Breeding Objectives for Terminal Sires For Use in U.S. Beef Production Systems[1,2]

M. D. MacNeil[3]
USDA Agricultural Research Service
Miles City, Montana 59301 USA

ABSTRACT

Breeding objectives facilitate implementation of consistent selection toward a specified goal. In a business context, profit maximization is often that goal. Thus, the aim of the research reviewed here was to develop economic breeding objectives for terminal sires. It is argued that commercial production systems provide the framework from which to develop breeding objectives for seedstock. Breeding objectives were developed for Angus, Charolais, Hereford, Limousin, and Simmental using economic input consistent with future projections of the respective breed organizations. The biological and economic framework was an aggregated model of an integrated beef production system that was employed in simulating commercial beef production in situations typical of the U.S. Use of crossbreeding was assumed, except in the objective developed for Angus. For each breed, economic values for survival, growth, feed intake, and carcass related phenotypes were calculated by approximating partial derivatives of profit with respect to each of the phenotypes. In general, results indicate a need for consistent multiple trait selection with joint consideration of both fitness and production traits and with differential emphasis on their components.

INTRODUCTION

Genetic predictions in the form of estimated breeding values (EBV) or expected progeny differences (EPD) provide breeders and commercial beef producers with opportunities to choose among candidates for selection based on their genetic merit. However, a precise definition for "genetic merit" has been illusive. In a business context, profit maximization has been a long standing goal and it is suggested that genetic merit be defined by the profitability of future progeny. Further, it is argued that since the seedstock sector exists primarily to provide germplasm for commercial producers that the relevant measure of profitability is the profitability of commercial production (Harris and Newman, 1994).

Selection for a single trait likely leads to undesirable correlated responses as a result of various genetic antagonisms among traits (MacNeil et al. 1984, Scholtz, et al. 1990a). These correlated responses likely compromise any improvement in profitability that might result from single trait selection. Thus, with a goal of improving profitability, a strategy for multiple trait selection is necessary. However, selection for production alone tends to decrease fitness (Roberts, 1979; Meuwissen et al., 1995). Thus, a comprehensive and consistently applicable breeding objective, related to traits that influence profitability in commercial production, is needed for multiple trait selection to be most effective (Harris and Newman, 1994).

Commercial beef production is generally most economically efficient when heterosis is captured (MacNeil and Newman, 1991). This efficiency arises from a potential to increase weaning weight per cow exposed by approximately 26% (MacNeil et al.,

---

[1] This research was conducted under cooperative agreements between USDA, ARS, Montana Agric. Exp. Sta., and ARC Animal Improvement Institute. USDA, Agricultural Research Service, Northern Plains Area, is an equal opportunity/affirmative action employer. All agency services are available without discrimination.

[2] Mention of a proprietary product does not constitute a guarantee or warranty of the product by USDA, Montana Agric. Exp. Sta., ARC Animal Improvement Institute or the authors and does not imply its approval to the exclusion of other products that may also be suitable.

[3] To whom correspondence should be addressed: 243 Fort Keogh Road (Phone 406/874-8213; FAX: 406/874-8289; e-mail: mike@larrl.ars.usda.gov). This work grew from a vision shared by Scott Newman and collaborative work with BeefBooster Cattle Alberta that was stimulated by discussions with John Stewart-Smith. Contributions of: William Herring, Smithfield Premium Genetics; Robert Williams, American International Charolais Association; Craig Huffines and Jack Ward, American Hereford Association; Kent Anderson and Lauren Hyde, North American Limousin Foundation; and Wade Schafer, American Simmental Association in developing and implementing the various objectives are greatly appreciated. In addition, I thank Larry Benyshek for his extensive review and summarization of genetic parameter estimates used herein.

1988) while only increasing feed energy requirements by 1% (Brown and Dinkel, 1982). Comparing heterosis estimates from experiments crossing inbred lines with heterosis estimates from crossbreeding experiments clearly indicates more heterosis will result from use of multiple breeds (Dickerson, 1973). Use of multiple breeds also allows breeders to capture benefits from complementarity (Cartwright, 1970). In addition, and of particular interest in the developing world, is the opportunity to use locally adapted (low input) maternal breeds and improve characteristics of the harvested progeny by using terminal sires (Scholtz, 1988; Scholtz, et al., 1990b).

Thus, the present objective is to discuss the development of breeding objectives for terminal sires of several breeds. Parallel approaches are applicable in defining objectives for specialized dam lines and general purpose germplasm.

Materials and Methods

A modified version of the simulation model described by MacNeil et al. (1994) was used in these investigations. The model is highly aggregated and reliant on user inputs for the phenotypic characterization of the germplasm used and economic characterization of the production environment. It simulates a production system that is constrained in size by a fixed energetic resource being available for cow-calf production. Owing to the substantial economic benefits that result from exploiting heterosis in beef production, use of crossbreeding is assumed. Phenotypic characterizations of breed resources, originating primarily from the germplasm evaluation and utilization programs conducted by USDA-ARS at Clay Center, NE (Gregory et al., 1991a,b and 1994a,b; Cundiff et al., 2004;) used in this study for traits of economic importance are given in Table 1.

In the U.S. situation, phenotypes for: cow weight, milk production, male and female fertility, calf survival, weaning weight (direct effects), postweaning average daily gain, postweaning feed intake, days fed, dressing percentage, USDA Yield Grade, and marbling score were assumed to determine profitability, in the U.S. situation. Number of calves produced was a function of male fertility, female fertility, and calf survival. Due to a lack of breed characterizations for male fertility, the composite trait pregnancy rate (male fertility x female fertility) was used to set the input for the respective fertility traits with male fertility assumed constant at 98%. Weaning weights were established as a base for the production environment.

The feedlot phase was divided into three periods. The first period (backgrounding) was terminated at a weight-constant endpoint of 386 kg. The second (growing) and third (finishing) periods were of 50 and 100 days duration, respectively. Energy density of rations fed increased with period, as did average daily gain. Feed conversion (feed/gain) decreased with periods. Carcasses are characterized on the tri-variate normal distribution of weight, marbling score, and cutability and their valuation results from price discrimination based on carcass weight, USDA Yield Grade, and USDA Quality Grade (Table 2). All carcasses were assumed to be of A maturity. Variable and fixed costs of cow-calf production were monitored. In the feedlot, fixed costs per day and feed costs were accumulated. Profit was computed as the difference between total carcass value and total cost. For the production systems that are simulated, genes of a terminal sire breed influence progeny that are harvested, but not attributes of producing females. Thus, only the phenotypes for: calf survival, weaning weight, postweaning average daily gain, postweaning feed intake, dressing percentage, USDA Yield Grade, and marbling score contribute to the breeding objective.

Economic values for survival, growth, feed intake, and carcass related phenotypes were calculated by approximating partial derivatives of profit with respect to each of the phenotypes. For each breed, a baseline economic analysis was conducted with breed characterizations given in Table 1 and economic factors affecting carcass value given in Table 2. Then, in separate simulations, the phenotypes for each of the economically relevant traits of the terminal sire breed were changed by one unit. The difference between simulated profit with a phenotype perturbed and profit in the baseline

Table 1. Phenotypic means of traits in the breeding objective for terminal sires for various breeds[1].

Breed	SV	WW(d)	ADG	FI	DP	YG	MS
Angus	94	550	3.43	26.8	63.1	3.5	5.4
Charolais	95	616	3.73	28.2	62.4	2.3	4.7
Hereford	93	552	3.43	25.2	62.1	3.3	5.0
Limousin	94	576	3.41	25.3	65.2	1.9	4.4
Simmental	91	612	3.77	25.9	62.6	2.3	4.8

[1] SV = calf survival, %; WW(d) = direct weaning weight, lbs ADG = average daily gain during finishing period, lbs/d; FI = postweaning feed intake during finishing period, lbs/d; DP = dressing percent, %; YG = USDA yield grade; and MS = marbling score (4.0 = slight[0], 5.0 = small[0], etc.).

simulation was taken to be the relative economic value for that trait. Economic values are expressed both on an enterprise basis and per cow joined. An indication of their magnitude relative to expected genetic variation was provided by multiplying the relative economic values by their respective genetic standard deviations. Genetic correlations (r_A) between objectives were calculated as:

$$r_A = a'_1\mathbf{Q}a_2/\sqrt{(a'_1\mathbf{Q}a_1)(a'_2\mathbf{Q}a_2)} \qquad \text{(James 1982)}$$

where, a_1 and a_2 = vectors of relative economic values and **Q** = the genetic variance covariance matrix among traits in the breeding objective (Table 3).

Results and Discussion

Technology for construction of selection indexes has existed for more than 60 years (Hazel, 1943) and has seen substantial adoption in other agricultural industries (see review Hazel et al., 1994) and countries (e.g. Ponzoni and Newman, 1989; Newman et al., 1992). Comprehensive analyses of Dickerson et al (1974) produced the widely recognized index (I) for general purpose use of British breeds in beef production: I = YW – 3.2BW; wherein YW = 365-d weight and BW = birth weight. The efficacy of selection index technology in improving profitability of milk production in the dairy industry was reviewed by VanRaden (2004). Amer et al (1998) proposed three indexes for beef bulls to be used in the U.K. as terminal sires.

The perspective taken here is that of a domestic commercial production unit that utilizes a fixed natural resource base for cow-calf production and markets calves produced based on their carcass merit. A similar farm level approach to derive economic values for dairy production was proposed by Groen (1988). In the present research, two-, three-, and four-year-old cows produce replacement females and male calves are fed out and marketed at

Table 2. Breed-specific factors contributing to price discrimination among beef carcasses ($/cwt).

Angus Base carcass price = $121.00

Trait	Premiums and Discounts				
Carcass weight	< 550 lbs = -$20.00			> 950 lbs = -$20.00	
Quality	Prime	High Choice	Low Choice	Select	Standard
Grade	$9.00	$5.00	$0.00	-$5.60	-$15.00
Yield Grade	1: $4.00	2: $1.50	3: $0.00	4: -$15.00	5: -$20.00

Charolais Base carcass price = $115.00

Trait	Premiums and Discounts				
Carcass weight	< 550 lbs = -$19.90			> 950 lbs = -$16.80	
Quality	Prime	High Choice	Low Choice	Select	Standard
Grade	$6.50	$1.30	$0.00	-$6.20	-$17.00
Yield Grade	1: $3.10	2: $2.00	3:- $1.00	4: -$14.50	5: -$19.50

Hereford Base carcass price = $121.00

Trait	Premiums and Discounts				
Carcass weight	< 550 lbs = -$17.50			> 950 lbs = -$12.75	
Quality	Prime	High Choice	Low Choice	Select	Standard
Grade	$7.25	$3.25	$0.00	-$4.50	-$18.00
Yield Grade	1: $3.00	2: $2.25	3: $0.00	4: -$15.00	5: -$20.00

Limousin Base carcass price = $121.00

Trait	Premiums and Discounts				
Carcass weight	< 550 lbs = -$20.00			> 950 lbs = -$20.00	
Quality	Prime	High Choice	Low Choice	Select	Standard
Grade	$7.00	$2.50	$0.00	-$10.00	-$20.00
Yield Grade	1: $4.00	2: $2.00	3:- $1.00	4: -$15.00	5: -$20.00

Simmental Base carcass price = $121.00

Trait	Premiums and Discounts				
Carcass weight	< 550 lbs = -$20.00			> 950 lbs = -$20.00	
Quality	Prime	High Choice	Low Choice	Select	Standard
Grade	$9.00	$4.50	$3.70	-$5.60	-$15.00
Yield Grade	1: $4.00	2: $1.50	3: $0.00	4: -$15.00	5: -$20.00

Table 3. Genetic variances (on diagonal), covariances (above diagonal) and correlations (below diagonal) among phenotypes in the breeding objective (ERT[1]).

ERT	SV	WW(d)	ADG	FI	DP	YG	MS
SV, %	8.74	-16.24	-0.04	0.00	0.00	0.10	0.00
WW(d)	-0.20	755.20	2.68	13.95	7.06	0.69	-4.07
ADG	-0.07	0.50	0.04	0.11	0.02	0.02	0.05
FI	-	0.61	0.70	0.69	0.10	-0.06	0.05
DP	-	0.27	0.10	0.13	0.91	0.04	0.11
YG	0.13	0.09	0.29	-0.25	0.14	0.07	0.08
MS	-	-0.21	0.39	0.08	0.16	0.43	0.50

[1] SV = calf survival, %; WW(d) = direct weaning weight, lbs ADG = average daily gain during finishing period, lbs/d; FI = postweaning feed intake during finishing period, lbs/d; DP = dressing percent, %; YG = USDA yield grade; and MS = marbling score (4.0 = slight^0, 5.0 = small^0, etc.).

harvest. Cows that are five-years-old and older are bred to the terminal sire breed and all progeny of the terminal sire breed are fed out and marketed at harvest. This enterprise is assumed to exist and fixed costs are therefore appropriate. It has also been assumed that additional feed may be purchased to support postweaning growth of market animals. Thus, the perspective here is relevant to seedstock selection for commercial production. It has been argued that total cost be expressed per unit of output and that genetic improvement comes from reducing costs per unit of product value rather than changing output or the value of it (Smith et al., 1986).

Presented in Table 4 are economic values for terminal sires of the various breeds. These results are expressed on an enterprise basis rather than per cow exposed or per progeny produced. Following Henderson (1963), if EPD were produced for these economically relevant traits then the economic values given in Table 4 (or a constant fraction of them) would be the appropriate selection index weights. Extending the breeding objectives, either to include genetic evaluations for indicator traits or eliminate some of the economically relevant traits is straightforward, given appropriate estimates of genetic variances and covariances (Schneeberger et al., 1992). In application rescaling the economic values from an enterprise basis to the basis of per cow exposed has some appeal.

Presented in Table 5 are the products of economic values and genetic standard deviations as indicators of the relative magnitudes of the economic values. On average results in Table 5 indicate relatively uniform emphasis to be placed on breeding values for traits affected in part by terminal sires. In comparison to postweaning feed intake, breeding values for postweaning average daily gain and USDA Yield Grade appear to contribute less to profitability. In comparison, breed-specific relative economic values for carcass weight, carcass conformation score, carcass fat score, gestation length and calving difficulty reported by Amer et al (1998) for terminal sires were 15.0, 7.3, 4.4, 3.2, and 7.8, respectively.

Survival of progeny appears to be an important consideration in selection of terminal sires. Mass selection for survival occurs naturally, particularly in harsh environments (Simm, et al., 1996). However, this result occurs despite the relative low heritability ($h^2 = 0.02$) of survival assumed in this research and there are reports of the heritability of calf survival being more than 3-fold greater (Cundiff et al., 1986). Even given low heritability, Martinez (1982) found mortality of half-sib progeny groups ranged from 3% to 12% for dairy sires with more than 400 offspring. Thus, prediction of differences in genetic merit among sires may warrant further investigation. Such investigation rests on a foundation of whole-herd reporting (i.e. reporting existence of calves that die at

Table 4. Breed-specific relative economic values for phenotypes in the breeding objective[1].

Breed	SV	WW(d)	ADG	FI	DP	YG	MS
Angus	1096.	130.	8956.	-3546.	2938.	-10149.	4761.
Charolais	733.	145.	5564..	-4074.	3319.	-284.	58.
Hereford	784.	138.	6719.	-2644.	2674.	-5896.	4024.
Limousin	736.	146.	7276.	-2552.	2760.	-2986.	5490.
Simmental	868.	102.	4082.	-2646.	1131.	-4120.	1764.

[1] SV = calf survival, %; WW(d) = direct weaning weight, lbs ADG = average daily gain during finishing period, lbs/d; FI = postweaning feed intake during finishing period, lbs/d; DP = dressing percent, %; YG = USDA yield grade; and MS = marbling score (4.0 = slight^0, 5.0 = small^0, etc.).

Table 5. Products of genetic standard deviations and breed-specific relative economic values for phenotypes in the breeding objective[1].

Breed	SV	WW(d)	ADG	FI	DP	YG	MS
Angus	3239.	3573.	1746.	-2952.	2797.	-2742.	3360.
Charolais	2167.	3985.	1085.	-3391.	3159.	-77.	41.
Hereford	2317.	3792.	1310.	-2201.	2545.	-1593.	2840.
Limousin	2175.	4012.	1418.	-2124.	2627.	-807.	3874.
Simmental	2566.	2803.	796.	-2203.	1077.	-1113.	1245.

[1] SV = calf survival, %; WW(d) = direct weaning weight, lbs ADG = average daily gain during finishing period, lbs/d; FI = postweaning feed intake during finishing period, lbs/d; DP = dressing percent, %; YG = USDA yield grade; and MS = marbling score (4.0 = slight^0, 5.0 = small^0, etc.).

birth in addition to reporting phenotypes of live calves). Lacking direct genetic predictors, current efforts to manage genetic differences in survival rests solely on use of indicator traits.

Feed intake also appears to be important as a component in prediction of differences in profit derived from progeny of terminal sires. Kirschten (2005) presents a review of genetic aspects related to efficient feed utilization elsewhere in these proceedings. Sufficient feed intake allows expression of productive functions and thus its consideration may be seen as the first critical step in evaluating consequences of selection (Emmans and Kyriazakis, 2001).

Presented in Table 6 are genetic correlations among the breeding objectives for terminal sires of various breeds.

For each breed of terminal sire, the environment defined in simulating the breeding objective differed. Economic environments were defined by distinct pricing grids and mating systems differed both in maternal breeds used and the way in which the maternal breeds were used. Despite these differences, most of these genetic correlations among breeding objectives for terminal sires approach 1.0. To the degree that they are less than 1.0 they reflect genotype by environment interaction for the composite trait profitability.

Summary

The breeding objectives presented here point to a need for consistent multiple trait selection. It is argued that commercial production systems provide the framework for these developments. In general, the emphasis given to breeding values for traits in the breeding objective is relatively uniform. Differences between production environments may also influence breeding objectives for terminal sires of various breeds.

References

Amer PR, Crump R and Simm G (1998) Anim. Sci. 67:445-454.

Brown MA and Dinkel CA (1982) J. Anim. Sci. 55:254-464.

Cartwright TC (1970) J. Anim. Sci. 30: 706-711.

Cundiff LV et al. (2004) Germplasm Evaluation Program, Progress Report No. 22 . USDA-ARS, Clay Center, NE.

Cundiff LV et al. (1986) J. Anim. Sci. 63:27-33.

Dickerson GE (1973) Proc. Anim. Breed. Genet. Symp. 54-77.

Dickerson GE et al. (1974) J. Anim. Sci. 39:659-673.

Emmans G and Kyriazakis I (2001) Proc Nutr. Soc. 60:115-125.

Gregory KE, Cundiff LV and Koch RM (1991a) J. Anim Sci. 69: 947-960.

Gregory KE, Cundiff LV and Koch RM (1991b) J. Anim. Sci. 69:3202-3212.

Gregory KE et al. (1994a) J. Anim. Sci. 1174-1183.

Gregory KE, Cundiff LV and Koch RM (1994b) J. Anim Sci. 72: 1138-1154

Groen AF (1988) Agric. Syst. 27:195-213.

Harris DL and Newman, S (1994) J. Anim Sci. 72:2178-2200.

Hazel LN (1943) Genetics 28:476-490.

Hazel LN, Dickerson GE and Freeman AE (1994) J. Dairy Sci. 77:3236-3251.

Henderson, C. R. (1963) In: W. D. hanson and H. F.

Table 6. Genetic correlations among breeding objectives for terminal sires of various breeds.

Breed	Charolais	Hereford	Limousin	Simmental
Angus	0.74	0.97	0.93	0.89
Charolais		0.80	0.74	0.85
Hereford			0.98	0.87
Limousin				0.80

Robinson (Ed.) Statistical Genetics and Plant Breeding. NAS-NRC Publ. 982.
James JW (1982) Proc 2nd World Genet. Appl. Livestock Prod. Madrid 5:130-139
Kirschten DP (2005) Proc. Beef Improvement Fed. Billings, Montana.
MacNeil MD and Newman S (1991) Proc. International Beef Symp. Great Falls. Montana 129-134.
MacNeil MD et al. (1984) J. Anim. Sci. 58:1171-1180.
MacNeil MD et al. (1988) Appl. Agric. Res. 3:44-54.
MacNeil MD et al. (1994) Can. J. Anim. Sci. 74:411-417.
Martinez ML (1982) PhD Diss. Iowa State Univ., Ames.
Meuwissen THE et al. (1995) Theor. Appl. Genet. 90:627-635.
Newman S et al. (1992) Livestock Prod. Sci. 32:111-130.
Ponzoni RW and Newman S (1989) Anim. Prod. 49:35-47.
Roberts RC (1979) Livestock Prod. Sci. 6:93-104.
Schneeberger M. et al. (1992) J. Anim. Breed. Genet. 109:180-187.
Scholtz MM (1988) Proc 3rd World Cong. Sheep and Beef Cattle Breed. 303 - 319.
Scholtz MM et al. (1990a) S. Afr. J. Anim. Sci. 20(4):169-173.
Scholtz MM et al. (1990b) Proc. 4th World Cong. Genet. Appl. Livestock Prod. XV:361-364.
Simm G. et al. (1996) Appl. Anim. Behavior Sci. 49:47-59.
Smith C James JW and Brascamp EW (1986) Anim. Prod 43:545-551.
VanRaden PM (2004) J. Dairy Sci. 3125-3131.