECEMBER 14

HOLIDAY INN  8:00 - 1:00
  What Do They Want? A Summary of Market Surveys - Dr. Dick Pruitt, SDSU
  Identifying Your Market and Setting Goals - Steve Radakovich, Iowa seedstock producer
  Establishing Genetic Lines for Goal Oriented Buyers - Dick Janssen, Kansas Angus breeder
  Customer Service - panel discussion
  Getting the Most for Your Promotion Dollar - Jim Shirley, American Angus Association
  Marketing Seedstock - panel discussion

ANIMAL SCIENCE COMPLEX  1:30 - 4:00
  Carcass Value Demonstration - Dr. Dan Gee, SDSU
  Ultrasound to Predict Carcass Traits in Live Cattle - Dr. Gene Rouse, Iowa State University
  Predicting Genetic Value for Carcass Traits - Dr. Larry Benyshek, University of Georgia
  Producing What the Consumer Wants - panel discussion
  Changes and Challenges, Symposium Wrap-up - Dr. Jim Males, SDSU
Introduction and Brief History

Selection alters the frequency of genes in a population (breed) affecting a particular characteristic. Population genetic change is difficult for breeders to understand because they deal with individuals when making selection decisions and in their merchandising programs. Nevertheless, breeds (populations) which practice intense selection for characteristics of economic importance to the cattle industry will change genetically and eventually be the successful populations because they will leave the most progeny in the next generation. The genetic improvement of a population (breed) cannot overlook the individual because the individual, if selected, is the vehicle containing the genes which are to be passed on to the next generation. Bull selection is central to directed changes in gene frequency of any defined beef cattle population because of the low reproductive rate in beef females. Sophisticated genetic prediction techniques have been developed to help U.S. beef cattle producers make sound selection decisions.

In 1971-72, the American Simmental Association published the first U.S. National Beef Sire Summary. Only a few far-ranging thinkers understood what the publication of this document really meant to the beef industry. Bulls were now compared across herds and/or generations. Beef cattle breeding had entered the twentieth century!

Proliferation and implementation of technology in the area of beef sire evaluation has been fantastic. Dr. C.R. Henderson (1973) presented an invited paper at the 1972 American Society of Animal Science meetings which formalized his mixed model procedures providing best linear unbiased predictions (BLUP) of breeding values.

Increased use of artificial insemination in beef cattle has provided a data structure which lends itself to rather sophisticated models. Increased sophistication of mathematical models used in National Sire Evaluation (NSE) has paralleled improvements in computer hardware. Introduction of large-scale scientific "super" computers has certainly opened the door to applications of models not thought possible only a few years ago.

National Sire Evaluation procedures first used a rather basic model including contemporary group effects, sire effects and residual (random error). The sire effects become the "Expected Progeny Differences" (EPDs) when the model is applied. The model required that sires and contemporary groups be "connected", that is at least some sires must be used over more than one contemporary group thereby forming "ties" between sires across contemporary groups. Each contemporary group had to have at least two sires represented.

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1Presented at the Beef Seedstock Symposium, South Dakota State University, Brookings, December 13-14, 1991.
The model assumed sires had been mated to comparable sets of cows (cows randomly allotted to sires) and that progeny were treated similarly within contemporary group. The model assumed genetic trend was nonexistent or relatively unimportant in the population. These were essentially safe assumptions in the early 1970's for analyses of field data from the newly imported Continental breeds. In the first analyses of the U.S. domestic British breeds, the programs were designed to meet these assumptions. Analysis procedures of the early 1970's approximated true mixed model procedures.

In the decade from 1975 to 1985, many changes took place in sire evaluation technology. Mathematical models used in the analyses began to account for more and more of the factors which could possibly bias EPDs. The inverse of Wright's Numerator Relationship matrix which enhances accuracy of genetic prediction became a part of sire evaluation procedures. The relationship matrix provided the means to incorporate pedigree information in the analysis procedure and a method to account for genetic trend. Use of the A-inverse, as it is now referred to, certainly was a major breakthrough in NSE because pedigree breeding now began to take on real meaning.

Even with improvements in models, breeders and researchers alike continued to question the effect of non-random or specific mating of dams to sires on sire evaluation results. At the same time (late 70's and early 80's), computer hardware was improving at a phenomenal rate. By 1984, it seemed feasible to include a dam effect in the basic model for sire evaluation. In 1984, model dependency on difficult to verify assumptions was becoming less of a problem in sire evaluation. Incorporation of dams into the model along with the A-inverse provided breeders the most accurate prediction of breeding values to date.

Another problem which continued to burden breeders and researchers was the older age at which bulls were entering national sire summaries. Scientists were concerned because the generation interval increases with the age of the parents in a population and this may result in reduced genetic change per year. Breeders like to use young bulls; therefore, they were making selection decisions based on information other than that contained in sire summaries.

Most researchers have contended that National Sire Evaluation was a means to an end rather than the ultimate in genetic improvement of performance characteristics. It was generally recognized that unless NSE was somehow merged with on-farm and ranch testing programs, genetic progress would be slow particularly in the commercial industry.

C.R. Henderson and R.L. Quaas (1975) discussed methods for best linear unbiased prediction of breeding values utilizing records on large numbers of relatives, as well as the individual's own record. The mathematical model termed the "animal model" by Cornell researchers R.L. Quaas and E.J. Pollak (1980) was less dependent on hard-to-verify assumptions and it incorporated the sire's own record into the analysis. It also provided genetic values on dams and young animals not yet producing progeny. The procedure adjusted for merit of mates of the individual reducing substantially, if not totally eliminating effects of non-random (specific) mating. Finally, the procedure provided simultaneous breeding values (or EPDs) for direct growth and maternal ability for those traits which are maternally influenced.
The "animal model" along with the data structure the purebred beef industry had established by ten years of AI and NSE seemed to provide the ultimate in genetic prediction techniques for beef cattle--across herd and/or generation evaluations of all individuals (male and female) in the breed. However, the complexity of the model resulted in a computational nightmare. Quaas and Pollak (1980) proposed an equivalent model called the reduced animal model. The reduced animal model was less of a computational nightmare but also seemed beyond computing strategy and hardware of the time.

Application of the reduced animal model was encouraged by the availability of large scale scientific computers and experience gained in developing computing strategy for more sophisticated models in 1983-84. In late 1984, the model was applied to large beef cattle populations and the technology has now been generally adopted by all the major beef breeds in the United States.

The technology in prediction of genetic values is rapidly being accepted across the beef cattle industry, because now the commercial industry can share directly and much earlier in the purebred industry genetic progress. Young bulls not yet producing progeny (nonparents) now have genetic values (EPDs) comparable across herds and/or generations just as the older progeny tested sires have had for years in NSE. In 1985, the U.S. purebred cattle industry moved from National Sire Evaluation to National Cattle Evaluation.

Evidence that Genetic Predictions Can Impact Breeding Programs

Procedures used in making genetic predictions have been developed on a sound theoretical basis. Genetic theory has always been difficult to directly substantiate and has relied many times on indirect proof. Research efforts must be enhanced to continue challenging the theory and assumptions on which national beef cattle genetic improvement programs are based.

Perhaps the first place to look for evidence that sire evaluation is influencing breeding programs is the genetic trend in breeds which have been using such programs. Figures 1 and 2 plot the genetic trend for yearling weight (YWT), weaning weight (WWT), birth weight (BWT) and milking ability as pounds of weaned calf (MAT) in the Angus and Horned Hereford breeds. The graphs represent the average breeding value for animals born in a particular year.

It is encouraging that the trends for weaning and yearling weight are positive. The WWT trends for 1970-90 are 2.4 and 2.2 lb/year for Angus and Hereford, respectively. The YWT trends for Angus and Hereford are 4.0 and 3.4 lb/year. The trends are probably not significantly different between these breeds.

The number of bulls evaluated through National Sire Evaluation became significant in the late 70's for the two breeds. The rate of genetic change for weaning and yearling weight from 1977 to 1990 is more than double the rate for the period 1970 to 1978. The magnitude of the effect of NSE on these breeds is difficult to quantitate; however, there has been increased interest in performance and along with that interest has come greater use of outstanding sire summary bulls in both breeds.
Milking ability has changed in the Hereford breed over the years; however, the Angus breed has made little change in this trait. This difference between the breeds probably results from the fact that Hereford breeders have been more conscientious of milking ability since that breed is generally thought to produce less milk than the Angus breed. Both breeds now have access to milking ability EPDs through their National Cattle Evaluation (NCE) programs so that genetic change can be made rapidly for that trait.

Birth weight has changed in both breeds. This change is a correlated response to selection for growth and frame. It is impossible to determine the practical significance of these birth weight changes. It is safe to say that birth weight extremes are a problem for the industry because of their effect on calving ease. In general, birth weight effects on calving ease are most important in heifers. A majority of calving difficulty problems could be eliminated by selection of easier calving bulls to use on heifers. Information is available through the NCE programs to help identify bulls which produce calves with smaller birth weights.

In the spring breeding season of 1977, a project was initiated at the Northwest Georgia Branch Experiment Station (NWBS), Calhoun, Georgia to determine the magnitude of genetic change for single trait (yearling weight) selection. The selection practiced in this herd was through NSJ, that is bulls used in the selection line were the top yearling weight EPD bulls from the American Hereford Association Sire Evaluation program. A control line was maintained to quantitate environmental changes in the project. Genetic trends for several traits of economic importance were obtained by regressing differences between the selection line and the control line on years. Most of the genetic change was due to sire selection since little selection was practiced on the heifer replacements going into the selection line. Differences between the selection and control line are shown in Table 1. Observation of the yearling weight differences in Table 1 show a linear increase from 30 lb in 1978 to 95 lb in 1983. This represents genetic change of 14 lb per year. This is more than double the trend shown in the industry during that same time period. Obviously, part of the difference between industry change and genetic change in this research project is due to the single trait selection practiced. Single trait selection is seldom the situation in a beef breeding program; however, the project does show that rapid genetic change can be made in a beef cattle herd.

Observation of the differences in Table 1 between lines for other traits gives an indication of the response of traits correlated with yearling weight to the intense selection for yearling weight. Generally, the correlated responses have been favorable. Birth weight has increased; however, this increase did not affect calving ease as dramatically as expected. Perhaps of some concern was the small change in postweaning average daily gain. Much of the change in yearling weight seems to be coming through weaning weight. This result indicated the need for a multiple trait analysis which more accurately accounts for the effects of selection at weaning on yearling weight (many records are lost between weaning and yearling). The project has not addressed changes in fertility; however, it is encouraging to see only small changes in mature cow calving difficulty and positive changes for scrotal circumference and pelvic size.
Figures 3 through 7 compare the genetic trends in the NWBS experimental herd with the genetic trend in the Horned Hereford breed for several traits. The data for the NWBS herd represented in these graphs includes calf crops through 1989. These calf crops are not included in the data in Table 1 since the selection practiced changed somewhat with the 1983 breeding season. Selection has been continued for yearling weight; however, some attention was given to ease of calving bulls for first calf heifers. The genetic trend for the NWBS herd has been over 7.3 lb per year from 1977 to 1989, whereas the trend for the Hereford breed for that same period was 4.5 lb per year.

Generally, the trend in the NWBS herd had been at least twice that in the Hereford breed until 1985. The use of low birth weight EPD bulls with lower yearling weight EPDs on a large number of heifers appears to have contributed to some decline in the rate of genetic change in the NWBS herd. Basically, this decline in the rate of genetic change from 1984 to 1985 indicates the necessity of maintaining intense selection pressure if rapid genetic improvement is to be accomplished. If calving difficulty becomes a problem as it did in the 1984 calf crop then it is imperative to find bulls with low birth weight EPDs which can also continue changing post-natal growth. It is of interest that calving difficulty was not a problem in the first six calf crops at the NWBS (see Table 1).

In addition to the change in selection pressure, another contribution to the decrease in yearling weight genetic change was that one of the top EPD bulls selected for use in the project produced progeny which did not perform up to expectation. This may have been due to random chance (simple sampling error) or perhaps a sire by environment (herd) interaction. Even with the decline from 1984 to 1985, the NWBS herd is changing much more rapidly than the Hereford breed.

Figure 4 compares the weaning weight trend for the NWBS and the Hereford breed. Again, until 1985 the trend had been over two times as great in the NWBS herd as the Hereford breed. From 1977 to 1989, the NWBS herd changed at a rate of 4.6 lb per year versus 2.9 lb per year for the Hereford breed.

Figure 5 compares the birth weight trends. Selection of lower birth weight EPD bulls did result in a decline in the rate of change for birth weight experienced in the first six calf crops. The NWBS herd has increased birth weight .6 lb per year while the Hereford breed increased only .3 lb/year.

No attention has been given to maternal (milking ability) EPDs in the selection of bulls for the NWBS. Observation of Figure 6 shows what can be expected in maternal ability change if attention is not given to the trait in the selection program. The NWBS milking ability breeding values have been up and down during the study.

Frame size has never been a consideration in the NWBS selection program. Generally, size appears to be increasing at a more rapid rate in the NWBS cattle than in the general Hereford population. This change is due to the relationship between weight and height. Hip height (see Figure 7) has increased at .15 in per year in the NWBS cattle while during the same period the Hereford breed changed .08 in per year.
Scrotal circumference has been shown to be related to male fertility as measured by semen evaluation techniques. Also, some evidence exists suggesting that age of puberty in females is related to the scrotal circumference of their sire. This trait has never been considered in the selection practiced at the NWBS. Figure 8 indicates what has been happening to the trait in the NWBS herd. Changes in scrotal circumference appear to have been generally random.

The NWBS project shows that rapid genetic change can be accomplished with single trait selection. However, caution must be exhibited since efficient beef cattle production requires the consideration of several economic characteristics. Information now available through National Cattle Evaluation programs will provide the necessary genetic values to consider several traits in a selection program. The concept of optimums continues to gather support in the commercial cattle industry. Successful commercial breeders are learning how to sort young bulls on the basis of EPDs from different breeds which can then be put together through crossbreeding to enhance production efficiency.

A question of importance to both commercial and purebred cattle breeders is the reliability of genetic values (EPDs) computed for young animals which have not yet produced progeny. A study concerning this question has been conducted at the University of Georgia with Limousin and Hereford for postweaning gain. The study involved 71 Limousin and 138 Hereford bulls, all of which had legitimate individual postweaning records, as well as progeny with records. Expected progeny differences were computed for these bulls using the reduced animal model, first based on their record plus pedigree and secondly based on only their progeny plus pedigree. The 71 Limousin bulls all had between 10 and 30 progeny, whereas the 138 Hereford bulls all had at least 30 progeny. The rank correlations between these two sets of EPDs were found to be .59 and .58 for Limousin and Hereford, respectively. This is in contrast to correlations for within contemporary group ratios for these bulls and their EPDs based on progeny which were .17 and .20 for the Limousin and Hereford, respectively. This does not prove conclusively that nonparent EPDs are the best predictors of breeding worth; however, it does show that selection decisions based on ratios may not retain those bulls which will have high EPDs after they have produced progeny. These correlations point out the necessity of accounting for genetic competition in the contemporary group when comparing across herds. This study suggests that the commercial industry can buy young bulls with more confidence that the values on which they select the bulls will indeed turn into more pounds of product in their herds.

Predicting Calving Ease

Dystocia can be a major problem in beef cattle production, resulting in significant financial losses to the industry. In 1967, Anderson and Bellows reported calf losses at or shortly after birth to be 5-8%, with 50% of these losses directly related to dystocia. These percentages probably have not decreased in recent years. The commercial industry appears quite sensitive to the problem as indicated by the commercial cattlemen's interest in birth weights of yearling bulls.
A disproportionate difference between fetus size and dam size is the major cause of dystocia. Many factors, both genetic and environmental, affect the size of the calf at birth and also the size of the dam. These include sex of calf, length of gestation, breed, heterosis, inbreeding, genotype, age and parity of dam and nutrition of dam. Size of dam has generally not been a good predictor of calving ease because larger dams tend to produce larger calves.

Pelvic size measured as pelvic area is inversely related to the occurrence of dystocia in heifers. Measurement of pelvic size has received more attention in recent years as a possible way to reduce dystocia. Pelvic area (computed as the product of a vertical and horizontal measurement) appears to have a heritability of .53 as reported by Benyshek and Little (1982) in a study involving Simmental cattle. However, that same study indicated the genetic correlation between pelvic size and birth weight to be large (.73). Thus, selection for increased pelvic size could be accomplished; however, without some attention to birth weight the actual decrease in dystocia would be minimal.

Pelvic size could be incorporated into National Cattle Evaluation Programs. This would require large numbers of heifers to be measured in the purebred industry. Pelvic size measurement is not difficult but does require some training. The measurement requires time and labor to collect the data. At present the effect of such selection on dystocia would appear to be minimal, thus it seems impractical for the purebred industry to gather the necessary data. Pelvic size measurements may be useful as a commercial producer management tool in making mating decisions for first calf heifers in conjunction with other available information such as birth weight EPDs.

The effect of calf shape on dystocia is a popular topic of conversation among cattlemen. It seems logical that shape of calf should have some effect on calving ease; however, scientific investigation has given little credibility to the idea. Laster (1974) measured new born calves within 24 hours of birth for shoulder width, hip width, chest depth, wither height and body length. He found these measurements independent of birth weight to have no relationship to dystocia. In two recently published studies (Nugent et al., 1991 and Nugent and Notter, 1991), it was also concluded that selection for calf body shape measurements (head circumference, shoulder width, hip width, heart girth, cannon circumference and length and body length) would not reduce dystocia.

Generally birth weight is considered by most to be the major antagonist to calving ease. Birth weight EPDs are available for all breeds with NCE programs. Scrutinizing the birth weight EPDs of individuals to be mated can lead to acceptable phenotypic birth weights and a reduction in dystocia. Perhaps of most importance is for the industry not to become captivated by single trait selection for growth such as yearling weight EPD. The relationship between postnatal growth and prenatal growth is positive and as shown by the birth weight changes in the Hereford selection project at the Northwest Georgia Branch Station (see figure 5) discussed earlier in this paper.

Birth weight can be moderated by using EPDs. This has been done in the Hereford Selection Project at NWBS. In addition to the NWBS study Arnold et al., 1990 at The University of Georgia has summarized a study concerning the accuracy of birth weight (BWT) and yearling weight (YWT) EPDs. In the four year study,
BWT and YWT EPDs were examined in a high-low birth weight selection study. Angus bulls were selected for either high BWT and high YWT, or low BWT and high YWT. The EPD selection criteria for sires was: high line BWT EPDs ≥ 7 lb and low line BWT EPDs ≤ 3 lb. Sire YWT EPDs for both lines had to exceed 40 lb with an accuracy of .8. The selected sires were randomly mated to Angus cows and resulting progeny data were analyzed for birth weight, weaning weight, postweaning gain and yearling weight. Table 2 shows the least squares means and the average EPDs for sires used in each line. The difference column in Table 2 shows that the difference in average EPDs of the sires used within lines predicted very well the actual line differences observed. This study shows that birth weight can be significantly altered using the EPD concept.

Calving ease EPDs are computed in some NCE programs. Some procedures use a linear model while others use a threshold model (nonlinear). Theoretically the threshold model appears superior, although considerably more difficult to compute. The scientific literature contains little information from breeding studies to indicate the usefulness of calving ease EPDs. Initial information from a Gelbvieh study at The University of Georgia (Bertrand, unpublished) indicates that birth weight is still the dominant factor in a multiple trait analysis involving birth weight and calving ease scores. The multiple trait linear model and threshold model appear to give the same rankings for calving ease in some studies. However, work at Cornell University with Simmental field data (Man Cang Dong, personal communication) found the rank correlation between direct calving ease EPDs from a linear versus threshold model to be .57. The Cornell study found birth weight to have less effect on calving ease EPDs in the multiple trait analysis than in the Georgia study. The genetic association between birth weight and calving ease was considerably larger in the Georgia study.

Generally, birth weight is the culprit in calving difficulty and must be dealt with accordingly, using birth weight EPDs.

**Maternal (Milk) Ability EPDs**

Maternal ability EPDs (MEPD) probably raise more controversy than any other selection criteria in the beef cattle industry. This resulted because it is a value that could not be easily selected for prior to the application of the animal model. One of the advantages of the animal model is that it addresses weaning weight as a trait of the calf (indicating genes for growth) and as a trait of the cow (indicating genes for milk). This in itself is certainly not controversial since cattlemen have tried to do this in one way or another for years. It is doubtful that many breeders ever bought a potential herd sire without looking at the productivity of the dam producing that sire. Thus, the animal model does mathematically and systematically what breeders have tried to do mentally for some time. The second controversy with MEPDs is that they are subject to more change than other EPDs since the only animals with records are females which have produced and suckled a calf.

The first step in discussing the MEPD is to understand how the value is computed. To obtain this understanding it is necessary to look at a simplified
equation which shows the factors considered in the computations. The following equation computes maternal ability breeding value which is two times MEPD.

\[
\text{MEPD} \times 2 = \text{Regression Coefficient} \times \left[ \begin{array}{c}
\text{Cow's calves' Contemporary weaning records} \\
- \text{group effect - growth records}
\end{array} \right] \\
+ \text{Regression Coefficient} \times \text{Sum of the milk breeding values for relatives of the individual} \\
- \text{Regression Coefficient} \times \frac{1}{2} \left[ \text{Sum of the milk breeding values for mates of the individual} \right] \\
+ \text{Adjustment for the relationship between growth and milking ability}
\]

If this equation is for a cow who has raised a calf, the first part of the above equation adjusts the records of her calves to reflect her milk production. First, the contemporary group effect is adjusted out of the record removing any environmental factors which may have influenced the record positively or negatively compared to all other calves' records in a particular contemporary group. Second, the calves' growth breeding values are subtracted from the records. This second subtraction removes the effect of the calves' innate genetic ability to grow leaving the portion of the record reflecting the cow's milking ability. This is the portion of the record that the cow would influence through her milking ability regardless of the genetics possessed by her calves. Finally, to get the records to more adequately reflect the cow's genetics for milking ability, the permanent environmental effect is subtracted from the record. The regression coefficient is a weighing factor which adjusts for the heritability of the trait and the relationship between this piece of information (records of her calves) and other possible sources of information (relatives of the cow).

The second part of the equation brings the pedigree of the individual (a cow in this case) into the computations. The procedure moves backwards and forward through the pedigree. It picks up information (breeding values) on the ancestors of the individual particularly the sire and dam. However, if progeny are available it will gather the information (breeding values) on each progeny. The third part adjusts for mates of the individual removing any bias caused by non-random or specific mating. The final entry in the equation adjusts for any genetic relationship between growth and milking ability.

The reliability of the MEPO is many times questioned by breeders, particularly MEPDs for yearling bulls. Correlations between the pedigree MEPDs on young bulls and the MEPDs those same bulls will produce as their daughters come into production is about .45. This is less than the .60 correlation found for early information (record and pedigree) versus later progeny test EPDS for growth traits. Once a young bull produces progeny with records the correlation will improve. MEPDs for sires can have a high degree of accuracy actually at the
same level as other trait EPDs once large numbers of daughters come into production. The problem is simply that a sire's accurate evaluation for maternal ability of his daughters comes later in his life and breeders need to make decisions early for rapid genetic change.

Changes in EPDs from one NCE analysis to the next are of major concern to cattle producers. Table 3 shows the rank correlations over time between maternal EPDs from the semi-annual analyses conducted for the American Hereford Association. As one might expect as the amount of information increases changes occur. Thus, most of the time the correlations for a six month period analysis, May versus December, are very high .98-.99. Generally, the farther apart in time any two analyses the lower the rank correlations, say for example May, 1985 and May, 1990. However, the lowest correlation in the table is .86. The table points out that most bulls do not change but even at a correlation of .98 some significant changes can occur because bulls attain data at different rates, thus sampling variances will be different.

The lower correlations shown in the May 1990 column of Table 3 resulted because the analysis changed from a single trait to a multiple trait analysis and new genetic parameters were incorporated. Also new age of dam and age of calf adjustment procedures were implemented at that time. Most of the time EPD changes for a single individual are the result of more information becoming available; however, the May 1990 column of Table 3 points out that procedure changes are usually the cause of general shifts in EPDs.

Some information is accumulating with respect to MEPDs from actual breeding experiments. Diaz et al., 1991 have researched the relationship between maternal EPDs of Polled Hereford sires and the actual milking ability of their crossbred daughters. Over the range of sire maternal EPDs (-22 to +35 lb) actual milk production increased by 27% of the mean, or by about .5% per pound of maternal EPD.

In general, MEPDs are more variable than growth EPDs; however, they still represent the best method of describing the genetics of milk production and maternal ability in beef cattle. The industry probably tends to over-emphasize MEPDs. The MEPD should be used only to gauge general trends in a breed. If a breeder emphasizes MEPD at the expense of growth EPDs, the results of the breeding program will undoubtedly be disappointing. However, it must also be pointed out that continual use of negative MEPD sires will lead to lower herd MEPDs and ultimately lower herd milk production. A common sense approach is warranted with respect to Maternal Ability EPDs.

Generally, National Cattle Evaluation has been firmly established in the U.S. beef industry. Theoretically the procedures are sound; however, considerable research needs to be done in refinement of the procedures and education of producers for maximum success in the industry. Indications are that programs are working and genetic change is taking place in the cattle industry. The selection practiced in the next few years in a breed may determine whether that breed exists in the U.S. beef industry of the 21st century.


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<td>1.4</td>
<td>1.5</td>
<td>1.6</td>
<td>2.4</td>
<td>1.7</td>
<td>2.2</td>
<td>.3</td>
</tr>
<tr>
<td>Yearling Fat Thickness (in)</td>
<td>.02</td>
<td>-.01</td>
<td>--</td>
<td>-.01</td>
<td>-.03</td>
<td>-.01</td>
<td>0</td>
</tr>
<tr>
<td>Yrlg. Scrotal Circumference (cm)</td>
<td>--</td>
<td>.4</td>
<td>.1</td>
<td>.5</td>
<td>.3</td>
<td>.8</td>
<td>.1</td>
</tr>
<tr>
<td>Yearling Pelvic Area (sq cm)</td>
<td>8</td>
<td>11</td>
<td>13</td>
<td>16</td>
<td>7</td>
<td>13</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Table adapted from Hough et al. (1985)

1Selection line least square mean - control line least square mean.

2Score 1 = no assistance; 2 = minor assistance; 3 = major assistance; 4 = cesarean section; 5 = abnormal presentation.

3Regression of line differences on years.
Figure 1. ANGUS GENETIC TREND

Figure 2. HEREFORD GENETIC TRENDS
Figure 3. YEARLING WEIGHT TRENDS
NWBS AND NATIONAL HEREFORD

Figure 4. WEANING WEIGHT DIRECT TRENDS
NWBS AND NATIONAL HEREFORD
Figure 5. BIRTH WEIGHT TRENDS
NWBS AND NATIONAL HEREFORD

Figure 6. WEANING WT MATERNAL TRENDS
NWBS AND NATIONAL HEREFORD
Figure 7. HIP HEIGHT TRENDS
NWBS AND NATIONAL HEREFORD

Figure 8. SCROTAL CIRCUMFERENCE TREND
NWBS AND NATIONAL HEREFORD
In 1971-72 the first U.S. National Sire Summary was published by a beef cattle breed association. At that time the idea of extending beef performance records into a national progeny testing program was indeed revolutionary. Until 1972, truly accurate comparisons of bulls could only be made within a herd-year-season contemporary group. The first and subsequent National Sire Summaries compared bulls across herds and/or generations.

In the years following the first sire summary publications, most researchers working in the area of national genetic evaluation had contended National Sire Evaluation (NSE) was a means to an end rather than the ultimate in a genetic improvement program. Three major problems existed with NSE from the industry’s point of view. First, bulls had to produce progeny before entering the program which resulted in published evaluations of old bulls. Older bulls were usually available only through AI which made them impractical for use in much of the commercial industry. Furthermore, the purebred industry tends to seek young bulls rather than old bulls in an attempt to reduce the generation interval and make faster genetic change. Thus, while the evaluations in National Sire Summaries were and still are very accurate, both the purebred and commercial industry struggled in the late 70's and early 80's with how to effectively use the published results. A second problem with NSE was breeders, particularly purebred breeders, contended some bulls in NSE were being mated to superior cows causing a serious bias in the evaluation of those bulls. Fortunately, research has shown this second problem was more perception than reality. The third problem was NSE programs did not use the individual’s own performance record in the analysis. This third problem was not serious for bulls with a substantial number of progeny; however, for a young bull with only a few progeny it meant neglecting a very important piece of performance information. Another deficiency of NSE was that it provided genetic values on males only, thus the females which provide half the genes in the population were ignored. The application of the "Animal Model" in 1984-85 provided evaluations essentially free of the problems associated with National Sire Evaluation and allowed the industry to move to the next phase of genetic improvement now referred to as National Cattle Evaluation.

Today National Cattle Evaluation (NCE) programs are available in all the major beef breeds and have several distinct advantages over NSE programs:

1) NCE provides a genetic value for an individual which incorporates any combination of progeny, pedigree (sire and dam) and individual record information. Thus, the individual’s own record, if available, is incorporated into the analysis. The genetic values from NCE programs

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1Presented at the Beef Seedstock Symposium, South Dakota State University, Brookings, December 13-14, 1991.
are in the form of "expected progeny differences" (EPDs) which are the same as sire EPDs from NSE programs.

2) The procedure adjusts for the superiority or inferiority of the mates of the individual. This reduces, if not totally eliminates bias, introduced by specific matings for both sires and dams.

3) The program provides maternal genetic values for those traits which are maternally influenced such as weaning weight.

4) The procedure accounts for genetic change over time in a breed, providing more precise comparisons of individuals from different generations.

5) National Cattle Evaluation computes genetic values for all animals in the breed, i.e. for sires and dams plus young animals (male and female nonparents) which have not yet produced progeny.

It is of major importance that breeders realize that the genetic values (EPDs) for young animals (nonparents) and for dams are comparable across herds and/or generations.

The following brief example will provide some insight into the usefulness of the EPD. Expected Progeny Differences are plus or minus values in units of original measurement (e.g. weaning weight in pounds). The EPDs are used to make comparisons among bulls from which the breeder wishes to make a selection. The comparisons are made one pair of bulls at a time. For example, compare two bulls, A and B, where bull A has a weaning weight EPD of +20 pounds and bull B has a weaning weight EPD of +5 pounds. The EPDs for these two bulls tell the producer if he were to select both bulls for his breeding program and mate them to a large number of comparable cows he could expect a 15 pound difference between the average weaning weights of the calves from the two bulls. Thus, if weaning weight is important in the producer's program, selection of bull A is obvious. The EPDs provide the producer a means of predicting differences between any two bulls without having to breed the bulls in his program. The difference between EPDs for bull A and B (20 - 5 = 15 pounds) is the difference a producer would expect in his own herd. In breeds which have NCE programs, there are thousands of bulls evaluated and it is possible although perhaps not practical to make this pairwise comparison for all of them. Expected progeny differences provide a prediction of future performance of progeny from an individual based on information currently available.

It is important that breeders realize what information EPDs do not provide. For example, selecting a bull with a +20 pound EPD does not guarantee that the breeder’s herd average will be increased by 20 pounds. This would be true if the herd average was the same as the overall breed average. If the herd is above breed average one would expect less than 20 pounds increase; however, if the herd was below breed average a greater than 20 pound increase could be expected. A second important note is that the NCE results cannot be used to compare breeds, that is, the EPDs are to be used only for within breed comparisons.

Traits available for comparison vary from breed to breed. Traits evaluated are birth weight, weaning weight, milking ability expressed as pounds of weaned calf, yearling weight, hip height, scrotal circumference and calving ease. Other traits such as carcass traits will be added in the near future.
Best linear unbiased prediction procedures (BLUP) used in National Cattle Evaluation programs are complex, to say the least. Let us now examine how factors such as the contemporary group influence the computation of an individual's expected progeny difference (EPD).

First, an example of a contemporary group effect. Remember the definition of a contemporary group is a set of animals of the same sex and similar age which have had equal opportunity to perform (same management, pasture, year, etc.). As an example, suppose we have two contemporary groups (these could be herds also) which have the same two sires, say A and B, represented. Each sire produces ten bull calves in each contemporary group. The performance of each sire's progeny in each group is summarized in the following table:

<table>
<thead>
<tr>
<th>Sires</th>
<th>Contemporary groups (herds)</th>
<th>Average across herds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>A</td>
<td>500*</td>
<td>550*</td>
</tr>
<tr>
<td>B</td>
<td>400*</td>
<td>450*</td>
</tr>
<tr>
<td>Average</td>
<td>450</td>
<td>500</td>
</tr>
</tbody>
</table>

*Average of 10 calves by each sire in each contemporary group.

The averages by sire across contemporary groups gives one the difference in progeny performance for the two bulls A (525) and B (425) with bull A's progeny having a 100 pound advantage (sire differences). The averages by group across sires quantitates the difference between contemporary groups. As you can see there is a 50 pound advantage for group 2. This is the contemporary group effect. If one assumes the females are similar for both groups then the 50 pound advantage for group 2 must come from some environmental source. Whatever the cause of differences between contemporary groups is of little concern; however, these differences may bias the evaluation of animals in those contemporary groups. Therefore, analysis procedures used in NCE adjust for these contemporary group differences which result in genetic evaluations (EPDs) computed as though all the cattle were raised in one giant contemporary group. If the contemporary groups were for some reason improperly identified, say for example, 5 of bull B's progeny in group 2 were in a different pasture, the estimate of the contemporary group effect could be wrong and perhaps bias the sire evaluations.

In order to understand the computation of an individual's weaning EPDs for growth let us examine several of the factors involved. First, remember all that is available to us for the identification of superior genetics are the records on individual animals. All of the analytical procedures are designed to separate the environmental and genetic factors affecting an individual's record thus providing a prediction of the individual's genetic worth. Thus as one thinks...
about factors affecting the EPD of an individual we are actually considering the genetic and environmental effects on the record of the individual.

The first factor to consider is the genetic makeup of the individual which is referred to as its breeding value (EPD = 1/2 Breeding Value). Obviously, this is the factor of most concern because it is directly related to the EPD of the individual. Another factor which comes to mind immediately with respect to a weaning record is the milking ability of the individual's dam. The milking ability of the individual's dam can be represented by her milk breeding value (2 times her milk EPD). Milking ability EPDs or breeding values are expressed as pounds of weaned calf (not pounds of milk). The milk breeding value of the dam represents her genetic potential for milking ability. A cow may have tremendous genetic potential for milking ability but may never exhibit that ability due to environmental effects (eg. suppose a high milking cow contracts mastitis). Thus, a third factor affecting an individual's weaning record might be any permanent environmental effect decreasing or increasing the milking ability of the individual's dam. The final factor which was discussed above is the contemporary group effect. These four factors explain much of the variability in weaning weight records; however, not all of the variation is explained by these factors thus there is a fifth factor which we will simply refer to as unknown or error.

Now that the factors affecting the weaning record of an individual have been identified it is possible to develop a mathematical model representing the record in terms of these factors:

\[
\text{Weaning Weight Record} = \text{Contemporary Group Effect} + \text{EPD of the Individual's Sire} + \text{EPD of the Individual's Dam} + \text{Mendelian Sampling Effect of the Individual} + \text{Milk Breeding Value of the Individual's Dam} + \text{Permanent Environmental Effect of the Dam} + \text{Unexplained Factors or Random Error}
\]

Notice in this equation that the individual's breeding value is represented by the sum of its parental EPDs and a Mendelian sampling effect. The Mendelian sampling effect accounts for the fact that an individual receives 1/2 of his genetic makeup from each parent in a random fashion. The Mendelian sampling effect is the reason that even full-sibs (offspring of the same parents) show considerable differences.

An equation similar to the above is developed for every individual in the breed which has a legitimate weaning record. These equations are solved by iterative techniques providing values for each entry in the equation to the right of the equals sign including the breeding value of the individual. The EPD is given by dividing the breeding value of the individual by two.

Keeping in mind that an individual's EPD is equal to 1/2 his breeding value, the following gives an individual's weaning growth breeding value:
Breeding Value = Regression Coefficient X (Record of the individual - contemporary group effect - milk breeding value of dam - permanent environmental effect of the dam)

+ Regression Coefficient X (Sum of breeding values for relatives of the individual (note: this includes sire and dam and/or any progeny of the individual))

- Regression Coefficient X 1/2 (Sum of breeding values for mates of the individual (note: applies when progeny are available))

+ adjustment for the relationship between growth and milk (note: in some breeds assumed to be zero)

Subtracting the contemporary group effect, milk breeding value of the dam and the permanent environmental effect of the dam adjusts the record for those environmental factors. After these factors are subtracted the portion remaining more adequately reflects the genetic makeup of the individual for growth. The regression coefficients are weighting factors computed according to the relationship between each piece of information contributing to the individual’s breeding value thus allowing the combination of information. Note that any combination of the possible information may be used to compute the breeding value. Notice also the procedure will go back in the pedigree to the sire and dam of an individual or forward in the pedigree to any progeny available. Mates of the individual are adjusted for by subtracting 1/2 of the mate’s breeding value when progeny records are available. Finally if there is a relationship between milk and growth it can be accounted for in the procedure.

A numerical example will show the importance of each factor in computations of an individual’s EPD. The following example is for two young calves (nonparents) which are full-sibs (same sire and dam) and it is data taken from one of the breeds presently being analyzed at the University of Georgia:
Weaning weight (lb) | Contemporary group effect (lb) | Breeding Values (lb) | Dam’s milk breeding value (lb) | Dam’s P.E. (lb)
calf A 645 | 120.9 | 469.96 | 70.0 | 14.2 | 15.6 | 15.5
calf B 570 | 102.9 | 486.80 | 70.0 | 14.2 | 15.6 | 15.5

Calf A
Breeding value = \( \frac{0.143 (645 - 469.96 - 15.6 - 15.5) + 0.429 (70 + 14.2)}{2} \)

\[
\begin{align*}
&= \frac{20.56 + 36.09}{2} = 36.325 \\
&= 36.325 \text{ lb}
\end{align*}
\]

\( \text{EPD}_A = \frac{36.325}{2} = 18.16 \text{ lb} \)

Calf B
Breeding value = \( \frac{0.143 (570 - 486.80 - 15.6 - 15.5) + 0.429 (70 + 14.2)}{2} \)

\[
\begin{align*}
&= \frac{7.44 + 36.09}{2} = 21.765 \\
&= 21.765 \text{ lb}
\end{align*}
\]

\( \text{EPD}_B = \frac{21.765}{2} = 10.88 \text{ lb} \)

As you can see only individual records and parental values enter into the computations since these two animals have not yet produced progeny. In the case of these full-sibs the only differences in the computations are the records and the contemporary group effects. Calf A has a larger weight (645) than calf B (570) but in addition the contemporary group effect (which might be thought of as an adjusted contemporary group average) for calf A (469.96) is smaller than the one for B (486.80). Calves in B’s contemporary group had a 16.84 pound environmental advantage which is given by the difference between the contemporary group effects (486.80 - 469.96). Thus calf B had a somewhat better environment in which to make his record. The effect of this better environment is adjusted out when the contemporary group effect is subtracted from the calf’s record. Calf B did not grow as well as calf A, plus B had a better environment than A therefore the record contribution to the breeding values for the two calves was 20.56 versus 7.44 pounds for A and B, respectively. Notice the pedigree contribution for both calves is larger than either record contribution which may...
not always be the case. Obviously, the pedigree contribution to an individual’s EPD depends on how large the EPDs (breeding values) are for its parents. Breeders should also note that the 18% difference between performance ratios translates to only a 6.56 pound difference in EPDs for these two calves. Ratios and weights may be misleading with respect to actual genetic transmitting ability. In the case of these two animals selection on weight or ratio would have retained the genetically superior individual. It should be noted as groups become more diverse with unrelated individuals, selection based on EPDs will more often retain the genetically superior individual than either weights or ratios.

The following is a comparison of two sires with progeny. The table contains information for sire A (breeding value = 88.4; EPD = 44.2 lb) and sire B (breeding value = 132.2; EPD = 66.1 lb).

| Individual | Average weaning ratios of progeny | Number | Weaning Contemporary Performance Breeding Breeding |
|------------|----------------------------------|--------|----------------|----------------|----------------|
| bull ID | Number | Average | Groups | Pounds (Ratio) | Value (lb) | Value (lb) |
| A | 408 males | 105.0 | 178(9703)* | 703 (124.5) | 65.4 | 20.0 |
| | 369 females | 103.9 | | | | |
| B | 424 males | 105.8 | 71(3547)* | 729 (136.5) | 150.4 | 45.8 |
| | 403 females | 104.7 | | | | |

*Number of contemporaries in parenthesis raised with progeny of A and B.

Notice the average progeny ratios do not reflect the difference in EPDs for sires A and B. The following will show why these averages are not indicative of the EPDs for the two sires. First, examine the following table which gives the contribution (in pounds) of each available piece of information to the sires’ breeding value and subsequent EPD:

<table>
<thead>
<tr>
<th>Sire ID</th>
<th>Sire’s own record</th>
<th>Sire’s parents</th>
<th>Progeny</th>
<th>Adjustment for mates</th>
<th>Breeding value (lb)*</th>
<th>EPD (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.1103</td>
<td>.2219</td>
<td>94.4230</td>
<td>-6.3611</td>
<td>88.3941</td>
<td>44.2</td>
</tr>
<tr>
<td>B</td>
<td>.1813</td>
<td>.5179</td>
<td>171.0545</td>
<td>-39.5536</td>
<td>132.2000</td>
<td>66.1</td>
</tr>
</tbody>
</table>

*Sum of the previous four columns, EPD = 1/2 Breeding Value.

The EPD for A is given by (.1103 + .2219 + 94.4230 - 6.3611) + 2 = 44.2. The EPD for B is given by (.1813 + .5179 + 171.0545 - 39.5536) + 2 = 66.1. It is readily seen that the major contribution to each sire’s EPD comes from their progeny (94.4230 and 171.0545). A sire’s own record and his ancestor’s account
for a very small part of his EPD when large numbers of progeny are available and
particularly when the progeny are far above or far below average.

Note there is a larger adjustment for mates of sire B than sire A (-39.5536
vs. -6.3611, respectively). The reason for this is that sire B was mated to cows
superior to those of sire A. The average EPD for sire B’s mates was 39.8 lb
whereas sire A’s mates averaged 6.4 lb. Even after adjustment for superior mates
B still had the larger EPD.

Observation of the table including the adjustment for mates does not yet
answer our question as to exactly why B’s EPD is so much larger than A’s. The
answer is found in the genetic competition within the contemporary groups in
which the progeny of these two sires were raised. Average breeding values for
the sires and dams of other progeny in the contemporary groups in which sire A’s
progeny were raised are 40.6 and 13.4 lb, respectively. The averages for sires
and dams of progeny raised contemporarily with sire B’s progeny are 61.4 and 34.4
lb, respectively. This simply says that the genetic merit (measured as breeding
value) of the contemporary groups in which sire B’s progeny were raised was
greater than those in which sire A’s progeny were raised. This coupled with the
fact that sire B’s progeny averaged 46.1 lb more than their contemporaries while
sire A’s progeny averaged only 2.2 lb more than their contemporaries results in
the large difference seen in progeny contribution to their EPDs. This genetic
competition within contemporary groups is not reflected in performance ratios
thus reducing their value as an aid to selection, particularly in comparisons
across herds. Clearly, NCE accounts for this and other factors making the EPDs
more precise for across herd comparisons.

An accuracy value is computed for each EPD which provides an indication of
the reliability of the EPD. Accuracy values range from zero to one with values
closer to one indicating greater accuracy or reliability of prediction. Unfortunately, accuracy values are only approximations and may sometimes
underestimate or overestimate the true accuracy of the EPD.

Mixed linear models (BLUP) are finding widespread application in the beef
cattle industry. The procedures provide a most accurate method for making
selection decisions. Today’s cattlemen, both purebred and commercial, who learn
to use the genetic information available in a creative breeding program will
achieve greater profitability over time. This is because genetic stability will
allow for sound management decisions including those decisions affecting,
marketing and merchandising.
CURRENT STATUS OF NATIONAL CATTLE EVALUATION PROGRAMS FOR CARCASS TRAITS

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ATHENS

At present, diet conscious consumers are exerting considerable pressure on the beef industry. Consumers continually indicate they are concerned about, and in fact, will not tolerate fat associated with red meat products (Breidenstein, 1988). This has resulted in many retailers trimming various cuts of beef to 1/8 inch of subcutaneous fat and in some cases a complete trimming of fat. It is probably conservative to estimate the industry produces an excess of 500 million pounds of fat each year from those carcasses with a yield grade above two. This excess fat represents the nutritional energy in more than a million yield grade 2 carcasses, each weighing 650 pounds. However, because the consumer is also concerned about palatability, the industry at present seems to have no alternative except to feed beef cattle for more than an optimum length of time in order to provide some assurance of "quality". In addition, the packing industry's reliance on dressing percent provides for an even greater emphasis on feeding cattle beyond the optimum length of time.

In addition to excess fat produced in the 12.1 billion pounds of graded beef, there is considerable inefficiency in the production of nongraded or no-roll beef. No-rolls may represent 35-36% of the steers and heifers slaughtered. Most no-rolls are either yield grade 4s or in the Select quality grade category. Conservative comparisons of average prices for Choice, yield grade 3s versus 4s, and Choice versus Select yield grade 3s indicates these no-roll carcasses would have had an added value of $578 million had they been in the Choice, yield grade 3 category. It is obvious that feeding and management alone cannot solve this inefficiency problem in the beef industry. The solution will require genetic manipulation of the raw product utilized by the packing and retail segments of the industry. At present, genetic manipulation available to the industry is either crossbreeding or selection; and both will be required for an efficient industry. However, permanent changes caused by selection should be considered as a method of controlling within breed variability, thus increasing uniformity of carcass product from crosses of breeds. Crossbreeding will aid the efficiency of production primarily through hybrid vigor for reproduction. Selection will have its effect on growth and carcass product. Commercial producers must have assurances that their selection of bulls within breeds provide germ plasm which will enhance the efficiency of breed crosses and not negate breed complementarity.

The accurate prediction of genetic values for carcass characteristics of economic importance to the beef industry would provide the necessary stimulus for a value based marketing system. Accurate carcass trait genetic values within a breed would allow commercial producers to develop breeding programs which would assure uniformity of specification products. The ability to accurately predict

1Presented at the Beef Seedstock Symposium, South Dakota State University, Brookings, December 13-14, 1991.
characteristics at the production level of the segmented beef industry would allow for a more orderly and fair marketing system for beef. If the commercial producer knows the specifications are being met by the germ plasm he is buying, this will enhance retained ownership and increase marketing on grade and yield. Identifying the genetic stocks which can produce uniformity of specified products would certainly enhance contract marketing.

If accurate genetic values are not developed for carcass attributes, it seems certain that the industry will continue to set prices based on averages and move toward even more inefficiency. Some breeds are already being cast as problems in the packing industry when in reality there are certain to be sires in all breeds which can produce progeny meeting specifications for various beef products. Consistent quality of brand name products will be impossible to achieve at a competitive price without identification of genetic stocks within breeds that can assure such quality.

In general, the possibility exists to develop genetic values in the form of expected progeny differences on yearling animals for both growth and carcass characteristics. This would allow commercial producers the opportunity to buy bulls which could assure the production of live cattle specifically for brand name beef products.

**Genetic Parameters**

There is considerable genetic variability within breeds for carcass characteristics. The heritability averages in Table 1 were adapted from Koch et al. (1982) and include two recent studies involving field data (Wilson, 1987 and Benyshek et al., 1988). Several breeds are represented in the average; however, the majority of the estimates are from British breeds. Little information is available for estimates of heritability for carcass traits from Continental, Brahman and Brahman derivative breeds. Johnston et al., 1991, working with Canadian Charolais field data, found ribeye area and marbling (Canadian system) to have heritabilities of .38 and .26, respectively.
<table>
<thead>
<tr>
<th>Carcass Characteristic</th>
<th>Average $h^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carcass wt.</td>
<td>.48</td>
</tr>
<tr>
<td>Retail Product Weight</td>
<td>.51</td>
</tr>
<tr>
<td>Percentageb</td>
<td>.49</td>
</tr>
<tr>
<td>Fat trim wt.</td>
<td>.55</td>
</tr>
<tr>
<td>Fat trim %</td>
<td>.57</td>
</tr>
<tr>
<td>Bone wt.</td>
<td>.50</td>
</tr>
<tr>
<td>Bone %</td>
<td>.53</td>
</tr>
<tr>
<td>Kidney fat wt.</td>
<td>.75</td>
</tr>
<tr>
<td>Kidney fat %</td>
<td>.83</td>
</tr>
<tr>
<td>Fat thickness</td>
<td>.43</td>
</tr>
<tr>
<td>Ribeye area</td>
<td>.40</td>
</tr>
<tr>
<td>Marbling Score</td>
<td>.41</td>
</tr>
<tr>
<td>Warner-Bratzler Shear</td>
<td>.31</td>
</tr>
</tbody>
</table>

*Koch et al. (1982); Wilson (1987) and Benyshek et al. (1988).

*Cutability: estimated percentage of retail product from round, loin, rib and chuck.

Carcass Characteristics

The three traits: fat thickness, ribeye area and marbling score will probably receive the most attention in selection programs. All three traits are moderate in heritability and could be changed significantly with intense selection over a short period of time. However, there are several problems that must be addressed before a National Cattle Evaluation program can be implemented. The first and most impending problem is identifying a mechanism for collecting carcass data. The National Cattlemen's Association, with the help of the Kansas Beef Board, is developing a national carcass data collection program which will be a first step in obtaining the necessary data for an NCE program focused on carcass traits.

A second problem is identifying what data to collect and at what endpoint. For example, the endpoint could be at a fat thickness, grade or weight. The same character, say ribeye area, may be interpreted differently at each of these endpoints. This problem will not easily be solved and the usefulness of large amounts of data at different endpoints is questionable.
In a NCE program for carcass traits the goal would be to change the genetics of the U.S. cattle population such that phenotypic cutability (amount of edible product) and palatability (eating quality) would be enhanced. This reveals the third major problem, i.e., measuring these general characteristics is impossible on a large scale. True cutability can only be obtained by breaking the carcass down to trimmed retail cuts and computing the cutability as the ratio of pounds of trimmed retail cuts to carcass weight. Palatability can only be assessed by using trained taste panels. Therefore, the system must use indicator traits to predict cutability and palatability.

Ribeye area, hot carcass weight, percent kidney, heart and pelvic fat thickness over the twelfth rib are used to predict cutability; and marbling score is used to predict palatability. The problem is that none of these individual traits does a very good job of predicting the overall characteristics of interest for efficient production. Generally, marbling accounts for only 30% of the variation in trained taste panel palatability scores. Marbling probably sorts out the really bad quality carcasses but unjustly penalizes some very good quality carcasses. The question becomes, can we live with a quality control system with this degree of accuracy? The answer is probably yes for buying on averages, but no if the industry is to have a value based marketing system selling one carcass at a time. Another problem with marbling is that the quality control factor is actually based on fat which consumers will probably eventually reject.

The yield grade prediction equation does not seem to fit today’s cattle. The reason for this is that those equations were developed many years ago on British cattle. Today’s cattle have different maturity patterns from those cattle used to obtain the original equations and there are many more breeds represented in the current cattle population. Of the four characteristics, fat thickness has the largest relationship, both genetically and phenotypically with cutability (genetic correlation = -.74 and phenotypic correlation = -.74). The best way to increase cutability in the beef cattle industry is to simply feed cattle for a shorter period of time. At present, this does not seem feasible in the feedlot and packing segments of the industry due to the reduced tonnage associated with reduced feeding time. This could change with increased numbers of cattle or further reduction in market share by the industry. The retail segment may send a signal that it no longer will absorb the cost of trimming worthless waste fat. The goal then from the feedlot and packing industry point of view is to develop cattle that will feed to current weights with reduced backfat, ensuring the same tonnage of palatable beef products.

The genetic correlations (Koch et al., 1982) between cutability and the three characteristics: ribeye area, percent KPH and carcass weight are .53, -.43, and -.11, respectively, and the phenotypic correlations are .27, -.43 and -.31, respectively. These correlations indicate that none of these characteristics would be the sound phenotypic predictors necessary for a marketing classification scheme, nor would they be good genetic indicators. Changing ribeye area alone will result in very little increase in cutability. In fact, increases in ribeye area may actually be somewhat detrimental to the industry in light of portion sizes being dictated by consumer diet-health considerations.
A final problem which will have to be addressed is how will other production traits change as the genetics for carcass characteristics are changed. For example, research based on breed differences seems to indicate that as cattle become leaner reproductive efficiency decreases. A slight decrease in reproductive efficiency would negate all of the profit envisioned with improved carcass characteristics. The general question of how the female counterparts of the desired lean steers perform as brood cows will need to be answered for an overall efficient industry.

Generally, for a NCE program to work for carcass traits, large numbers of individuals must be measured. This will be difficult if the data has to be gathered on carcasses at a packing plant. Live animal measurements which are good indicators of carcass traits will have to be developed if NCE is to be successful for carcass traits.

**Ultrasound Technology**

One major breakthrough in the last couple of years has been the development of portable ultrasound technology for live cattle imaging. This holds out the possibility that we may now be able to collect actual carcass data for ribeye area and backfat on breeding animals and progeny without the time and expense of slaughter tests. Ultrasound is not without its limitations (for instance, marbling cannot currently be measured with acceptable accuracy) but it does appear to be fast, accurate for some traits and certainly less expensive than slaughter tests.

Before this new technology can be incorporated into current genetic evaluation programs, studies must be implemented by breeds to obtain reliable estimates of heritability for various imaged carcass traits. In addition, as selection for net merit becomes more important, multiple trait selection will require a clear understanding of phenotypic, genetic and environmental relationships among a variety of production traits including growth, carcass and reproduction.

Arnold et al., 1990 at The University of Georgia analyzed a field dataset (n=2411) from the American Hereford Association consisting of ultrasound images of ribeye area and fat thickness on yearling bulls. This study found heritabilities for ribeye area and fat thickness measured via ultrasound to be .28 and .26, respectively. In the same study an analysis of actual carcass data from Hereford steers provided heritability estimates of .46 and .49 for ribeye area and fat thickness, respectively. These two analyses show that there is some difference in the variability associated with ultrasound images and actual carcass data. In this case the datasets were both Hereford (steers in one dataset and bulls in the other dataset) and sires did not overlap so they were essentially independent datasets. A very important difference between the two datasets was in the genetic correlations between the two traits. In the actual carcass data, the genetic correlation was found to be -.37 indicating as one characteristic increased the other would decrease. In the ultrasound dataset on yearling bulls the genetic correlation between fat and ribeye area was .48 which was just the opposite of the steer data. It may be that these characteristics are not the same traits in steers and intact males. The positive correlation in
the bull data may be an artifact of the small amount of variability for backfat. If both these relationships are biologically sound then there are serious problems with using yearling live animal ultrasound measurements for fat thickness on bulls in a carcass improvement program. These early results indicate that it is necessary to image other muscles in the live animal if the accuracy of predicting breeding values for cutability is to be enhanced.

The question of imaging marbling in live animals is being addressed at several institutions. Brethour (1990) reported the correlation between carcass marbling scores and ultrasound speckle to be .5 in a study of 619 animals made up of steers, heifers and bulls. If a national program of carcass genetic improvement is to be successful, then the issue of palatability will have to be addressed. The scientific literature is lacking information concerning the muscle biology involved with the aspects of beef palatability. It will be difficult to develop selection programs which can have significant economic impact if there is not a better understanding of the basic biology of carcass quality.

It is possible to change the genetics of the U.S. beef population for carcass traits since there is significant genetic variability within and between breeds. The key to success will be determining how to manipulate that genetic variability in an economical manner.
LITERATURE CITED


Calving Difficulty in Beef Cattle: Part I

Harlan D. Ritchie, Michigan State University
and
Peter T. Anderson, University of Minnesota

Calving difficulty (dystocia) can increase calf losses, cow mortality, and veterinary and labor costs, as well as delay return to estrus, and lower conception rates. In two studies at the U.S. Meat Animal Research Center (MARC), Clay Center, Nebraska, calf losses within 24 hours of birth averaged 4 percent for those born with little or no assistance compared to 16 percent for those requiring assistance. Calf mortality increased by a 0.35 percent per pound increase in birth weight. In a Hereford herd at the U.S. Livestock and Range Research Station, Miles City, Montana, 57 percent of all calf losses were reported to be due to dystocia.

Researchers at MARC noted that the number of cows detected in estrus during a 45-day A.I. period was 14 percent lower in those requiring assistance than in those calving with no difficulty. Conception to A.I. was 6 percent lower in cows experiencing dystocia than in those with no dystocia. Pregnancy rate after the entire breeding season (70 days) was 16 percent lower in cows that had been assisted (85 percent vs. 69 percent). At Miles City, pregnancy rate among cows that had cesarean deliveries was 26.6 percent lower (52.4 percent vs. 79.0 percent) than the herd average.

Factors Affecting Dystocia

The numerous factors that are believed to influence calving difficulty are listed below. As will be noted later, several of these factors are interrelated.

1. Age of dam
2. Calf's birth weight.
3. Sex of calf
4. Pelvic area

5. Gestation length
6. Cow size
7. Shape of calf
8. Breed of sire
9. Breed of dam
10. Uterine environment
11. Hormonal control
12. Geographic region
13. Season of year
14. Environmental temperature
15. Nutrition of dam
16. Condition of dam
17. Implants and feed additives
18. Feeding time
19. Exercise
20. Other unknown factors

This bulletin (Part I) covers the first fourteen of the above factors. The second bulletin (Part II) covers the remainder of these factors and finishes with a discussion of calving time management and genetic management.

Age of Dam

Table 1 is a summary of calving data from MARC and Colorado State University (CSU), relating age of dam to calving difficulty. These data illustrate that age of dam has a profound effect on the incidence of dystocia. First-calf, two-year-old heifers represent the greatest source of trouble to the beef herd owner. Difficulty in two-year-olds is three to four times as high as in three-year-olds, and three-year-olds have about twice as much difficulty as four-year-olds. By the time a cow reaches four to five years of age, dystocia problems are minimal. Calving difficulty in MARC Hereford and Angus cows was higher than in CSU Hereford cows, presumably because the former tended to be mated to larger continental sires, whereas the latter were mated only to Hereford sires.

1'(Authors' note: This bulletin is first in a series of two on calving difficulty).
Table 1. Effect of dam’s age on calving difficulty

<table>
<thead>
<tr>
<th>Dam’s age (years)</th>
<th>Research station</th>
<th>% calving difficulty</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>MARC</td>
<td>54</td>
</tr>
<tr>
<td>3</td>
<td>CSU</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>5 (and over)</td>
<td></td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

Calf’s Birth Weight and Sex

Table 2 is taken from a Miles City study correlating calving difficulty with several traits in two-year-old Hereford and Angus heifers. A perfect correlation would be 1.0; anything over 0.40 was highly significant; 0.18 to 0.40, significant; less than 0.18, nonsignificant. Birth weight of the calf was the trait most highly correlated with calving difficulty, followed by sex of calf. Pelvic area, gestation length, and cow weight had considerably less influence. Much of the influence of sex of calf is believed to be indirect, through its effect on increased calf size. However, after correcting for birth weight, differences in dystocia between sexes still remain, suggesting that other factors besides fetal size may be involved.

Table 2. Effect of various traits on dystocia in Hereford and Angus Heifers

<table>
<thead>
<tr>
<th>Trait</th>
<th>Correlation with dystocia</th>
<th>Breed of cow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Hereford</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Angus</td>
</tr>
<tr>
<td>Calf’s birth weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>.54</td>
<td>.48</td>
</tr>
<tr>
<td>Calf’s sex</td>
<td>-.47</td>
<td>-.26</td>
</tr>
<tr>
<td>Pelvic area, precalving</td>
<td>-.18</td>
<td>-.22</td>
</tr>
<tr>
<td>Gestation length</td>
<td>.25</td>
<td>.10</td>
</tr>
<tr>
<td>Cow wt., precalving</td>
<td>-.01</td>
<td>-.20</td>
</tr>
</tbody>
</table>

As birth weight increases, percent assisted births increases 0.7 percent to 2.0 percent per pound of birth weight. Compared to heifer calves, bull calves have slightly longer gestation length, weigh 5 to 12 lb more at birth, and exhibit a 10 percent to 40 percent higher assistance rate. Several researchers have reported that calves requiring assistance weigh 5 lb to 7 lb more than those born without assistance. Research has also shown that the impact of birth weight on dystocia is much greater in 2-year-old cows, and that as cows become older, birth weight assumes less significance.

Pelvic Area

It is generally agreed that a major cause of dystocia is the disproportion between the size of the fetus and the pelvic opening of the dam, especially in first-calf heifers. This disproportionality is illustrated in Table 3, which is a summary of data from CSU. As birth weight increased and pelvic area declined, calving difficulty increased. Relative to the amount of variability in the two traits, changes in birth weight were considerably greater than changes in pelvic area. Unfortunately, phenotypic correlations between pelvic area and calving difficulty are not high, averaging only -.20 (Table 2).

Table 3. Effect of birth weight and pelvic area on calving difficulty in first-calf heifers

<table>
<thead>
<tr>
<th>Calving difficulty score</th>
<th>Yearling pelvic area (cm²)</th>
<th>Calf birth wt. (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (no assistance)</td>
<td>151</td>
<td>72</td>
</tr>
<tr>
<td>2 (minor assistance)</td>
<td>145</td>
<td>77</td>
</tr>
<tr>
<td>3 (major assistance)</td>
<td>141</td>
<td>82</td>
</tr>
<tr>
<td>4 (caeserian)</td>
<td>131</td>
<td>94</td>
</tr>
</tbody>
</table>

Heritability estimates for pelvic area are moderate to high, averaging about .50. This means that selection for larger pelvic size can be quite effective. However, several studies have demonstrated a positive relationship between pelvic area and body size (weight and frame) from birth to 18 months. Consequently, selection for increased pelvic area without some constraint on body size could possibly result in a parallel increase in birth weight and mature size and little change in calving ease. Therefore, it has been recommended by several researchers that selection for increased pelvic area be conducted within a size category.
It is agreed among many authorities that pelvic size should be viewed as a threshold trait and that heifers below a certain minimum pelvic area should be culled. Prebreeding minimum culling levels for pelvic area may range from 140 to 180 square centimeters depending upon the breed, herd, environment and other factors. Based on Miles City data, pelvic measurements have limited usefulness in predicting dystocia on an individual basis, but can be significant herd-wide. Their research shows that a 10 square centimeter increase in pelvic area would be accompanied by a 2-lb increase in calf birth weight and a 0.02 decrease in calving difficulty score.

Many purebred breeders now measure pelvic areas on their yearling bulls and publish the data in their sale catalogs. Because the genetic correlation between male and female pelvic area is high (.60), selection for increased pelvic size in bulls should result in increased pelvic size in heifer progeny. However, as noted above, selection for increased pelvic size should not be conducted without some constraint on birth weight. If no attempt is made to control birth weight, selection for increased pelvic size by itself may not be very effective. Ideally, pelvic areas in sale catalogs should be adjusted to a standard age such as 365 days. Beef Improvement Federation (BIF) suggests the following age adjustments be used: .25 and .27 square centimeters per day of age for yearling bulls and heifers, respectively.

**Gestation Length**

As shown in Table 2, gestation length is not highly correlated with dystocia. Using Simmental field data, Cornell researchers reported similar results. They found the correlation between birth weight and calving difficulty to be somewhat higher than the correlation between gestation length and calving difficulty (.40 vs .26). They concluded that sire differences in gestation length are not particularly useful predictors of differences in calving ease and that birth weight is a better, and more frequently recorded, predictor of calving ease. Nevertheless, using short-gestation sires has two important advantages: (1) calves are older and heavier at weaning time; and (2) because calves are born earlier, the cows have more time to recover and rebreed on schedule.

**Cow Size**

As indicated in Table 2, smaller heifers tend to have a higher incidence of dystocia than larger heifers but the correlations are low (-.01 and -.20). In Alberta research, it was reported that the ratio of calf birth weight to dam weight was the most important factor affecting dystocia, accounting for 28% of the total variation in calving difficulty. Calf birth weight by itself accounted for 18% of the total variation, and dam’s pelvic area accounted for less than 1% of the total variation. If one reviews all of the research that has been conducted on calving difficulty, no more than 50% of the total variation in dystocia can be explained by factors that can be defined or measured. In many studies, only 20 to 30% of the variation can be explained by quantifiable traits.

**Shape of Calf**

Many cattle producers believe that differences in a newborn calf’s shape can have an important effect on ease of delivery. For example, a slender, lighter-muscle, finer-boned calf theoretically should be born more easily than a thicker, heavier-muscle, coarser-boned calf of the same weight. However, researchers at MARC were unable to find any calf shape measurements significantly correlated with calving ease, even though they believe that such relationships likely exist. Data from Germany showed a relatively high correlation (.62) between chest girth at 330 days of age in Simmental sires and the calving difficulty of their progeny. In France, it was reported that the calf’s body length and rump width were significantly correlated with calving difficulty in 2-year-old cows and that selection of French beef breeds based on muscle development and growth rate early in life had led to an increase in birth weight and calving difficulty. In a Virginia study, researchers concluded that selection for calf shape, independent of birth weight, would not be expected to reduce dystocia. In summary, calf shape probably plays a role in dystocia but it is extremely difficult to quantify.

**Breed of Sire**

Research at MARC and elsewhere has demonstrated that significant differences exist...
between breeds of sires in calving difficulty and birth weight. In Cycles I, II and III (1970-76) at MARC, average assistance rates and birth weights of half-blood calves sired by 16 diverse breeds ranged from 2.9 to 20.4 percent and from 68.6 to 90.6 pounds, respectively. In Cycle IV (1986-89), the ranges were 0.3 to 9.2 percent and 71.3 to 90.2 pounds. In general, birth weights and assistance rates increased as mature size and growth rate increased.

**Breed of Dam**

Breed of dam effects on dystocia and birth weight do not follow a consistent pattern, except for Zebu-influenced females. Data from many sources clearly demonstrate that as the percentage of Zebu breeding increases in the dam, birth weight and dystocia decline. In Cycles I, II and III at MARC, Brahman- and Sahiwal-sired F₁ dams exhibited assistance rates of only 1 and 2 percent, respectively, compared to a range of 7 to 17 percent for 14 European breedtypes.

**Uterine Environment**

Researchers at MARC reported that fetal growth during the last 20% of gestation is dramatically lower in Brahman than in Charolais cows, which helps explain the lower birth weights of calves from Brahman-influenced dams, as noted above. They provided evidence which suggested that this difference is due to differences in uterine blood flow and function of the utero-placental tissues. Research at Miles City has likewise shown that diverse breeds of dams differ greatly in the growth rate of the fetuses they are carrying.

**Hormonal Control**

Several hormones are associated with parturition (e.g., ACTH, cortisol, estrogen, prostaglandin, progesterone, oxytocin and relaxin). Increased blood levels of relaxin prior to parturition have been shown to enhance cervical and pelvic dilatation, resulting in normal delivery of the fetus. Unlike some species, circulating blood concentration of relaxin in cows remains consistently low the last days of pregnancy. Iowa research has shown that injecting first-calf heifers with relaxin within the last 5 to 6 days before calving significantly reduces the incidence of dystocia. Cows can be induced to calve within 48 to 60 hours by injecting them with a corticosteroid or a prostaglandin within 10 days of parturition. However, such treatments commonly result in difficult calvings and retained placentas. When the Iowa researchers combined relaxin with either dexamethasone (a corticosteroid) or cloprostenol (a prostaglandin), these problems were reduced significantly. Whether hormonal control of parturition can become a practical management strategy remains to be determined.

**Geographic Region**

Hereford cows of comparable genetic make-up were moved from Miles City, Montana, to Brooksville, Florida, and vice versa. Ten years after this switch was made, birth weights in the Montana herd that had been moved to Florida had declined from 81 lb. to 64 lb. Conversely, birth weights in the Florida herd that had been moved to Montana had increased from 66 lb to 77 lb. Other studies have yielded similar results, indicating that calves of comparable genotype will be born lighter in the south than in the north.

**Season of Year**

Research has shown that calves born in the fall of the year are generally lighter in weight and experience less dystocia than those born in the spring.

**Environmental Temperature**

Prolonged exposure to high environmental temperatures will result in reduced birth weights, which can in turn lower the incidence of dystocia. There is less information on cold stress. However, the available data have shown that low environmental temperatures are related to heavier birth weights and increased calving difficulty. It is likely that differences observed between geographic regions and seasons of the year, as discussed above, are related to differences in environmental temperature.
Calving Difficulty in Beef Cattle
Part II

Harlan D. Ritchie, Michigan State University
and
Peter T. Anderson, University of Minnesota

Dietary Energy

Many cattlemen believe reducing dietary energy during late pregnancy will decrease fetal size resulting in improved calving ease, whereas increasing energy will increase fetal size leading to a higher incidence of dystocia. Generally speaking, research has shown that lowering the energy allowance will decrease birth weight but will not significantly reduce dystocia. At MARC, Hereford and Angus 2-year-old heifers were fed three levels of energy (10.8, 13.7 or 17.0 lb TDN/head/day) for 90 days prior to calving. Increasing the level of dietary energy resulted in increased birth weight but not increased dystocia; in fact, the incidence of calving difficulty was lower in the medium and high energy groups than in the low energy group.

Inadequate nutrition of the young developing heifer can affect her subsequent calving performance. Miles City research showed that restricting the energy of weaned heifer calves during their first winter can have a carry-over effect, resulting in decreased precalving pelvic area and increased dystocia (46 percent vs. 36 percent) compared to adequately fed heifers. From weaning to first breeding as yearlings, heifers should be fed to weigh at least 65% of their potential mature cow weight. This translates to a range in average daily gain of approximately 1.25 lb to 1.75 lb for 200 days. Depending upon initial weight, frame size, body condition and environment, this means that daily TDN requirement will range from 8 lb to 13 lb per head.

When they calve as 2-year-olds, heifers should

*(Authors' note: This fact sheet is second in a series of two on calving difficulty).*

weight 85% of their mature cow weight. This translates to an average daily gain of about 1 lb per day from breeding to calving. Adequate pasture conditions will support this level of performance. During the winter prior to calving, pregnant heifers require from 9 lb to 13 lb of TDN per day. The mature pregnant cow requires from 7.5 lb to 13 lb of TDN.

Dietary Protein

There is some concern in the cow-calf industry that high levels of protein during the last trimester of pregnancy may lead to a significant increase in birth weight and dystocia. At Miles City, crossbred 2-year-old pregnant heifers were fed diets containing either 86 percent (low) or 145 percent (high) of the NRC crude protein requirement for 82 days prior to calving. Heifers fed the low protein diet had significantly lighter calves at birth and less calving difficulty. Heifers on the high protein diet gained more weight, had higher condition scores at calving, maintained more body weight throughout the study, and weaned significantly heavier calves. In a repeat study at Miles City, there were no differences in calf birth weight or calving difficulty. Research at other institutions has shown no consistent effect of protein level on dystocia. It would appear that precalving dietary protein level should be near the NRC requirement. If it is extremely low, weight and condition of the cows and weight, vigor and post-natal growth rate of the calves may be reduced. If it is unduly high, it represents an economic waste. During the last trimester of pregnancy, crude protein requirements range from 8.2 to 9.8 percent for heifers and 7.6 to 8.2 percent for mature cows.

Body condition

Prior to the last trimester of gestation, females should be evaluated for body condition. Those in thin condition (body condition score 4 or less on a 1 to 9 scale) should be fed separately from those in moderate or higher condition so their dietary energy level may be increased. By calving time, the goal would be to have mature cows in moderate condition (score of 5) and first-calf heifers in high moderate condition (score of 6). Over-feeding females to the point
of obesity has been shown to increase the incidence of dystocia. Texas researchers reported that as fatness score increased above a moderate level in first-calf Santa Gertrudis heifers, calving difficulty increased. They concluded that efforts should be made prior to calving to prevent over-conditioning of females in an effort to reduce dystocia.

Implants and Feed Additives

Numerous studies have shown that implanting heifer calves with zeranol (Ralgro®) increases pelvic area at breeding time. However, in most instances, this increase did not persist up to calving time and there was little effect on calving difficulty. Similar results have been reported when Synovex-C® implants were used on suckling heifer calves. Some producers believe that feeding an ionophore such as monensin (Rumensin®) or lasalocid (Bovatec®) increases calving problems. However, research has shown these compounds have no effect on gestation length, calf birth weight, pelvic area, or dystocia.

Feeding Time

The time of day the cow herd is fed during calving season has been shown to influence when calves are born. The data indicate that cows fed at night are more apt to calve during daylight hours when they can be observed closely. Gus Konefal, a Hereford breeder in Manitoba, was the first to recommend this feeding strategy. Consequently, it has been called the "Konefal Method" of daytime calving. This system involves feeding twice daily, once at 11:00 a.m. to 12 noon and again at 9:30 p.m. to 10:00 p.m. This regime starts about 1 month before the first calf is born and continues throughout the calving season. By following this feeding program, Konefal reported that 80 percent of his cows calved between 7:00 a.m. and 7:00 p.m. Similar results were obtained in a study at Iowa State University. These two studies prompted Miles City researchers to conduct a 3-year study on feeding time. Their results were not as dramatic as those of the earlier studies. Nevertheless, the percentage of cows calving between 10:00 p.m. and 6:00 a.m. was consistently 10 to 20 percent lower for the late-fed than for the early-fed cows. Similar research conducted at the Brandon Research Station showed a 13.5 percent reduction in cows calving between midnight and 7:00 a.m.

Exercise

Forced exercise for several weeks prior to calving has been shown to improve the calving ease of closely confined dairy heifers. However, Miles City researchers could find no difference in calving ease between heifers maintained in a typical feedlot and those forced to walk 2 miles a day. It was concluded that unless beef heifers are under extremely close confinement, exercise is of no benefit in reducing dystocia.

Calving Time Management

In addition to knowing how to give assistance, it is also important to know when to help. For years, the general recommendation was to intervene if the cow was in intense labor for 2 to 3 hours without making progress. Research at Miles City suggests that it may be beneficial to give assistance earlier. They reported that intervening as soon as the cervix was fully dilated and the membranes and the calf's feet extended from the vulva (beginning of second stage of labor) resulted in significant advantages over a group of females that received no assistance unless it was needed to save the calf. These advantages were: higher percent in heat at beginning of breeding season (91 percent vs. 81 percent); higher first service conception rate (75 percent vs. 60 percent); and higher pregnancy rate in October (90 percent vs. 76 percent). These advantages were observed in mature cows as well as in first-calf heifers. It was reported that duration of the second stage of labor averaged 54 minutes for heifers and 23 minutes for cows. Out of this research, the following time limit was set at the Miles City station: if definite progress has not been made after 1 hour of intense labor, the calf is pulled. They caution, however, that the cervix should be fully dilated and the calf's feet visible. Also, the position of the fetus must be normal; for example, if either of the legs or head are back they must be corrected before assistance is given.
Genetic Management

From a genetic standpoint, there are several traits which may be considered in a selection program to keep dystocia under control; they are: (1) Individual birth weight; (2) EPD (expected progeny difference) for birth weight; (3) The sire’s EPD for direct (his own) calving ease on first-calf heifers; (4) The sire’s EPD for maternal (his daughters) calving ease on first calves (5) The sire’s pelvic area; (6) The pelvic area of potential replacement heifers.

Birth Weight and EPDs for Birth Weight

Although individual birth weights can be used as a guide in selecting young unproven bulls, EPDs are better predictors because they combine data from several sources — the individual, his ancestors and his half-sibs. As a bull becomes older and sires a significant number of progeny, the accuracy of his EPDs improve markedly. By then, his individual birth weight is of little or no significance. A number of studies have shown strong correlations between EPDs of sires and actual birth weights of their progeny, especially among sires with high accuracy (over .80).

In order to minimize dystocia in first-calf heifers, ideally they should be mated to bulls with breed average or lower birth weight EPDs. For maximum precision, a young unproven bull’s EPD should be compared against the breed average for bulls in his own birth year group. Breed average information is contained in many of the sire summaries published by breed associations.

As noted before and shown in Table 4 (CSU data), birth weight is a moderately heritable trait and is positively genetically correlated with other growth traits. Therefore, many bulls having average to below average birth weight EPDs will be average or lower for other growth traits. However, there are exceptions, and a search of sire summary lists can be used to identify bulls that have low birth EPDs and high weaning and yearling EPDs.

A calf’s birth weight is influenced by both the sire’s and the dam’s genotype for birth weight. Therefore, selecting heifers from sires with low birth weight EPDs can stack the herd’s pedigrees in favor of calving ease.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Heritability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth weight</td>
<td>.41</td>
</tr>
<tr>
<td>Weaning weight</td>
<td>.32</td>
</tr>
<tr>
<td>Yearling weight</td>
<td>.43</td>
</tr>
<tr>
<td>18-month weight</td>
<td>.61</td>
</tr>
</tbody>
</table>

Table 1. Heritabilities of growth traits and their genetic correlations with birth weight.

EPDs for Calving Ease

Direct Calving Ease. Except for Simmentals, this EPD is reported as a ratio; sires with higher ratios will calve easier when mated to first-calf heifers. The Simmental Association provides direct calving ease EPDs for both heifers and cows. Simmental EPDs are expressed in percent unassisted births, with positive numbers indicating greater calving ease. In general, EPDs for direct calving ease are closely related to EPDs for birth weight. All breed associations publish EPDs for birth weight, but only three associations report calving ease EPDs.

Maternal Calving Ease. This trait is reported and interpreted in a manner similar to direct calving ease. This EPD predicts how easily a sire’s daughters will calve, not how easily the sire himself will calve.

Heritability estimates of calving ease have been lower than those reported for birth weight. This suggests that genetic progress made by selecting directly on calving ease EPDs would be slower. An exception would be the Simmental breed in which calving ease EPDs have been shown to be a more accurate indicator of dystocia than birth weight EPDs. This is because Simmental calving ease EPDs incorporate birth weight as well as a score for calving ease. For long-term improvement in the herd, using sires with high maternal calving ease EPDs and retaining their
daughters should be beneficial.

Pelvic Area

Please refer to the first fact sheet (Part I) in this series for a complete discussion of selecting for pelvic area.

Selecting Natural Service Bulls

The producer who is not in a position to artificially inseminate first-calf heifers does not normally have the option of using highly proven sires with high accuracy EPDs for birth weight and/or calving ease. An alternative is to purchase an older bull, known for his calving ease, from another producer in the area. Transmission of disease is a potential risk when this is done. A more realistic option is to purchase an unproven bull that has a low birth weight EPD, a large pelvic area and a low individual birth weight (adjusted for age of dam). If birth weight EPDs are not available, try to look for sons of highly proven calving ease sires. Even better, look for young bulls whose sire and maternal grandsire are both highly proven calving ease sires. If no information is available except for an individual birth weight, consider the age of the dam when the bull was dropped because younger cows give birth to lighter calves. Ideally, birth weights should be adjusted to a 5- to 10-year-old dam equivalent by adding the following adjustments: 2-yr-olds, 8 lb; 3-yr-olds, 5 lb; 4-yr-olds, 2 lb; 11-yr-olds and over, 3 lb. These are standard adjustments published by the Beef Improvement Federation; some breeds have their own adjustments. However, relying solely on individual birth weight is risky business. A low birth weight bull whose sire may have unknowingly been a high birth weight sire is not likely to be a good candidate for use on virgin heifers.

Summary

In summary, research has shown the following strategies to aid in alleviating calving problems:

1. Develop heifers properly so they achieve at least 65 percent of their mature weight by breeding time and 85 percent by the time they calve as 2-year-olds.

2. Breed virgin heifers one heat period before the mature cow herd and give them extra attention at calving time.

3. Know the pregnant female's nutrient requirements. Neither underfeed nor overfeed her. Body condition scores at calving time should fall within a range of 5 to 6 on a 9-point scale.

4. Using the Konefal Method may cause more females to calve in the daytime when they can be observed closely.

5. Know when and how to give assistance and when to consult a veterinarian.

6. Measure pelvic areas of potential replacement heifers and cull the lower end.

7. Mate virgin heifers to low-risk bulls:
   a. Proven AI sires with high accuracy EPDs for birth weight and/or calving ease.
   b. Unproven bulls with low birth weight EPDs, large pelvic areas and low individual birth weights.

8. Retain daughters of sires that combine low birth weight EPDs and high maternal calving ease EPDs.
Impacts of Type on Feed and Market Requirements

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So you want to make them bigger! Or, do you want to add some milk to your cow herd? Improvements in these and other traits offer opportunities to increase production through higher weaning weights. However, the increased outputs are accompanied by increased feed and management inputs. Available research indicates that the increased production may or may not outweigh the increased inputs.

Mature cow size and level of milk production are typically the factors considered when changes in cattle type are discussed. Numerous research studies have been conducted to evaluate the effects of these factors on biological and economic efficiency. In these studies, biological efficiency varied widely as conditions changed from study to study. The bottom line was that no one type, breed or kind worked best under all conditions. In fact, when biological efficiency was measured as the total energy required by a cow and calf to produce a pound of edible beef, there were virtually no significant differences noted among the breeds or types.

Economic efficiency has varied according to the resources available. When an abundant supply of high quality feed is available, the larger, heavier milking cow has generally been more profitable. However, when the feed supply is restricted below the level needed to maintain high reproductive rates in these larger, high producing cattle, the smaller cow with somewhat lower milking ability generally becomes the more economically efficient.

Thus, commercial cattlemen must face the question, "How do I design a breeding and selection program that produces cattle that are adapted to my resources?"

Effects of Type Changes on Nutritional Requirements and Reproduction

Let's first look at how various type changes affect the energy requirement (pounds of total digestible nutrients (TDN) per day) of the cow. Cornell University researchers define (Table 1) the relationship of frame score (FS) and hip height to mature cow weight and to TDN requirements postweaning and at two different levels of milk production during peak lactation. Increasing cow size from FS 3 to a FS 5 results in an additional 145 lb of cow weight to maintain. This additional size requires an 11% increase in TDN during gestation and a 7 to 8% increase during lactation. If the feed is available, the larger intake capacity of the bigger cow will generally allow her to consume enough feed to meet these higher requirements.

Table 1. Relationship of Frame Score and Hip Height to Mature Cow Weight and Energy Requirements Following Weaning and During Peak Lactation

<table>
<thead>
<tr>
<th>Frame score</th>
<th>Cow hip height, in.</th>
<th>Mature cow weight</th>
<th>Postweaning</th>
<th>12 lb per day</th>
<th>18 lb per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>44</td>
<td>880</td>
<td>7.4</td>
<td>11.6</td>
<td>13.2</td>
</tr>
<tr>
<td>2</td>
<td>46</td>
<td>955</td>
<td>7.9</td>
<td>12.0</td>
<td>13.7</td>
</tr>
<tr>
<td>3</td>
<td>48</td>
<td>1030</td>
<td>8.3</td>
<td>12.6</td>
<td>14.2</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>1100</td>
<td>8.7</td>
<td>13.1</td>
<td>14.7</td>
</tr>
<tr>
<td>5</td>
<td>52</td>
<td>1175</td>
<td>9.2</td>
<td>13.6</td>
<td>15.2</td>
</tr>
<tr>
<td>6</td>
<td>54</td>
<td>1250</td>
<td>9.6</td>
<td>14.1</td>
<td>15.7</td>
</tr>
<tr>
<td>7</td>
<td>56</td>
<td>1320</td>
<td>10.1</td>
<td>14.6</td>
<td>16.1</td>
</tr>
<tr>
<td>8</td>
<td>58</td>
<td>1395</td>
<td>10.5</td>
<td>15.0</td>
<td>16.6</td>
</tr>
<tr>
<td>9</td>
<td>60</td>
<td>1470</td>
<td>10.9</td>
<td>15.5</td>
<td>17.0</td>
</tr>
</tbody>
</table>

*Adapted from Fox et al., 1988.
Stocking rates must therefore be adjusted to meet the demands of the bigger cows. The land necessary to carry 100 of the 1030 lb cows will carry approximately 92 of the 1175 lb cows and only 86 of the 1320 lb cows. These additional feed costs have to be made up through additional calf growth or increased selling price per pound.

The actual weight increase for each frame score increase in size will vary among different breeds and cattle types. Therefore, the mature weights of larger framed cows could easily exceed the predictions of Fox and coworkers. Researchers at Colorado State University projected cow weights for different frame scores (FS) to be: FS 2-3 = 850 lb, FS 3-4 = 1000 lb, FS 4-5 = 1150 lb, FS 5-6 = 1300 lb, FS 6-7 = 1450 lb. Check the weights on your own cows. Most producers are usually surprised by the mature weight of their current cow herd; consequently, they have often failed to make the necessary adjustments in stocking rates and winter feeding programs.

Heavier milking cows also require more feed. As shown in Table 1, increasing peak milk production from 12 lb per day to 18 lb per day requires approximately 1 1/2 lb more TON per day. This translates into a 10 to 14% increase in energy requirement, depending on the cow's size. The 1984 NRC indicates that increasing the peak milk production potential of an 1100-lb cow from 10 lb per day (average) to 20 lb per day (superior) will raise her daily requirement for energy by 25%, protein by 30%, phosphorus by 25% and calcium by 40%. Whereas increases in requirements due to size were partially offset by increases in intake, increased intake due to increases in milk production do not usually offset the increased requirements. Therefore, increased diet quality (i.e., higher percentage TDN), whether in the form of grain or higher quality forage, may be needed to meet these higher nutritional demands (Table 2).

Table 2. Impact of Cow Size and Milk Production Level on Feed Intake (DMI) and Feed Quality (% TDN)

<table>
<thead>
<tr>
<th>Cow weight</th>
<th>Avg milk</th>
<th>High milk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DMI</td>
<td>% TDN</td>
</tr>
<tr>
<td>1000</td>
<td>20.2</td>
<td>57</td>
</tr>
<tr>
<td>1200</td>
<td>23.0</td>
<td>56</td>
</tr>
<tr>
<td>1400</td>
<td>25.6</td>
<td>55</td>
</tr>
</tbody>
</table>

Impact of Frame Size on Reproduction

When feed resources are restricted, the larger framed cattle are more susceptible to decreases in reproductive performance. The results of an Iowa study (Buttran and Willham, 1987) demonstrate the interaction that occurs between frame size and management conditions (Table 3). Under favorable management conditions, there were no significant differences among small, medium and large framed first calf heifers in the percentage cycling during a 42-day breeding season or in the percentage calving the following year. However, when management conditions were marginal, the large framed heifers reacted more adversely. Even though reproductive performance of both groups was depressed, the small framed heifers had both a higher percentage cycling and a higher percentage calving than the large framed heifers.

Table 3. Effects of Size and Management on Reproductive Traits of First Calf Heifers

<table>
<thead>
<tr>
<th>Trait</th>
<th>FAVORABLE MANAGEMENT</th>
<th>MARGINAL MANAGEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SMALL</td>
<td>MEDIUM</td>
</tr>
<tr>
<td>Cycling rate, %</td>
<td>98.5</td>
<td>98.3</td>
</tr>
<tr>
<td>Calving rate, %</td>
<td>84.9</td>
<td>84.5</td>
</tr>
</tbody>
</table>

* Adapted from Buttran and Willham, 1987.
In addition to the effects on mature size, changes in size also impact the weight at puberty of replacement heifers. Weight at puberty is a function of mature size. As mature size potential increases, the weight needed for a heifer to begin cycling also increases. For example, if a FS 3 heifer reached puberty at 575 lb, a FS 6 heifer may need to weigh 750 lb before she starts cycling. Thus, if the selection program creates an increase in mature size potential, the replacement heifer development program will have to be adjusted accordingly to get the heifers to their heavier target weights. Perhaps more importantly, larger framed cattle are generally later maturing cattle. This means that they reach stages of physiological development, such as puberty or maturity, at older ages. Therefore, it becomes difficult for extremely large framed cattle to reach puberty in time to be bred at 13 to 15 months of age in order to calve at 22 to 24 months.

This is not to say increases in growth cannot be accomplished without increasing age at puberty. However, to improve both of these traits at once will require a strict heifer culling program and a strong selection emphasis on earlier maturing breeds and scrotal circumference when selecting sires.

Another potential type change that deserves consideration is the emphasis to improve carcass cutability. Increasing the thickness and musculature of an animal is another way to increase its mature weight. If frame and body condition are held constant, differences in muscling can create as much as a 150- to 200-lb variation in the mature weight of the beef cow. These changes in size and weight will cause increases in nutritional requirements similar to those caused by increased frame size.

Also, be aware that carcass traits and reproductive traits are antagonistic. Increased selection pressure in one of these areas generally results in a decrease in performance in the other area. Pruitt and coworkers at South Dakota State University reported that thin cows at calving (condition scores 2 and 3) had only a 15 to 25% probability of cycling by the beginning of the breeding season and an 87 to 93% change of becoming pregnant in a 60-day breeding season. This compared to a 60 to 75% probability of cycling and a 98 to 99% probability of pregnancy for moderately conditioned cows at calving (condition scores 5 and 6). This research indicates that we do run the risk of reproductive problems if we breed all of the fat and fleshing ability out of replacement females.

**Impact of Frame Size on Market Potential**

Frame scores are useful in determining the appropriate market weight. Table 4 lists the approximate live and carcass weights at which steers and heifers of varying frame scores will reach a market endpoint of Low Choice (approximately 30% carcass fat). It is obvious that both live and carcass weights increase dramatically as frame scores increase. It is also important to realize that, just as with mature cow weights, heavy muscled Limousin steers and heifers will likely weigh more than is predicted in Table 4 for a given frame size.

<table>
<thead>
<tr>
<th>Frame score</th>
<th>Approximate weight at Choice grade, lb</th>
<th>Steers</th>
<th>Carcass&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Heifers</th>
<th>Carcass&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Live</td>
<td></td>
<td></td>
<td>Live</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>750</td>
<td>472</td>
<td>600</td>
<td>378</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>850</td>
<td>536</td>
<td>700</td>
<td>441</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>950</td>
<td>598</td>
<td>800</td>
<td>504</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1050</td>
<td>662</td>
<td>900</td>
<td>567</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1150</td>
<td>724</td>
<td>1000</td>
<td>630</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1250</td>
<td>788</td>
<td>1100</td>
<td>693</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1350</td>
<td>850</td>
<td>1200</td>
<td>756</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1450</td>
<td>914</td>
<td>1300</td>
<td>819</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1550</td>
<td>976</td>
<td>1400</td>
<td>882</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Assuming a dressing percent of 63% (hot carcass basis).
If the acceptable carcass weight range is 550 to 850 lb, we need to produce feeder cattle (steers and heifers) in the 4 to 7 frame score range. For a herd of small framed cows (frame scores 2 and 3), bulls with frame scores of 6 to 8 would be needed to generate the desired frame score in the offspring. However, calving difficulty could definitely be a problem in this instance of using larger mature size bulls on the small cows. For moderate framed (4 to 5 frame) cows, bulls in the 4 to 7 frame score range would be desirable. For large framed cows (6 to 7 frame score), bulls of the same frame score or smaller would be needed to produce the specified feeder cattle. If packer pressure narrows the acceptable carcass weight range, the acceptable range in frame scores for feeder cattle will also narrow and breeding programs will need to be adjusted accordingly.

The predicted impacts on market steers and replacement heifers from using various frame score bulls on 1050 lb and 1150 lb cows are shown in Table 5. Even though the changes in weight are not as dramatic as one might think, one must be aware that these predictions are averages and that the extremes of the calf crop can quickly move outside of acceptable weight ranges. Also, it is important to realize that “frame creep”—where frame size increases as a correlated response to selection for increased growth rate—usually occurs gradually through a series of selection decisions.

<table>
<thead>
<tr>
<th>Cow size</th>
<th>FS 3-4 (Wt 1050)</th>
<th>FS 4-5 (Wt 1150)</th>
<th>FS 4-5 (Wt 1150)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bull FS</td>
<td>Steer wt</td>
<td>Steer wt</td>
<td>Heifer breeding wt</td>
</tr>
<tr>
<td>4</td>
<td>1065</td>
<td>1135</td>
<td>735</td>
</tr>
<tr>
<td>5</td>
<td>1095</td>
<td>1165</td>
<td>755</td>
</tr>
<tr>
<td>6</td>
<td>1125</td>
<td>1195</td>
<td>775</td>
</tr>
<tr>
<td>7</td>
<td>1155</td>
<td>1225</td>
<td>795</td>
</tr>
<tr>
<td>8</td>
<td>1185</td>
<td>1255</td>
<td>815</td>
</tr>
<tr>
<td>9</td>
<td>1215</td>
<td>1285</td>
<td>835</td>
</tr>
</tbody>
</table>

Matching Type to Resources

There is no one right type or kind for all situations. Under different production environments, the different cattle types will re-rank themselves in terms of production efficiency and profitability. Therefore, each producer must evaluate the type of cattle that adapt and perform most economically in their own production system.

Selection for extremes, whether it be extreme frame, extreme weight, extreme muscling or extreme milk production, is fairly easy, and rapid progress in the selected traits can be made. Remember, however, that nature selects against extremes and, unless rapid change is needed, extremes in type really aren’t needed, either.

Many factors must be considered in a multiple trait, balanced selection program designed to produce cattle that perform efficiently within their given resources and environment. It has often been said that we should “match the cow to the environment and the bull to the marketplace” to truly capture economic efficiency while meeting the needs of the consumer. For commercial cattle producers, this is best accomplished through a planned crossbreeding that properly utilizes the variety of genetics that are available to the beef industry. As seedstock producers, it is imperative that you establish the role that you want your breed and your herds to play in the commercial cattle production scheme. Once that role is firmly established, you must then design your breeding programs to produce cattle that meet the goals and objectives of your customers!
Which Cows Are More Efficient?

D.M. Marshall
South Dakota State University

On the surface, the topic of cow efficiency may seem to be primarily of importance to commercial cow-calf producers. The topic is also of importance to seedstock producers, because the primary purpose of the seedstock industry is to provide genetic resources for the commercial industry. It is critical that seedstock producers develop a good understanding of the challenges faced by commercial producers in order to provide the best possible services.

Feed costs for the cow herd represent the single largest expense in producing retail beef. The proportion of total energy utilized in beef production that is required to support the breeding herd is larger for cattle than for most other meat species, because of a relatively low reproductive rate. Fortunately, much of the energy for the breeding herd can be supplied through feedstuffs that are readily grown in areas not well suited for tillable crop production, and can be harvested economically by the cow herself. While relatively cheap, such feedstuffs are not free. Furthermore, supplemental feeding is needed at times to sustain the cow herd year-round. An important objective for the commercial producer, then, would seem to be to limit feed costs. However, attempts to decrease feed costs should be approached with caution because of the effects of cow nutrition and body condition on reproductive success.

Matching Genetic Type to Environment

The concept of matching genetic type to the existing environment has received a lot of attention in recent years. It is often more economical to utilize resources that are inherently available rather than those that must be purchased elsewhere. Thus, it seems logical for most commercial producers to choose cattle types that fit the local resources rather than choose cattle types they happen to like and then adjust resources to fit the cattle. Of course market demands should also dictate cattle type. Environmental criteria include feed availability and factors related to stress such as temperature, moisture, wind, terrain, disease and parasites. Genetic factors include milk yield potential, mature size, and stress resistance (adaptability). The concept sounds great, but the challenge under most situations is that the environment at a given location is not constant. Year to year differences and particularly seasonal differences can be quite extreme.

The Flexible Cow? In the northern plains region, we have both heat and cold stress. We have good feed supplies some years and are plagued by drought in other years. Such variable conditions dictate that we use cow types that are tolerant to a wide range of environmental conditions, rather than cow types with specialized adaptations. We generally learn through trial and error which breeds are generally well suited to a particular environmental situation. Imposed and natural selection within a breed can further enhance adaptability, but requires considerable time. In seedstock production, we might consider more emphasis on selection under commercial conditions as opposed to conditions that provide for maximum expression of the animal's genotype for growth.

Antagonisms Between Traits

An intricate network of interrelationships among cow size, cow feed requirements, milk production, reproductive efficiency, calf growth rate and feed conversion are important to the net efficiency of production. Selection on one trait will cause correlated changes in other traits. Some relationships of concern include cow milk production potential and mature size with feed requirements; carcass leanness with marbling and cow fleshing ability; and, growth rate with mature size, carcass weight, and calving ease.

The existence of antagonisms between traits indicates a need to select for a balance of traits rather than extremes. On the other hand, all pure breeds do not have to be all things to all producers, because crossbreeding systems allow the commercial producer to combine the strengths of different breeds in a complementary manner. Terminal breeding systems that distinguish between
sire types and dam types have the potential to reduce the effects of antagonisms between traits. Each breed organization and each individual seedstock breeder must determine the extent to which they should emphasize general-purpose versus specialized breeding stock. In general, we expect general-purpose stock to be used in rotational breeding systems and specialized stock to be used in terminal matings.

**Milk Production**

Higher milk-producing cows require more feed, and produce larger calves. Remembering the law of diminishing returns, the key is to avoid going beyond the point where the extra weaning weight is no longer sufficient to pay for the extra feed costs.

Evidence suggests that higher milking breeds require more feed per unit of cow weight not only during lactation, but also to maintain energy or weight equilibrium (i.e., maintenance requirements) in dry, nonpregnant cows (Ferrell and Jenkins, 1984; Solis et al., 1983). The relationship of milk production with overall efficiency of feed utilization by a cow and her calf is less clear. Montano-Bermudez and Nielsen (1990) evaluated low, medium and high milk potential breed groups, and reported a slight advantage in efficiency of feed utilization to weaning for the low group. They also reported diminished postweaning feed efficiency for calves from the high milk group. Figure 1 shows relationships of milk yield and cow size with efficiency of feed utilization for weaned calf production from an SDSU study of first-lactation beef females and their calves (Freking and Marshall, 1990). Production efficiency was calculated as cow-calf feed energy (ME) per unit of calf weaning weight, and so a lower value indicates improved efficiency. The figures for milk production are based on calf intake after an overnight separation from the dam. At any given cow size, increased levels of milk yield were associated with improved efficiency of feed utilization to weaning. The incremental improvement in efficiency, though, was less with each additional unit increase in milk yield.

![Figure 1. Relationships of overnight milk production and heifer size to production efficiency (cow and calf ME / calf weaning weight) in first-calf heifers. Adapted from Freking and Marshall (1990).](image)

It has often been suggested that cow milk yield potential should be matched to the feed supply, letting cow reproductive performance serve as a guideline to tell us when we're getting too extreme. An additional factor that deserves attention, but has generally been overlooked, is the
volume of milk that the calf can efficiently utilize. Results of Taylor et al. (1986) suggest that cows convert feed to milk most efficiently when producing near their maximum potential. For example, if you want 18 lb of milk per day, then it more efficient to use to use cows whose maximum potential is approximately 18 lb than cows whose maximum potential is 30 lb. While it has always been recognized that sufficiently increased calf weaning weights must be produced by higher producing cows to maintain efficiency, we've tended to focus on this from an output (calf weight)-standpoint rather than from an input (calf intake) standpoint. Calf appetite and determining the optimal level of milk intake for a calf of a given growth potential appear to be areas where additional research could be useful. From the standpoint of a commercial breeding program, appropriately matching sire type to dam type would be the obvious approach through which we attain the optimal match of dam milk yield potential and calf milk intake.

Cow Size

Feed requirements per cow obviously increase with increasing cow size, although maintenance requirements per unit of cow weight do not appear to be affected by cow size (Ferrel and Jenkins, 1984). Furthermore, most studies have not shown a significant association of cow size with efficiency of feed utilization by the cow-calf pair to weaning (Marshall et al., 1976; Freking and Marshall, 1990). Simulation studies generally indicate that larger, higher producing cows are economically more efficient under conditions of an abundant, high quality feed supply, whereas smaller cows are more profitable when the feed supply is limited. A study conducted under Montana range conditions included Simmental-Hereford cross cows that were either 1/4, 1/2 or 3/4 Simmental (Table 1, Kress et al., 1990). The F1 group was intermediate in cow weight and calf weight, but ranked highest for calf weaning weight per cow exposed to breeding (i.e., when cow reproduction and calf survival were into account).

Table 1. Performance of Simmental-Hereford Cows in Montana

<table>
<thead>
<tr>
<th>Dam Breed Group</th>
<th>Cow weight, kg</th>
<th>Calf weight, kg</th>
<th>Calf wean wt per cow exposed, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1S3H</td>
<td>530</td>
<td>156</td>
<td>179</td>
</tr>
<tr>
<td>1S1H</td>
<td>545</td>
<td>161</td>
<td>189</td>
</tr>
<tr>
<td>3S1H</td>
<td>571</td>
<td>166</td>
<td>169</td>
</tr>
</tbody>
</table>

*Adapted from Kress et al. (1990)*

Associations between feed supply, cow body condition, and reproductive performance have been established. Nature tends to respond to feed shortages by helping to ensure survivability of an existing calf by delaying or denying the conception of a future calf. The question of how cow size fits into this scheme is probably related more to management than to inherent genetics. Heritability tends to be quite low for most reproductive traits. In general, larger, higher producing cows will reproduce adequately if provided sufficient levels of appropriate quality feed. We have used both Angus-Hereford and Simmental-Hereford cross cows at the Antelope Range Livestock Station in northwestern South Dakota for a number of years, and have generally attained adequate pregnancy rates among both breed groups (Marshall et al., 1990). Pregnancy rates have averaged slightly higher numerically for the Angus-Hereford group, but the difference has not been statistically significant.

An Australian study was initiated in 1974 to compare the performance of three lines of Angus cattle, selected for either High growth, Low growth or at random (Control). Results based on the 1989 calf crop or on cow traits averaged over 1987-89 are presented in Table 2. The High line calves were heavier at all ages and High line cows were heavier and taller. In a cow-calf efficiency evaluation, the High line cows consumed more feed from calving to weaning, but increased weaning weights of their calves resulted in better efficiency of feed utilization. Preliminary data indicated no significant difference in reproductive performance of High versus Control lines. Calving
difficulty in heifers tended to be lower for High and Low lines compared to Control, while line differences in cows were not significant.

Table 2. Deviations From Control for Lines Selected for High Versus Low Growth Rate.

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth weight</td>
<td>-15%</td>
<td>+9%</td>
</tr>
<tr>
<td>Yearling weight</td>
<td>-14%</td>
<td>+15%</td>
</tr>
<tr>
<td>Cow height</td>
<td>-4%</td>
<td>+3%</td>
</tr>
<tr>
<td>Cow weight</td>
<td>-10%</td>
<td>+8%</td>
</tr>
<tr>
<td>Cow-calf feed eaten,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>calving to weaning</td>
<td>-1.6%</td>
<td>+2.3%</td>
</tr>
<tr>
<td>Adj. weaning weight</td>
<td>-9.6%</td>
<td>+6.8%</td>
</tr>
<tr>
<td>Cow-calf efficiency,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>calf wt / feed eaten</td>
<td>-8.0%</td>
<td>+5.4%</td>
</tr>
</tbody>
</table>

*Adapted from Parnell et al. (1990).

**Calf Weight to Cow Weight Ratio -- A Note of Caution.** The ratio of calf weight to cow weight is often used as an indicator of efficiency. Caution should be exercised with this ratio, however, as research has demonstrated it is sometimes biased, generally in favor of smaller breed types (Dinkel and Brown, 1978). This is basically because smaller cows, on average, must consume more feed per unit of body weight than larger cows to achieve a given level of production.

**Management -- a Key to Cow Size.** Close monitoring of body condition scores and pasture condition, in conjunction with adjustment of stocking rates and supplemental feeding, provide for some leeway in optimal cow size in a given environment. The ability of the producer to manage stocking rates, along with the relative cost of supplemental feeding, are among the factors that should be used to determine optimal cow size. The end result is that some producers can successfully utilize larger cows, while their close neighbors are better off with smaller, lower-producing cows.

**Breed Effects**

Few people care to see figures where their favorite breed ranks worse than other breeds for various characteristics. However, most seedstock breeders are willing to recognize that all breeds have strengths and weaknesses, and that breeds should be characterized by their potential contributions to breeding systems in commercial herds. Breed associations and individual seedstock breeders must identify those areas of the commercial industry for which they wish to provide services, and then develop breeding objectives accordingly.

A number of studies have looked at breed differences on efficiency of feed utilization by the cow-calf pair, with conflicting results. A couple of the earlier studies indicated relatively small differences between breeds for dam-calf conversion of feed energy to weaning weight (Klosterman et al., 1974; Marshall et al., 1976). Studies in which significant differences between breeds have been noted include those by Jenkins and Ferrel (1991) and Green et al. (1991). We should have additional results from work here at SDSU in the near future. One finding that many cow efficiency studies have had in common is a relatively large amount of variation from cow to cow in efficiency of feed utilization. When the full spectrum of economically important traits is considered, though, the common adage that there is more variation within than between breeds is not really true. Thus, selection of breeds is an important consideration for commercial production.

Several different breeds can be used with success with respect to environmental adaptability in this region, especially in an appropriately designed crossbreeding system. The British beef breeds have been selected within our environment for a long enough period of time to be well adapted.
The popularity of these traditional breeds in commercial crossbreeding is well-justified on that basis. The continental European breeds have not been selected under local conditions for nearly as long, but several of these breeds are well enough adapted to perform adequately, particularly in a crossbreeding program. Crossbreeding allows the use of some breeds that are not well-suited to the environment as straightbreds, because crossbreeding dilutes the proportion that a particular breed contributes to a given breeding system.

Most everyone would agree that no one breeding program is best for all commercial production situations. Even for a particular situation, more than one breeding system can generally be used with desirable results, although some may certainly work better than others. My feeling is that we can exercise quite a bit of flexibility in choosing breed types for a particular production system, as long as we avoid obvious mismatches among sire type, dam type, environmental resources, and management abilities. Personal preferences can and should play a role in breed selection.

**Labor/Management Constraints**

An important aspect of matching cattle type to resources that is sometimes overlooked is management ability. As mentioned previously, proper management of stocking rates and supplemental feeding is especially critical for high producing cows in order to attain adequate reproductive performance. Lower producing cows in general require less intensive management. Calving difficulty is another area of concern. Research papers often tout the potential efficiency of breeding systems that utilize a sire breed of larger mature size compared to the breed type of the dams. The logic of such a system is that maintenance requirements of the small-to-moderate size dam are held to moderate levels, while use of a "terminal" sire type will provide adequate growth potential in the calf. The problem with such a system is that the potential for calving difficulty tends to increase as the mature size difference between sire and dam increases. A producer who does not have the time and skills to effectively deal with calving difficulty should generally avoid using breeds or sires that are more prone to cause calving difficulty.

**Consumer-Market Demand**

The common recommendation for commercial breeding systems is to match cow type to resources and sire type to market demand. Again, the potential for calving difficulty must be considered. Several other questions should also be addressed. Are all calves sold at weaning or is ownership retained past weaning on some? What end market are cattle being targeted for -- the restaurant trade, supermarket trade, institutional trade or some other market niche? How important are leaniness, marbling and size of the carcass for these markets? What other market-related criteria are important?

**Summary**

Beef production is a multi-faceted industry. Many different types of cattle are produced under many environmental situations with a multitude of management practices to meet several consumer-demand niches. The set of production conditions (i.e., genetics, nutrition, and other management practices) that will provide maximum efficiency for a commercial cow-calf producer will depend on the particular environmental conditions, marketing demands, and management constraints under which the individual producer operates. The seedstock producer should identify which type(s) of commercial producers for which they wish to provide services, and then develop their breeding objectives and marketing practices accordingly. A good knowledge of cow biology and interacting environmental factors can assist the seedstock producer in that endeavor.
LITERATURE CITED


ESTABLISHING GENETIC LINES FOR
GOAL ORIENTED BUYERS

Richard Janssen

I would like to thank you for inviting me here tonight to share with you a few thoughts about our breeding program. It’s exciting to be in the Angus business today as we are having more fun breeding cattle on our farm now than ever before. It is also exciting to see changes we can make using the latest technology available.

In order for you to get an idea of where I’m coming from and why I’m doing the things I’m doing today, I’d like to briefly take you back to when I first started. I was raised on a farm in central Kansas where my parents maintained 50 registered Angus cows as part of their farm operation. It was only natural for me to show Angus steers and heifers as my 4-H projects. I have seen this breed swing from the small belt-buckle cattle of the fifties to some of the extremely large framed cattle we have today.

My personal involvement in breeding Angus cattle began in 1964 when I graduated from Kansas State. At this time performance testing was becoming the in thing, and AHIR was in its early stages of growth. The movement in our industry for size and growth was on as Angus cattle were getting discounted in the market place for being to small. We joined in the hunt for larger framed cattle, as we bought the largest framed Angus cows we could find and mated them to the largest framed Angus bulls we could find. We made some progress but because of the lack of real genetic knowledge of our breeding stock the progress was limited. When open AI came on line in the 1970’s along with the advancements in the National Sire Summary, progress speeded up. We could use bulls from anywhere with more information available than ever before. The attitude prevailed of mating biggest to biggest. The bigger your seedstock became the more dollars you got for them. We followed the trend. The in 1983, we had a rude awakening. We lost 25% of our calf crop out of 2-year old heifers before we knew what was happening. Prior to this time we had been calving out our heifers in a pasture a couple miles from home with very few problems. Apparently with our aggressive use of AI, rapid generation turn over and our quest for larger framed cattle, we created a problem our management could not handle. I think it is important for you to understand that our management consisted of my wife and I, with some part time help mainly in the summer.

At this time our cattle operation consisted of approximately 125 mother cows and we farmed about 1300 acres of wheat and milo. We had always tried to run our farm similar to the commercial cattle operations in our area where we sold most of our cattle. Baby-sitting heifers during calving season was something we did not have time for, nor did our customers. We knew the type of cattle we had developed over the past 18 years were very salable, but from our own experience they were not providing the calving ease necessary to fit our management. We no longer had any predictability in calf weights or when they would be born. Some of our heifers were having calves 5 to 10 days over their normal due dates with some birth weights in excess of 100
pounds. It was obvious to us we needed to make some adjustments in our breeding program. We thought if we'd use bulls with 0 to +2 birth EPD's on our heifers, we would solve our problems. We did see some improvement, but birth weights were still very inconsistent. Since our records showed that many of our bulls were being sold to calve out first calf heifers, the product we were selling had to be improved.

That's when the idea of breeding cattle for a single common purpose, that of growth, gave way in our minds to the idea of different cattle for different purposes. So in 1985, we finally made a dramatic move. Going back to the 16th century breeder, Robert Bakewells "LIKE BEGETS LIKE" concept of breeding cattle, we set out to find cows in our herd with a history of light birth weight calves to breed to bulls with the lowest acceptable birth EPD's available. Angus cattle in general had long been noted for their calving ease, milk and carcass quality. We do not believe this is their only purpose, but do believe that a portion of the breed needs to maintain these traits. By using our produce of dam summary, keeping in mind that 50% of genetics for calving ease comes from the cow and 50% for the sire, with 100% of the environment from conception to birth provided by the cow, we began searching for cows with a history of light birthweight calves. Since we did not have EPD's at this time we used our Produce of Dam summary to look for cows that had a history of light birth weight calves, some even when bred to bulls with birth weight EPD's of +4 and up. These cows calves, because of their lighter birth weights, had been our source of bulls we had been selling to our commercial buyers as calving-ease bulls. We knew from the experience we had had with our 2-year old heifers that bulls with +4 EPD's for birth weight had the potential of siring some excessively big calves. Our "calving ease bulls" were probably not a very predictable product. Another point of information we looked for on the produce of dam summary was the gestation length. We found 12 cows we thought would work. The gestation length of their calves averaged a -5 days short of the normal 283 days.

Referring back to our idea of different cattle for different purposes we decided that the proper function of these cows was the production of calving ease seed stock. We called these cows System 1's.

Since we had a decided to mate likes to likes, we called John Crouch at the American Angus Association and asked for a computer sort on bulls in the sire summary that were minus on birth weight EPD's and plus on milk. We had two purposes in mind when we called for this sort. One, to give us the bloodlines that we could use on the System 1 cows we had identified and second, to find a potential source of cows to add to this group because we did not feel that 12 cows were enough to give this program an adequate test. This was the beginning of our systematic selection approach to breeding cattle on our farm. I'd like to add that the perimeters that we have drawn up are the result of how our cattle function under our management and environment and may or may not function the same under different management systems.

Systematic selection is simply putting perimeters on breeding functions. Our first function is calving ease. Our breeding process is first build around EPD for birth weights. The lowest birth EPD's on John’s sort with acceptable performance was -3.6 and we knew from experience that +1.0 was a high as
we wanted to go. It is important to note that we must have some flexibility in our perimeters due to EPD’s changing each time a new sire summary is run. Therefore, we have set the perimeters for birth EPD’s on our System 1 cows at -4.0 to +1.5. We set the perimeters for actual birth weights of 60 to 80 pounds. The reason for using actual birth weights is to put more selection pressure on the product we wanted to produce. Our records showed that the majority of 2-year old heifers, if raised with adequate nutrition, had the ability to have an 80 pound calf unassisted. We will continue to monitor each cows gestation length.

Our second function was milk. We believed that System 1 cows should be above breed average for milk. Since we expected these cows to be smaller at maturity we felt confident that they could carry a higher milk value under our management and environment and still breed back. We set the perimeters for milk EPD’s on the System 1 cows at 0 to +20. Again allowing for some flexibility due to changes in the sire summary.

It was interesting to note that when EPD’s came out on our cows in the fall of 1986, our original 12 System 1 cows birth EPD’s averages -1.3 and their milk EPD’s averages +8.2.

Our third function was growth. We did not limit growth as long as the first two functions were maintained.

After we set our perimeters on our System 1 cows, we went back to the bulls on John’s original sort. The bloodlines of Emulation 31 appeared three times, Emulation 31 himself and 2 of his sons, which were bred by Tom Elliot at N-Bar Ranch in Montana. Our interest in these bloodlines led to the development of a long distance friendship with Tom. Since we were looking for both bulls and females with a calving ease base, N-Bar Ranch where Emulation 31 had been used for many years, was our natural choice. We purchased from Tom 22 cows which were either daughters of Emulation 31 or line bred to him. At this time we also purchased and interest in one of the bulls that was on John’s sort, Emulation N-Bar 5522, a son of Emulation 31.

This gave us a base of 34 System 1 cows to use with the three bulls we selected off the sort, N-Bar Emulation 5522, Traveler 1148 GDAR and SS Rito 0715 OH3. Adding to the bulls we were using on our System 1 females is a product of our System 1 1987 calf crop, Gardens Transition. He had an actual birth weight of 72 pounds, was 6 days short of normal gestation length, a 205 day weight of 605; ratio 109, with a 365 day weight of 1181; ration 109. His scrotal cm. measured 39cm and we collected 209 unites of semen on his first collection. At 13 months he weighted 1260, with .2 inches of back fat and had an ultra sound rib eye of 15.1 square inches. His mild EPD of +16.5 ranks him in the top 1% of the breed, and his dam is triple bred to Emulation 31. In the spring of 1989, Lemon Impact was added to our program. He had an actual birth weight of 70 pounds and at the Tifton Bull Test, in Tifton, Georgia, he had a 140 day rate of gain of 4.75, weighing 1406 at a year with .4 inches of back fat and a scrotal measurement of 43cm. When carcass EPD’s became available, we realized the bulls we had selected to use in our program were all plus on marbling EPD, minus on back fat EPD, and for the most part plus on ribeye area. Although this information is for the most part on the sires and/or
sires of the dams, we are now actively engaged in collecting carcass data on all the bulls we use in our program.

Our next step was defining the perimeters for our System 2 cattle, which we called combination. These cattle would have moderate birth EPD’s with added growth. We set birth EPD’s at +1 to +4 with actual birth weights of 80 to 95 pounds. By studying the progeny records of our females plus the bulls EPD’s that we had been using, we found that the majority of their calves fell into this range. On our System 2 cows, we looked for milk EPD’s that were breed average or above and set our perimeters at -5 to +15. Growth again was not limited as long as the first 2 functions were maintained. Just as calving ease was the major emphasis in our System 1 cattle, growth became important in this group. Our search for bulls with birth EPD’s of less than +4 pounds and with growth EPD’s higher than our S-1 cattle was no easy task. We finally located a bull that fit our perimeters.

This bull was introduced to increase growth and still maintain moderate birth weight. His name is Fortune 3261. His weaning EPD of +47.2 pounds ranks him in the .04% of the breed, and his yearling EPD of +59.1 pounds ranks him in the .54%.

Another bull that fit our perimeters was a son of Rito Excell. We had always admired Excell’s moderate birth weights and tremendous growth but were a little gun shy of his milk EPD’s. Excell Led 2600 has a weaning EPD of +33.0 pounds that ranks him in the top 2% and a yearling EPD of +59.0 pounds that ranks him in the top 5% of the breed.

Our third step was defining the perimeters for our System 3 cattle. We felt there was a market for a maximum growth group of cattle within our industry and established birth EPD’s of +4 to +8 with actual birth weights of 95 pounds and up. Milk EPD’s were set at -5 to +10 pounds with growth being this system’s primary function.

We had very few cows that fit into this system and when mated to high growth bulls (which were also carrying high birth EPD’s) their calves birth weights were very high. Since our commercial bull buyers have been discriminating against high birth weight bulls, our plans for this system have changed. We no longer breed cows with high birth EPD’s to bulls with +5 birth EPD’s and up, but will sample a few growth bulls on System 2 cows mainly for comparisons with our System 2 sires. Two bulls that we have used are Rito 9J9 and Scotch Cap. The System 3 group will primarily become a place to identify those cattle that fall out of our System 2 specifications.

To give you an idea of how our program is working under our management and environment, we have put the results of our 1989 calf crop, from birth to yearling, on graphs. This may give you a better understanding of how we use systematic selection to improve the predictability of the products we are selling.

In our past few years of work on Systems 1, 2 and 3, we have gained an appreciation for the EPD approach to livestock selection and are convinced of their value to our breeding program. Not only is it our goal to create a highly predictable product by using EPD’s, but to also identify the genetics needed to produce superior carcass composition cattle that will not only meet packer specifications, return a profit to the producer, but will also satisfy our ultimate consumer, the people who enjoy eating beef.

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These graphs represent the results of how our system program has worked on our farm. The program may vary under different management and environmental conditions.
Real-time Ultrasound to Predict Carcass Traits in Live Cattle

Prepared by
Gene Rouse, Professor
Iowa State University
December, 1991

Ultrasound technology offers a low-cost alternative to expensive and time-consuming progeny testing of beef sires for carcass merit. Expected progeny differences (EPDs) for carcass traits such as fat cover, ribeye area, and marbling would provide a tremendous tool to the beef cattle industry for producing a high quality, uniform end product. With these EPDs, breeders and commercial bull buyers will be able to directionally change the end product through genetic improvement programs.

The objective of this report is to relate the accuracy with which fat cover and ribeye area can be measured with ultrasound equipment when compared with carcass measurements and to demonstrate how serial scans with ultrasound relate changes in body composition of cattle as they mature.

Ninety-three small-framed cattle were fed at the McNay Research Farm and slaughtered at three endpoints to evaluate product produced specifically for the Japanese market. One third of their small-framed cattle were processed at the conventional time for the U.S. retail market (0.4 inch outside fat cover and low Choice quality grade). Another third was fed an additional 60 days and the remaining third was fed 120 days after the initial slaughter. One-hundred-ninety-nine medium- and large-framed cattle were compared as steers and bulls and fed to three compositional endpoints. The endpoints represented the same age for bulls and steers, with cattle processed at 30-day intervals, beginning with conventional retail slaughter time for the first group.

All cattle were scanned before the slaughter dates and once or twice before the slaughter date, depending on the trial. These scans were collected in an attempt to evaluate the change in composition as cattle mature.

All cattle scanned in 1990 were measured with an ALOKA 633 real-time ultrasound machine. The transducer used was 12.5 cm long with a frequency of 3.5 MHz. Split-screen application had to be utilized to measure ribeye area with this length transducer. Since this time, an ALOKA 500 and with a 17-cm probe transducer has been purchased for data collection in 1991. This new unit is portable and the new transducer eliminates the need for split-screen application.

Figure 1 relates the change in weight and height for small-framed steers during the last 160 days on feed. Relative to these figures, steers were slaughtered at 20, 80 and 160 days or 132, 192, and 257 days on feed. Both weight and height increased linearly between the first and third slaughter.

Figures 2 and 3 compare changes in weight and height for bulls and steers. Rhodes cattle were weighed and measured in areas corresponding to each of the five scans at 30-day intervals. One third
of the cattle in each pen were slaughtered on each of three dates designated on the figures as 60, 90, and 120 days. Steers were taller at the hip than bulls, with the magnitude of difference increasing with time on feed. Bulls were heavier than steers during this 120-day period.

Figure 4 relates the changes in fat cover and ribeye area for long-fed small-framed McNay steers. Fat cover more than doubled, and ribeye area increased slightly more than one square inch. These scan results indicate that fat is being deposited at a faster rate than muscle at this stage of development.

Steers were fatter than bulls (Figure 5) at each scan, with the difference increasing slightly with each successive scan. But the difference in fat between steers and bulls was not as large as shown in previous studies. This result may be explained in part by the bulls being nearly 100 pounds heavier at each scan and by only medium- and large-framed cattle being included in this trial.

Figure 6 compares muscle differences between bulls and steers. Square inches of ribeye area increased faster for bulls than for steers.

Table 1 relates carcass parameters for both trials, or a total of 295 carcasses. Table 2 indicates that the correlation between the ultrasonic fat measurement and the carcass fat measurement was 0.91, a very high correlation. When two trained meat scientists measured the carcass fat in a sample of 95 cattle, the correlation was .97. Stated in another way (shown in Table 3), ultrasonic and carcass fat measurements were within 0.1 inches 70% of the time and within 0.2 inches 94% of the time.

The correlation between ultrasonically measured ribeye area and carcass ribeye area was 0.86. Table 4 also relates that the correlation between two trained meat scientists measuring the same ribeyes was 0.92 on a sample of 95 of the 295 cattle measured. Deviations from carcass ribeye area measurements were less than 1.0 square inch 81% of the time and within 2.0 square inches 98% of the time (Table 5).

Table 6 relates the correlation and average deviation between repeated scans on two consecutive days on the same animal. Ninety-seven percent of the time repeated scans were within 0.1 inches of fat cover and 81% of the time within 1.0 square inches of ribeye (Table 7).

With high-quality ultrasound equipment and a well-trained technician, ultrasound measurements for fat cover and ribeye area are very accurate and can be used to make genetic progress for the carcass traits. Serial scanning through time can be used to relate changes in body composition as cattle increase in weight.
Table 1. Least squares means, standard deviations, and the ranges for the carcass parameters of 295 small-, medium-, and large-framed steers and medium- and large-framed bulls.

<table>
<thead>
<tr>
<th>Carcass Parameters</th>
<th>Mean</th>
<th>Std dev</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ribeye area</td>
<td>12.28</td>
<td>± 1.38</td>
<td>9.40</td>
</tr>
<tr>
<td>Fat cover</td>
<td>0.54</td>
<td>± 0.26</td>
<td>0.12</td>
</tr>
<tr>
<td>Bulls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ribeye area</td>
<td>13.76</td>
<td>± 1.45</td>
<td>10.70</td>
</tr>
<tr>
<td>Fat cover</td>
<td>0.36</td>
<td>± 0.18</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Table 3. Deviations of ultrasonic measurements of fat cover from carcass fat measurements.

<table>
<thead>
<tr>
<th>Fat deviation in inches</th>
<th>Freq.</th>
<th>%</th>
<th>Cumulative %</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Animals</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>.1</td>
<td>208</td>
<td>70.5</td>
<td>70.5</td>
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<td>.2</td>
<td>69</td>
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<td>.3</td>
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<tr>
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<td>100.0</td>
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<td>Steers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.1</td>
<td>134</td>
<td>69.8</td>
<td>69.8</td>
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<tr>
<td>.2</td>
<td>46</td>
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<td>.3</td>
<td>7</td>
<td>3.6</td>
<td>97.4</td>
</tr>
<tr>
<td>.4</td>
<td>5</td>
<td>2.6</td>
<td>100.0</td>
</tr>
<tr>
<td>Bulls</td>
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</tr>
<tr>
<td>.1</td>
<td>74</td>
<td>71.8</td>
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<tr>
<td>.2</td>
<td>23</td>
<td>22.3</td>
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</tr>
<tr>
<td>.3</td>
<td>6</td>
<td>5.8</td>
<td>100.0</td>
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</table>

Table 2. The correlations between ultrasonic fat measurements and carcass fat cover.

<table>
<thead>
<tr>
<th>U-FAT</th>
<th>C-FAT</th>
<th>C-FAT-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-FAT</td>
<td>1.0</td>
<td>.91</td>
</tr>
<tr>
<td>C-FAT</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>C-FAT-2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

U-FAT = ultrasound fat cover (n=294)
C-FAT = carcass fat cover (n=294)
C-FAT-2 = carcass fat cover measured by a second person (n=94)

Table 4. Correlations between ultrasonic measurement of ribeye area and carcass ribeye.

<table>
<thead>
<tr>
<th>U-REA</th>
<th>C-REA</th>
<th>C-REA-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-REA</td>
<td>1.0</td>
<td>0.86</td>
</tr>
<tr>
<td>C-REA</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>C-REA-2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

U-REA = ultrasound ribeye area (n=294)
C-REA = carcass ribeye area (n=294)
C-REA-2 = carcass ribeye area measured by a second person (n=94)
Table 5. Deviations of ultrasonic measurements of ribeye area from carcass ribeye area.

<table>
<thead>
<tr>
<th>REA Deviation in Square Inches</th>
<th>Freq.</th>
<th>%</th>
<th>Cumulative %</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Animals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>239</td>
<td>81.0</td>
<td>81.0</td>
</tr>
<tr>
<td>2.0</td>
<td>50</td>
<td>16.9</td>
<td>98.0</td>
</tr>
<tr>
<td>3.0</td>
<td>6</td>
<td>2.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Steers</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1.0</td>
<td>156</td>
<td>81.3</td>
<td>81.3</td>
</tr>
<tr>
<td>2.0</td>
<td>31</td>
<td>16.1</td>
<td>97.4</td>
</tr>
<tr>
<td>3.0</td>
<td>5</td>
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</tr>
<tr>
<td>Bulls</td>
<td></td>
<td></td>
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<tr>
<td>1.0</td>
<td>83</td>
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<td>80.6</td>
</tr>
<tr>
<td>2.0</td>
<td>19</td>
<td>18.4</td>
<td>99.0</td>
</tr>
<tr>
<td>3.0</td>
<td>1</td>
<td>1.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 7. Deviations between repeated ultrasound scans for fat cover and ribeye area on the same animal.

<table>
<thead>
<tr>
<th>Fat Deviation in inches</th>
<th>Freq.</th>
<th>%</th>
<th>Cumulative %</th>
</tr>
</thead>
<tbody>
<tr>
<td>.1</td>
<td>30</td>
<td>96.8</td>
<td>96.8</td>
</tr>
<tr>
<td>.2</td>
<td>1</td>
<td>3.2</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ribeye Deviation sq. inches</td>
<td>Freq.</td>
<td>%</td>
<td>Cumulative %</td>
</tr>
<tr>
<td>1</td>
<td>25</td>
<td>80.6</td>
<td>80.6</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>16.1</td>
<td>96.8</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>3.2</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>31</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6. The correlation and deviations between repeated ultrasound scans (ribeye area and fat cover) on the same animal.

<table>
<thead>
<tr>
<th></th>
<th>Correlation</th>
<th>Avg. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ribeye Area</td>
<td>.79</td>
<td>.68</td>
</tr>
<tr>
<td>Fat Cover</td>
<td>.95</td>
<td>.04</td>
</tr>
</tbody>
</table>
Figure 1. Mean weight and hip measurements at four scan dates for small-framed McNay steers.

Figure 2. Mean hip height measurements on five scan dates from Rhodes medium- and large-framed bulls and steers.
Figure 3. Mean weights on five scan dates for Rhodes medium- and large-framed bulls and steers.

Figure 4. Changes in carcass parameters (ribeye area and fat cover) as determined by ultrasonic scanning during a 160-day fattening period for small-framed steers.
Figure 5. A comparison of the increases in fat cover measured ultrasonically between bulls and steers five times at 30-day intervals.

![Fat Cover Graph]

Figure 6. Changes in ribeye area for bulls and steers measured ultrasonically five times at 30-day intervals.

![Ribeye Area Graph]
During the past ten years, the use of Expected Progeny Differences (EPDs) by both seedstock producers and commercial cattlemen has increased markedly. EPDs have proven to be very valuable for discerning within breed sire differences, but are still of no value for comparing sires between breeds. Even though EPDs were never intended for across breed comparisons, many commercial cattlemen find this limitation to be very frustrating.

Represented in Table 1 are the birth year EPD averages for all animals born in 1990 for six different breeds. One quick glance reveals why EPDs cannot be compared across breeds. Anyone with knowledge of breed differences will quickly recognize that Angus are not going to average 2.7 (3.1 - .4) pounds more than Simmental at birth. Furthermore, it would be incorrect to assume that Herefords would average nearly 30 pounds more at one year of age and produce significantly more milk (7.0 versus .5) than Simmental. These breed average figures help illustrate the confusion that can develop when bull buyers attempt to compare bulls of different breeds.

Why do these EPDs vary so much? First and foremost, the breed populations are totally different and there are virtually no direct comparisons of sires among breeds represented in the breed databases. The only reliable breed comparison data resides primarily in university and government research projects. Secondly, the base reference point for each breed is different and thirdly, each breed has a unique genetic trend.

Additionally, when crossbreeding systems were first designed, it was under the assumption that breeds would retain their distinct characteristics. However, this has not been the case as many breeds have changed resulting in increased similarities. This coupled with greater sophistication of many crossbreeding systems now being used has elevated the need for commercial producers to directly compare sires across breeds.

What's more, it is common for breeders to maintain more than one breed to better accommodate their customer's bull needs. Consequently, the differences in EPDs between breeds can also be challenging for seedstock producers.
Producers are increasingly developing "job descriptions" for their bulls and expect bulls within breeds to meet specific requirements. Any number of examples could be cited where producers may want to compare sires of different breeds in order to select bulls that more nearly match their specifications. Presently, the only way to compare sires across breeds is to develop a good level of understanding of breed differences based on well designed breed comparison research. Even with this knowledge, however, it would still be much less confusing if producers could directly compare EPDs. The question becomes, if there is such a strong demand for interbreed EPDs, then why don't we just go out and calculate them and be done with it. Unfortunately, it's not quite that simple. The purpose of this presentation will be to discuss a few of the challenges of generating accurate interbreed EPDs.

NECESSARY INFORMATION

Some of the necessary information needed to calculate accurate interbreed EPDs includes:

1. Breed constants appropriate to the breeds of interest and to the environments and mating systems being considered.
2. Heterosis adjustments which would potentially differ among crosses.
3. Knowledge of the reference base (zero EPD point) for each breed.
4. Sire EPDs appropriate for prediction of cross breed performance.
5. Knowledge of possible genotype by environment interactions.

BREED CONSTANTS

Breed constants may be derived from breed comparison research or industry crossbreeding programs. Unfortunately, not all breed comparison research will produce good breed constants because of sampling of sires within the breeds being compared. Use of bulls in such experiments with accurate EPDs is preferred because the data can be adjusted for sire sampling. Unfortunately, many breed evaluation experiments have not used breed association EPDs as part of their analysis of breed differences. However, one of the most comprehensive breed comparison research projects that did use A.I. sires with EPDs is the Germ-Plasm Evaluation (GPE) Program at the U.S. Meat Animal Research Center (MARC).

Early evaluations did not consider sire EPDs, however, a more recent analysis of the MARC data has included this information and should provide more accurate breed constants. Additionally, there are other research projects throughout the United States that could possibly be re-analyzed to generate breed constants. One in particular is Project NC-196, which is national in scope involving twenty cooperating research stations. Plans have been made to develop a database contributed to by all stations. This information will eventually make it possible to generate viable breed constants for use in the calculation of interbreed EPDs.
HETEROSIS

Heterosis is defined as the difference between the average of the reciprocal crosses and the average of the parental purebreeds contributing to the cross. Effects of heterosis in Bos taurus X Bos taurus breeds and in crosses of Bos indicus (Brahman type) X Bos taurus breeds are shown in table two. The values are average, for several experiments.

The data indicate that heterosis effects vary with different traits and with different breed crosses. For example, heterosis is greater in Bos indicus X Bos taurus cattle in subtropical environments than Bos taurus X Bos taurus crosses in temperate regions in the U.S. This creates a challenge in the calculation of interbreed EPDs because of the different magnitudes of specific heterosis used to calculate the breed constants. Breed comparisons could be biased since they may not reflect the actual genetic differences among the breeds. Dr. L.D. Van Vleck concluded in his research that differences in specific heterosis as small as two to four percent could bias the breed constants enough to change breed rank. With this in mind, Dr. Van Vleck questioned the advisability of using crossbred data to generate breed EPD tables until more was known about specific heterosis.

BREED BASES AND GENETIC TRENDS

In order to connect within breed EPDs to breed differences, the reference points for each breed’s EPDs must be defined. The reference point is sometimes technically defined as the population of foundation animals used to build up the relationships in the data set. EPDs are then expressed relative to the foundation animals that begin the accumulation of pedigree relationships. In most of the British breeds, this group dates back to the middle 1970’s, whereas the base or zero point population for most Continental breeds is in the 1980’s. Today the three kinds of bases being used by breed associations in North America are floating base, fixed base, and rolling base.

A floating base is one in which the group of animals representing the base may change from one year to the next. If there is genetic trend in the population, then the zero point is different from one evaluation to the next. Consequently, a sire’s EPD will change in proportion to the genetic trend. For example, if the trend for yearling weight averaged 1 lb. per year, a bull with an EPD of +20 in 1980 may actually be +10 by 1990. The bull is the same genetically, however, he has changed compared to the average of the base population. It is important to keep in mind that zero (0.0) is average for the base population, not the entire breed.

If the base is fixed, genetic trend will not change the bull’s EPD. For example, if a bull has a weaning weight EPD of +10 he will remain at +10 with each new evaluation. An advantage of a fixed base is that a producer can set standards that will not change from one evaluation to the next. The advantage of
a floating base is that EPDs keep up with genetic trend and there will not be a need to change the base reference point.

The Canadian National Cattle Evaluation uses a three-year rolling base which is calculated by including all animals born in the current and previous two years. Instead of the base being fixed to a single birth year or population, the base is actually fixed to the most recent three year average.

A summary of six breeds' zero reference points for birth weight, yearling weight and milk is given in Table 3. As you can see, the bases range from 1970 for Hereford milk to 1984 for Limousin birth weight and weaning weight. It has been suggested that all breeds should have a common base. Even though a common base is not necessary to calculate interbreed EPDs, the positive educational value was considered during a special symposium on interbreed EPDs, held in October 1989. Dr. John Pollack, Cornell University, chaired a committee charged with developing a recommendation for a common base. The committee suggested during the May, 1990 Beef Improvement Federation (BIF) meeting that each breed fix its base at 1982. Breed associations with national cattle evaluation programs were asked to evaluate the impact that a base fixed at 1982 would have on their breed's EPDs.

The results were presented at the May 1991 BIF meeting. Printed in Table 4 is an abbreviated summary of birth weight, yearling weight, and milk. As you can see, some breeds would be affected much more than others. Specifically, those breeds with bases in the 1970's that have seen considerable genetic trend would be affected greater by a base move to 1982 than with those breeds with more current bases and less genetic trend. The May 1991 meeting was followed by a survey in which breed associations were asked to give their opinions about the fixed base proposal. Of the 12 breeds that responded, seven voted in favor of a base fixed at either 1982 or 1985. Not surprising, those breeds that voted against a fixed base were the ones that would likely be affected most by a base different than what was currently being used. It's interesting to note that nearly all of the breed representatives were concerned that a standardized fixed base would lead some people to erroneously conclude that EPDs could be compared across breeds.

It is clear that getting all breeds to agree on a common base is not likely. But as stated earlier, this is not really a barrier since a common base is not a requirement for calculating interbreed EPDs.

**GENETIC X ENVIRONMENT INTERACTIONS**

After a thorough review of the research literature, Dr. Larry Cundiff concluded in a paper he presented at the 1989 BIF Convention that interbreed EPDs should be derived separately from experiments conducted in temperate and subtropical regions if Bos indicus breeds are to be compared to Bos taurus breeds. He went on to conclude that genotype X environment interactions are not
important for weaning weight among Bos taurus breed crosses in temperate regions and that weaning weight EPDs across Bos taurus breeds could be derived from one or more experiments conducted under temperate conditions. However, analysis of data from more experiments may be required to accurately assess calving assistance.

Even on a within breed basis, EPDs may have some shortcomings when comparing sires for use in temperate environments versus subtropical environments. Dr. Cundiff suggested that within breed EPDs for herds located in subtropical regions should be computed from herds located in subtropical regions and EPDs for herds in temperate regions should be computed for herds located in temperate regions. It does not appear, however, that sire X contemporary group interactions and sire X herd interactions are large enough to significantly reduce selection response. In summary, depending on the breeds, the traits and diversity of environments, some consideration to breed X environment interactions may be advisable when calculating interbreed EPDs.

WOULDN'T THERE BE WINNERS AND LOSERS?

This is a common question that, quite frankly, may be a misconception. If the focus was on a single trait such as growth, or milk production, or calving ease, this would be a valid concern. But, realistically, no breed is superior in all traits. Therefore, when interbreed EPDs become a reality, some breeds will excel in certain traits and be below average in other traits. There will be no winners and losers, but, hopefully, just a more accurate means of comparing sires regardless of the breed.

This is why including more traits in the interbreed EPD analysis is important. For example, some breeds may excel in growth and milk, but without a good mature size EPD, it will be difficult to assess sires across breeds for efficiency. Other traits like calving ease, scrotal circumference, and lean yield should also be included in order to obtain a complete genetic picture. Astute commercial cattlemen will take advantage of the differences and use sires that best fit their needs.

BREED ASSOCIATIONS' VIEWPOINT

Given the significant investment in their respective databases, it is no wonder why some breeds are reluctant to unconditionally support interbreed EPDs. It has been estimated that breed associations and their members have collectively invested over $80 million in their breed databases. Considerably more money and effort have been committed to the development, calculation, and use of within breed EPDs.

Moreover, breed associations have been dedicated to building the credibility
and accuracy of EPDs. There is great concern that if interbreed EPDs fail to be as accurate as within breed EPDs, the credibility of the entire EPD concept could be jeopardized. Breed associations are not opposed to interbreed EPDs, but, their cautious approach is understandable. In fact, in January 1990, the U.S. Beef Breeds Council expressed their support of interbreed EPD research subject to:

1. Greater efforts made to add to the database which would be used to develop these predictions.
2. Research personnel, in cooperation with the Beef Improvement Federation, continue to examine the concept, evaluate the implications, and apprise the industry about the appropriate manner in which to interpret and utilize this information.
3. That no data be released until all breeds who are members of the U.S. Beef Breeds Council with sire summaries be examined for utilization, application, and inclusion in the published reports.
4. That BIF develop appropriate industry guidelines for the uniform application of a methodology to produce across-breed EPDs under the conditions cited in 1, 2, and 3.

**SUMMARY**

Given the potential value and interest in interbreed EPDs, they no doubt will become a reality within the next three to five years. More research will be required to generate the databases needed to produce representative breed constants. Other areas of question such as the influence of specific heterosis and breed X region interactions will also require attention. Provided adequate funding is available, the information and technology will be in place to produce viable interbreed EPDs. Their ultimate value will be determined by the end-users.

In the meantime, it remains essential that producers: 1) conduct an audit of their resources; 2) determine what type of cattle will best match their resources and marketing goals; 3) develop a job description for the bulls of each breed to be used in the crossbreeding system; 4) have a good understanding of breed differences; and, 5) use within breed EPDs to identify bulls that best match their specifications.
### TABLE 1. BREED AVERAGE EPDS FOR ANIMALS BORN IN 1990

<table>
<thead>
<tr>
<th>Breed</th>
<th>Birth Weight</th>
<th>Yearling Weight</th>
<th>Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angus</td>
<td>+3.1</td>
<td>+31.4</td>
<td>+6.2</td>
</tr>
<tr>
<td>Gelbvieh</td>
<td>+ .3</td>
<td>+ 6.6</td>
<td>+ .9</td>
</tr>
<tr>
<td>Hereford</td>
<td>+1.9</td>
<td>+35.0</td>
<td>+7.0</td>
</tr>
<tr>
<td>Limousin</td>
<td>+.5</td>
<td>+ 5.8</td>
<td>+ .2</td>
</tr>
<tr>
<td>Polled Hereford</td>
<td>+3.0</td>
<td>+26.1</td>
<td>+1.8</td>
</tr>
<tr>
<td>Simmental</td>
<td>+ .4</td>
<td>+18.7</td>
<td>+ .6</td>
</tr>
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</table>

### TABLE 2. HETEROSIS EFFECTS

<table>
<thead>
<tr>
<th>Trait</th>
<th>Bos taurus X Bos taurus</th>
<th>Bos taurus X Bos indicus</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Individual Heterosis</td>
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</tr>
<tr>
<td>Birth Wt.</td>
<td>2.4%</td>
<td>11.1%</td>
</tr>
<tr>
<td>Weaning Wt.</td>
<td>3.9%</td>
<td>12.6%</td>
</tr>
<tr>
<td>Postweaning Gain</td>
<td>2.6%</td>
<td>16.2%</td>
</tr>
<tr>
<td></td>
<td>Maternal Heterosis</td>
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</tr>
<tr>
<td>Calving rate</td>
<td>3.7%</td>
<td>13.4%</td>
</tr>
<tr>
<td>Calf survival</td>
<td>1.5%</td>
<td>5.1%</td>
</tr>
<tr>
<td>Birth weight</td>
<td>1.8%</td>
<td>5.8%</td>
</tr>
<tr>
<td>Weaning weight</td>
<td>3.9%</td>
<td>16.0%</td>
</tr>
</tbody>
</table>

From: Cundiff, 1989
### TABLE 3. APPROXIMATE BIRTH YEAR ZERO POINTS FOR EPDS

<table>
<thead>
<tr>
<th></th>
<th>Birth Weight</th>
<th>Yearling Weight</th>
<th>Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angus</td>
<td>1977</td>
<td>1977</td>
<td>1977</td>
</tr>
<tr>
<td>Gelbvich</td>
<td>1982</td>
<td>1982</td>
<td>1982</td>
</tr>
<tr>
<td>Hereford</td>
<td>1979</td>
<td>1976</td>
<td>1970</td>
</tr>
<tr>
<td>Limousin</td>
<td>1984</td>
<td>1984</td>
<td>1983</td>
</tr>
<tr>
<td>Polled Hereford</td>
<td>1975</td>
<td>1975</td>
<td>1975</td>
</tr>
<tr>
<td>Simmental</td>
<td>1980</td>
<td>1975</td>
<td>1977</td>
</tr>
</tbody>
</table>

### TABLE 4. IMPACT OF 1982 BASE

<table>
<thead>
<tr>
<th></th>
<th>Birth Weight</th>
<th>Yearling Weight</th>
<th>Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angus</td>
<td>-.9</td>
<td>-11.6</td>
<td>-.5</td>
</tr>
<tr>
<td>Gelbvich</td>
<td>0.0</td>
<td>0.0</td>
<td>-.2</td>
</tr>
<tr>
<td>Hereford</td>
<td>-.4</td>
<td>-12.8</td>
<td>-4.1</td>
</tr>
<tr>
<td>Limousin</td>
<td>+.1</td>
<td>+ 1.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Polled Hereford</td>
<td>-.8</td>
<td>- 8.4</td>
<td>-1.4</td>
</tr>
<tr>
<td>Simmental</td>
<td>-.4</td>
<td>- 6.4</td>
<td>-1.2</td>
</tr>
</tbody>
</table>