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# Breeding for Profit: an Introduction to Selection Index Concepts[1]

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## INTRODUCTION

The selection problem, that of choosing which individuals become parents, is inherent in all of beef production. This problem almost invariably involves evaluating animals on more than one trait and making compromises among traits to arrive at a final evaluation of each candidate for selection. In a capitalist society, profitability seems a logical unit of expression for that final evaluation. It is certainly the basis of evaluation intended in the original development of selection index in the animal sciences (Hazel and Lush, 1942; Hazel, 1943). Thus, a desire on the part of producers to maximize profitability is assumed throughout this presentation.

Profitability implies a buy-sell transaction takes place and thus seemingly suggests that it is maximized by producing the product of greatest value to the customer at least cost. These changes in profitability are usually referred to as relative economic values. It is the relative economic values which provide direction to the selection program. The knowledge that most genetic improvement is made by seedstock breeders and recognition of consumers as implicit customers (commercial producers, feedlot operators and etc. are intermediaries) has led to the philosophy that seedstock selection decisions be based on ultimate customer satisfaction. Said differently, seedstock selection decisions should be made in a way that maximizes profitability for the entire industry as though it were one vertically integrated production system.

Existence of industry-wide specifications for beef product, such as those proposed as a result of the national beef quality audit (National Cattlemen's Beef Association, 1995), do not suggest that there should be industry-wide selection indexes. Resources available for production (classically: land, labor, capital, and management) and level of production vary among production units resulting in different economic structures. As a result, relative economic values will differ among production units and each may have a different selection index. It is unlikely that there will be a "one size fits all" solution to the problem of selecting breeding stock to maximize profit.

Causing genetic change in profitability Is not a new idea for the Beef Improvement Federation. Five years ago, Bourdon (1992) discussed the genetic tradeoffs among economically

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important traits. At that same meeting the systems committee also dealt with economic values of various traits (MacNeil and Newman, 1992). Further, at an American Society of Animal Science symposium held that year, Harris and Newman (1992) presented a comprehensive review of how genetic evaluation might become economic improvement. At the genetic prediction workshop held in 1994, we again broached the subject (Barwick, 1994; Melton, 1994; and Newman et al., 1994). More recently, Melton (1995) provided an economic framework for genetic improvement.

The goals of this presentation are as follows. First, basic selection index formulation is reviewed. The present review differs little from earlier reviews of the same topic by Cunningham (1972) and James (1982) among others. Second, a vision for using national cattle evaluation to predict economic merit is developed following the work of Henderson (1963) and Schneeberger et al. (1992). Third, alternative methods to estimate relative economic values for use in selection indexes are discussed. The presentation is concluded with a vision of the Beef Improvement Federation's role in bringing about seedstock selection programs motivated by profit maximization. It is also hoped that this review provides entry-points into the significant body of scientific literature on selection indexes.

## CLASSICAL SELECTION INDEX

Selection index is a technology to maximize genetic improvement in a specified objective, in this case profitability. The relative contribution to profitability of any candidate for selection as a potential parent **(H)** can be specified as:

$$\mathbf{H} = \mathbf{a}\ \mathbf{g} \qquad (1)$$

where, the **g** is a vector of true breeding values for the set of economically important traits; and **a** is the marginal contribution of member of **g** to profitability. The value **H** is referred to as the breeding objective in a substantial portion of the literature. Obviously, the true breeding values cannot be known without error and hence selection must be practiced on predictors of them. The original specification of selection index foresaw use of a correlated variable **(I)** based on the phenotypic performance of each animal for several traits (Hazel, 1943). Hence, **I** was defined as:

$$\mathbf{I} = \mathbf{b}\ \mathbf{p} \qquad (2)$$

where, the **p** is a vector of phenotypic values for the set of selection criteria; and **b** are the weighting factors used in making selection decisions. In order to maximize the correlation of **H** and **I**($R_{IH}$), the information is combined as:

$$\mathbf{Ga} = \mathbf{Pb} \qquad (3)$$

where, **G** is a nxm matrix of genetic variances and covariances among all m traits; **a** is a mx1 vector of relative economic values for all traits; **P** is a nxn matrix of phenotypic variances and covariances among the n traits measured and available as selection criteria; and **b** is a nx 1 vector of weighting factors to be applied to the traits used in making the selection decisions. The preceding equation is then solved as:

$$\mathbf{P}^{-1}\mathbf{Ga} = \mathbf{b} \qquad (4)$$

to obtain weighting factors contained in **b** and candidates for selection are ranked based on **I**.

Alternative indexes that target the same breeding objective can be compared based on the magnitude of $R_{IH}$ calculated as:

$$R_{IH} = \mathbf{b'Pb/a'Qa} \qquad (5)$$

where **b**, **P**, and **a** are as defined previously, and **Q** is a mxm matrix of genetic variances and covariances among all m traits considered part of the system. Also, it is sometimes useful to compare two indexes based on the correlation ($r_{12}$) between them:

$$r_{12} = \mathbf{b'_1Pb_2/[(b'_1Pb_1)(b'_2Pb_2)]}^{.5} \qquad (6)$$

When performance of relatives of the candidates for selection and(or) repeated observations of some traits has been recorded, the accuracy of the index as formulated previously can also be improved by including that information. Computer programs to perform these calculations are widely available.

***An Example*** Consider the situation where 3 measures, birth weight (BW), yearling weight (YW), and scrotal circumference (SC) are taken on yearling bulls and 2 traits, net reproduction (NR) and carcass merit (CM). If, arbitrarily, NR is 20-fold more important than CM in determining profitability, how should the performance records be evaluated? Equation 3 needs to be solved for the selection index weighting factors. The necessary information can be obtained for estimates of phenotypic variance (or standard deviations), heritability and genetic and phenotypic correlations reported in the scientific literature. Alternatively, if enough data is available from the population being evaluated, these statistics can be calculated expressly for this population. For the purpose of this example, let the full genetic variance-covariance matrix be:

**Q=**

| | | | | |
|---|---|---|---|---|
| 4.04 | 11.07 | 0.00 | -0.01 | 3.02 |
| 11.07 | 199.15 | 8.00 | 0.00 | 35.28 |
| 0.00 | 8.00 | 2.01 | 0.05 | 0.89 |
| -0.01 | 0.00 | 0.05 | 0.01 | -0.13 |
| 3.02 | 35.28 | 0.89 | -0.13 | 156.25 |

with the outlined partition being **G**. The phenotypic variance-covariance matrix is:

**P=**

| | | |
|---|---|---|
| 14.98 | 54.77 | 1.04 |
| 54.77 | 538.24 | 15.07 |
| 1.04 | 15.07 | 5.02 |

Explicitly, the economic values previously inferred are:

$$\mathbf{a} = \begin{matrix} 0.00 \\ 0.00 \\ 0.00 \\ 20.00 \\ 1.00 \end{matrix}$$

Then without showing the math, which would presumably be performed using a computer,

$$\mathbf{b} = \begin{matrix} -0.075 \\ 0.068 \\ 0.193 \end{matrix}$$

Consider 5 candidates for selection with records as follows:

| Bull no. | BW, kg | YW, kg | SC, cm |
|---|---|---|---|
| 93502 | 41 | 460 | 34 |
| 93552 | 45 | 494 | 36 |
| 93452 | 32 | 464 | 33 |
| 93469 | 44 | 486 | 36 |
| 93507 | 40 | 549 | 38 |

Based on equation 2, their evaluations for potential contributions to profitability are as follows:

| Bull no. | Evaluation | Rank |
|---|---|---|
| 93502 | -0.075(41) + 0.068(460) + 0.193(34) = 34.8 | 5 |
| 93552 | -0.075(45) + 0.068(494) + 0.193(36) = 37.2 | 2 |
| 93452 | -0.075(32) + 0.068(464) + 0.193(33) = 35.5 | 4 |
| 93469 | -0.075(44) + 0.068(486) + 0.193(36) = 36.7 | 3 |
| 93507 | -0.075(40) + 0.068(549) + 0.193(38) = 41.7 | 1 |

## EXTENDING SELECTION INDEX TO NATIONAL CATTLE EVALUATION

The preceding derivation of selection index largely assumed selection to be based on phenotype as a means of improving genotypic merit. Solutions to mixed-model equations are now widely used as predictors of genetic merit for individual traits. Henderson (1963) demonstrated that the BLUP for $\mathbf{H}$ was similar to equation 1 with the true breeding values replaced by their respective BLUP. This development has important advantages in application. First, appropriate adjustments for unequal amounts of information are incorporated into the predictions of $\mathbf{G}_i$. Second, the $\mathbf{a}_i$ can be customized to account for differences in breeding, production, and marketing systems. However, it is unlikely that predicted breeding values (or expected progeny differences) will be available for all economically important traits as part of a national cattle evaluation.

Multiple trait mixed model equations used in national cattle evaluation are:

$$\begin{bmatrix} X'R^{-1}X & X'R^{-1}Z \\ Z'R^{-1}X & Z'R^{-1}Z + (A*G_{11})^{-1} \end{bmatrix} \begin{bmatrix} \beta \\ u \end{bmatrix} = \begin{bmatrix} X'R^{-1}y \\ Z'R^{-1}y \end{bmatrix} \tag{7}$$

where, **X** and **Z** are known incidence matrices relating observations **(y)** to fixed effects **(β)** and breeding values **(u)**, respectively;

- **A** is the numerator relationship matrix;
- $\mathbf{G_{11}}$ is the genetic variance covariance matrix among traits included in the national cattle evaluation; and
- **R** is the residual variance covariance matrix.

These mixed-model equations may be augmented as follows to include the breeding values of economically important traits **(g)** for which no data has been recorded (Schneeberger et al., 1992):

$$\begin{bmatrix} X'R^{-1}X & X'R^{-1}Z & \\ Z'R^{-1}X & Z'R^{-1}Z + A^{-1}*G^{11} & A^{-1}*G^{12} \\ 0 & A^{-1}*G^{21} & A^{-1}*G^{22} \end{bmatrix} \begin{bmatrix} \beta \\ u \\ g \end{bmatrix} = \begin{bmatrix} X'R^{-1}y \\ Z'R^{-1}y \\ 0 \end{bmatrix} \tag{8}$$

where,

$$Var \begin{bmatrix} u \\ g \end{bmatrix} = A * \begin{bmatrix} G_{11} & G_{12} \\ G_{21} & G_{22} \end{bmatrix} = G, \quad \text{and}$$

$$G^{-1} = A^{-1} * \begin{bmatrix} G^{11} & G^{12} \\ G^{21} & G^{22} \end{bmatrix}$$

It follows that, for the kth candidate for selection, predicted breeding values for the economically important traits are: $\mathbf{g_k = G_{21}G_{11}^{-1}u_k}$ (9)

and as per Henderson (1963) candidates for selection can be ranked using equation 1 with predicted breeding values substituted for the true breeding values. Thus, BLUP of the breeding objective is: $\mathbf{a'g_k = a'G_{21}G_{11}^{-1}u_k}$, (10) and the selection index weights (b) for predicted breeding values from national cattle evaluation are:

$$\mathbf{b} = \mathbf{a}'\mathbf{G}_{21}\mathbf{G}_{11}^{-1} \tag{11}$$

It follows that the k candidates for selection can be equivalently ranked based on genetic evaluations currently produced using $\mathbf{I}_k = \mathbf{b}'\mathbf{u}_k$. This is the same formulation of selection index weights for available predicted breeding values used in the Australian B-OBJECT software (Barwick, 1994).

Where breeding values can be calculated for all traits in the recording scheme simultaneously, the preceding strategy seems to be the recommended approach to developing breeder specific selection indexes. It is believed that most organizations providing genetic evaluation services are moving in the general direction of multiple-trait evaluation. Managers of these services could serve their customers by providing a framework to use in calculating $\mathbf{a}$. This framework would most likely include traits for which data are not recorded. Hence, compiling genetic covariances for the non-recorded economically important traits with recorded traits also becomes an important part of the mission of national cattle evaluation services. Adjustments in methodology made necessary by differing analytical strategies combining single and multiple trait evaluations for subsets of all traits can be developed. Bowman et al. (1996) provide an illustrative example pertaining to selection indexes for dairy bulls.

In some situations, national cattle evaluation may not develop full multiple trait prediction systems for some time. This may be particularly true for some categorically distributed traits. If the genetic and environmental covariances necessary for multiple trait BLUP of EDP are assumed known, use of univariate predictions may compromise selection response by up to 15% (Villanueva et al., 1993). However, if the true covariances are unknown, but estimated and subject to error, the loss in efficiency of selection associated with using univariate genetic predictions may be reduced. Wilton (1982) suggested that, in practice, replacement of genetic predictions from multiple-trait evaluations with corresponding predictions from a series of single-trait evaluations may be an adequate approximation. Thus, calculating selection index weights as in equation 11 and applying them to the available BLUP of breeding values may be a starting point from which to implement genetic evaluation for profitability.

***AN EXAMPLE*** The same bulls evaluated previously using their phenotypic information also had EPD calculated as part of a national cattle evaluation. The selection index weighting factors appropriate to the EPD can be calculated using equation 11. Necessary partitions of the genetic variance covariance matrix are outlined below:

| | | | | | |
|---|---|---|---|---|---|
| Q= | 4.04 | 11.07 | 0.00 | -0.01 | 3.02 |
| | 11.07 | 199.15 | 8.00 | 0.00 | 35.28 |
| | 0.00 | 8.00 | 2.01 | 0.05 | 0.89 |
| | -0.01 | 0.00 | 0.05 | 0.01 | -0.13 |
| | 3.02 | 35.28 | 0.89 | -0.13 | 156.25 |

As previously, ignoring the calculations, the new selection index weights for the EPD of the candidates for selection are:

| | | | |
|---|---|---|---|
| b= | -0.075 | .068 | .193 |

Notice that these selection index weights for the EPD are exactly equal to the selection index weights for the phenotypes. Then, given national cattle evaluation results for the candidates for selection below,

| Bull no. | BW, kg | YW, kg | SC, cm |
|---|---|---|---|
| 93502 | +0.3 | 42 | +0.0 |
| 93552 | +1.6 | 50 | +0.6 |
| 93452 | -4.4 | 34 | -0.2 |
| 93469 | +1.0 | 50 | +0.3 |
| 93507 | +0.5 | 53 | +0.5 |

their evaluations for potential contributions to profitability are as follows:

| Bull no. | Evaluation | Rank |
|---|---|---|
| 93502 | -0.075( 0.3) + 0.068(42) + 0.193( 0.0) = 2.8 | 4 |
| 93552 | -0.075( 1.6) + 0.068(50) + 0.193( 0.6) = 3.4 | 2 tie |
| 93452 | -0.075(-4.4) + 0.068(34) + 0.193(-0.2) = 2.6 | 5 |
| 93469 | -0.075( 1.0) + 0.068(50) + 0.193( 0.3) = 3.4 | 2 tie |
| 93507 | -0.075( 0.5) + 0.068(53) + 0.193( 0.5) = 3.7 | 1 |

Notice, that while the ranks are substantially the same using a selection index of EPD as they were using a selection index of phenotypes, there has been some re-evaluation of individuals. In this case, the evaluation based on EPD is preferred because the EPD are a more accurate indicator of genetic merit than is phenotype.

## RELATIVE ECONOMIC VALUES

At its core, selection index is nothing more than a formalized statement of trade-offs among various traits used in evaluating candidates for selection. It is discovering and quantifying a complete set of traits that are economically important that is new to our conventional way of thinking about genetic evaluation and improvement. Up to this point, the relative contributions of various traits to profitability were taken as given. However, this cannot be the case if selection is to be most efficient for individual producers. We are required to develop a comprehensive and systematic way of relating changes in performance levels at the animal level to changes in profitability at the enterprise or production system level.

It seems likely the originally intended method of deriving relative economic values was multiple regression of profit on phenotypic performance. This approach brings to light primary problems of choosing appropriate independent variables, over-specified and collinear regression models, and data recording. Use of explicit simulation models, be they a few straightforward equations or interactive systems of thousands of equations, has been a frequently chosen alternative. However, while providing mathematically tractable estimates of the relative economic values, solutions to the root problems of the multiple regression models have been then left to intuition.

There is a substantial body of literature, stemming from Moav and Hill (1966), in which relatively straightforward "profit equations" have been used as the basis for deriving the relative economic values necessary to guide genetic improvement (e.g., Ponzoni, 1988; Newman et al., 1992; Wolfova et al., 1995). Alternatively, viewing genetic improvement as technological change using a farm-level model based on neoclassical econometric theory of the firm may provide more general solutions (Amer and Fox, 1992).

The method using profit equations for determining relative economic values for beef production was implemented by Ponzoni and Newman (1989) and is reviewed here as an example of that technology. Profit ($\pi$) was the difference between revenue and cost, which is further expanded to reflect profit derived from male calves, surplus heifer calves, and cull cows.

| | | |
|---|---|---|
| Revenue | = | n of male calves x value per individual |
| | + | n of surplus heifer calves x value per individual |
| | + | n of cull cows x value per individual |
| | | |
| Cost | = | feed consumed by male calves x feed price |
| | + | feed consumed by heifer calves x feed price |
| | + | feed consumed by cows x feed price |
| | + | n of male calves x husbandry cost per individual |
| | + | n of female calves x husbandry cost per individual |
| | + | n of cows x husbandry costs per individual |
| | + | n of male calves x marketing cost per individual |
| | + | n of surplus heifer calves x marketing cost per individual |
| | + | n of cull cows x marketing cost per individual |
| | + | fixed costs |

Translation of the revenues and costs into biological and economic units follows.

$$\pi_{\text{male calves}} = .5N[NCW - .01(CD\text{-}50)][CW_m(1.95\text{-}.025(FD_m - 8.)) - .03FI_m - 2.68 - 21.62]$$

where,

| | | |
|---|---|---|
| $N$ | = | number of cows, which was assumed constant and equal to 1000; |
| $NCW$ | = | number of calves weaned by a cow, which may be modified as a function of calving date (CD), such that earlier average calving date results in a greater number of calves weaned; |
| $CW_m$ | = | carcass weight of 9-month old male calves, the nominal value of which (\$1.95/kg at 8 mm of fat) may be modified by differences in fat depth ($FD_m$) at the rate of \$.025 per mm; |
| $FI_m$ | = | feed consumed to 9-months of age by a male calf at a nominal value of \$.03/kg. |

Husbandry, and marketing costs per male calf are \$2.68 and \$21.62, respectively. Similarly,

$$\pi_{\text{female calves}} = .5N[NCW- .01(CD-50)][CW_f(1.80-.03(FD_f -8.))-.03FI_f -4.43-26.75] -.139N[NCW- .01(CD-50)][CW_f (1.80-.03(FD_f -8.)-26.75]$$

with the added term accounting for the revenue not received as a result of retaining 139 replacement heifers; and

$$\pi_{\text{cull cows}} = .112N[1.65CW_c-30.6\ 1]-N[.03FI_c -6.25]$$

Given this mathematical description of the production system, Ponzoni and Newman (1989) calculated relative economic values for the biological traits as partial derivatives of $\pi$ with respect to each trait holding the other traits constant at their respective mean levels. In the present example, accounting for time lags in the manifestation of genetic improvement has been ignored. However, there is technology available to account for different discount rates (McClintock and Cunningham, 1974) over an appropriate planning horizon. This approach can be reconciled with breeding objectives based on production efficiency (Dickerson, 1970) if all costs are considered variable costs (Smith et al., 1986).

The profit equation can be thought of as a highly, if informally, aggregated simulation model (MacNeil and Harris, 1988). More explicit and complex bio-economic simulation models can likewise be used to estimate relative economic values using the principles of sensitivity analysis. In principle, a set of parameters which describe the present situation is developed for the model. The partial derivative of profit with respect to the parameter is approximated by the difference between runs of the model before and after perturbing the parameter some small amount. However, determining relative economic values for state variables can be problematic. Changes in state variables usually result as a consequence of changes in parameters which have manifold effects. Thus, it can be difficult to achieve that state where the one variable being evaluated is incrementally changed and all other variables remain constant. Some formal modeling procedures may facilitate sensitivity analysis with respect to state variables. As the simulation model becomes less aggregated and more mechanistic, the sensitivity analyses becomes more difficult as a result of the increased number of parameters and state variables (MacNeil et al., 1985). This general approach has also been widely used in estimating relative economic values (e.g., Dekkers, 1991; Groen, 1988; MacNeil et al., 1994; Tess et al., 1983a,b,c).

Following Amer and Fox (1992), neoclassical economic theorists view the beef production unit as a firm using both genetic (X) and non-genetic (Z) inputs in production of a product (Y). Improvement in genetic inputs to production is viewed as technological change. Economic description of the beef production enterprise begins with a mathematical formulation of total cost (TC):

$$TC = C(Y, V_x, V_z),$$

where, $V_x$ and $V_z$ are costs to the producer for genetic and non-genetic inputs into the production process. This function ©) increases at a decreasing rate at low levels of output reflecting economies of scale, wherein it costs less to produce each successive unit of product. At high levels of output TC increases at an increasing rate reflecting limitations imposed by ability to manage the enterprise. The partial derivative of TC with respect to Y is the marginal cost and the ratio of TC to Y is the average cost.

Marginal revenue (MR) is the increase in revenue received from one additional unit of output which for beef production can be assumed constant and equal the output price. The profit maximizing level of output occurs when MC = MR and marginal cost is increasing. At this point, total revenue is the product of Y and MR. As in the profit equation approach, profit remains as the difference between total revenue and total cost. Notice that this solution is not the same as derived by minimizing cost per unit of output as advocated by Dickerson (1970).

A change in average genetic merit of the herd is represented in this model by shifts in the cost functions. Note that, with MR held constant, there becomes a new profit maximizing level of production as well. The relative economic values for various trait used in selection index as derived under this model are the changes in the firm's profit at optimum levels of production which result from a unit change in each trait (McArthur, 1987). Applications of econometric theory in estimating relative economic weights are more limited than applications of either profit equations or simulation models. The works of Melton and coworkers are a prominent exception (Melton, 1995).

## GENERAL COMMENTS

In this presentation, issues related to non-linear indexes (Pasternak and Weller, 1993), restricted indexes (Brascamp, 1984; Niebel and VanVleck, 1982a,b), and multistage selection indexes (Xu and Muir, 1992) have been ignored. These enhancements, to the more basic approaches reviewed here, merit consideration in developing a program of customer service. Restricted selection indexes have been criticized for severe losses of potential economic gain (Gibson and Kennedy, 1990). Selection indexes are well-adopted to periodic recalculation providing a logical framework for non-linear relationships between profit and performance or other changes in economic conditions (Hazel et al., 1994). Periodic recalculation of linear indexes will apparently compensate for non-linear relationships of profit and economically important traits with little loss in efficiency of selection (Groen et al., 1994). Multistage selection indexes may merit development to reduce testing costs and shorten generation intervals.

With generation intervals of five or more years and substantive genetic improvement requiring more than one generation, it is obvious that relative economic values pertain to the long-run. Relative economic values should not be influenced by year-to-year fluctuations in prices. For example, calculation of relative economic values based on either 1993 or 1996 prices for feeder cattle is probably misleading. Use of average prices received by farmers for feeder cattle over the past 10 to 15 years, adjusted for inflation, is preferred. Another important consequence of considering long run economic scenarios is that all costs become variable.

As stated previously, the neoclassical approach is more general than the profit equation approach. There are no economies or diseconomies of scale in the profit equation approach for calculating relative economic values and thus the total cost curve is linear. This implies beef production firms would tend toward infinite size, which is seemingly inconsistent with the actual behavior of beef producers. Smith et al. (1986) suggested that incremental profits received from rescaling the production enterprise (increasing output) be removed from economic weights derived using profit equations. However, not allowing size rescaling to enter into a breeding objective seems inconsistent with a long run view of the genetic improvement process and profit maximization by the firm. From a practical perspective, that while there is some evidence these two approaches are not equivalent, the linear profit equation method provides a useful approximation of economic weights obtained from neoclassical theory for intra-breed selection indexes (Amer et al., 1994; Bright, 1991; Visscher et al., 1994). In closing, it should be noted that small errors either in economic weights (VandePitte and Hazel, 1977; Smith, 1983) or genetic parameters (Harris, 1963) may lead to only minor losses in efficiency of selection.

## INDUSTRY EXAMPLES

Acceptance of selection index technology by seedstock breeders varies widely by species and across countries. Commercial breeding companies have been quicker to adopt the technology than individual breeders. In this section we relate some experiences of two commercial breeding companies with selection indexes as a means to demonstrate the usefulness of them. Several other examples could be cited including: early European work in poultry by Moav and coworkers (1966) and in dairy (Wilton et al., 1968, 1969). Australian work in several livestock species principally by Ponzoni and coworkers (1979, 1981, 1989, 1990); and more recent U.S. work (Faust et al., 1992a,b, 1993; Lamb et al., 1992a,b,c; Tess et al., 1982a,b,c).

***Swine Breeding:*** Today's market hog is produced from at least one, and generally two, crossbred parents. Parent lines trace back to "purebred" grandparent (and sometimes great grandparent) lines. These progenitor lines were produced using within line selection based on selection indexes developed specifically for them. These selection indexes contain estimated breeding values for a variety of traits weighted by their relative economic values and genetic correlations.

Use of specialized sire and dam lines offers several important advantages. Existing between-breed differences for economically important traits can be exploited to produce parent stocks with near optimal additive genetic makeup and that generally expresses high levels of hybrid vigor. Further, each specialized (great-)grandparent line can be selected differently, emphasizing those traits it contributes to the final cross. Genetic antagonisms, such as the unfavorable relationship of lean growth rate with reproductive rate, reduce the rate of genetic progress in a composite or pure-line parent-stocks. However, their impact on genetic improvement is greatly reduced by selection for complementary traits in specialized sire and dam lines.

For example, a line contributing to the final crossbred parent boar line can be selected for lean growth and meat quality, but ignoring maternal traits. Conversely, maternal lines are selected for productivity (e.g., number of pigs weaned per sow per year) and for efficient lean growth, but ignoring meat quality traits. Note that the economic importance of efficient lean growth necessitates selection for components of it in all specialized lines, whether maternal or paternal in ultimate usage.

Relative economic values for each trait are established using a commercial production system model. These relative economic values are the recognition that economic return from a one standard deviation increase in one trait will not be equal to a similar increase in another trait. Only economically important traits and indicators of economically important traits that will respond to selection are ultimately used by the breeding stock producer. For reproductive traits, general industry estimates put the value of an extra pig born at about $13.50, and the value of an extra pound of 21-day weaning weight at about $0.50. It is not efficient to measure or base selection on traits without economic value and thus these traits are not pursued.

Use of genetic relationships, both among animals and among traits, is routine to improve accuracy of predicting overall genetic merit, especially in young animals and when sequential culling is practiced. Potential replacement stock and established breeding animals are retained for reeding or culled based on the most current prediction of their genetic merit.

The wide variety of potential traits contains some favorable (e.g., feed conversion and growth rate) and some unfavorable (e.g., growth rate and back-fat) genetic correlations. Further, initial selection decisions are often made before any individual animal expresses all the traits that determine its ultimate genetic merit. Examples include initial selection among potential breeders which first occurs at weaning (3-4 week old pigs) before expression of female reproductive ability and longevity, and the carcass or meat quality attributes. In this instance information from relatives and from genetically correlated traits is found to be particularly important for improving the accuracy of selection decisions. Use of specialized sire and dam lines, high reproductive rates characteristic of swine, short generation intervals, and intense selection yield rapid genetic improvement and also facilitate near-maximum exploitation of hybrid vigor.

***<u>Beef Cattle Breeding:</u>*** Beefbooster began using selection index technology in the last five years. Criteria used to evaluate bulls are based on economics of commercial beef production, emphasizing profitability and a balance between traits affecting reproduction, calf growth and carcass merit. To achieve the balance necessary between traits influencing profitability even with the multiple-trait criteria to balance economically important traits, bulls remain specialists, intended to function in a specific role to profitably produce beef. It is virtually impossible to find a single bull who can perform well as a heifer bull (minimizing calving difficulty in first-calf heifers), as a maternal bull (siring daughters that profitably raise a calf every year) and as a terminal bull (siring high growth, high cutability market calves). Seedstock strains were developed to address needs for these different types of bulls, and bulls from each strain are evaluated according to criteria specific to the role of that strain. This means that besides meeting performance specifications, each bull has been bred for a specific purpose and is not the result of a general-purpose breeding program that may fit bulls into different roles according to their performance.

Bulls are evaluated with multiple trait indexes using economic weights on measurable traits that include birth weight, gain before and after weaning, scrotal circumference and ultrasound carcass measurements. Examinations for fertility, structural soundness and disposition help to ensure that functional bulls are made available to commercial producers. Seedstock breeders have first choice of bulls. Bulls remaining after the breeders' selections are split into the top (red class, highest price), middle (orange class) and bottom (yellow class, lowest price) thirds according to index rank. Cow indexes use EBV for birth weight, preweaning gain (direct and maternal), postweaning gain, and mature weight. The index rankings are used by seedstock breeders to cull the bottom end of their cow herd.

## CONCLUSION

Selection index provides a systematic means for making selection decisions that are consistent with improved profitability. This technology permits us to exploit information on relatives and to use correlated traits to improve accuracy. The emphasis applied to each trait is scaled by the importance of that trait in determining overall profitability. The beef industry needs to make progress toward providing genetic evaluations that will result in improved profitability for commercial producers. The difficulty of deriving relative economic values for use in selection index suggests a niche for recording financial information consistent with this goal. The Beef Improvement Federation can facilitate improved profitability on the part of beef producers willing to adopt selection index technology through guidelines for 1) deriving relative economic values and 2) implementing selection index technology in national cattle evaluation.

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