Breeding objectives for Angus and Charolais specialized sire lines for use in the emerging sector of South African beef production

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Abstract

Breeding indigenous cows to terminal sires may facilitate production of calves in the emerging sector that better meet commercial feedlot requirements. Thus, the objective of this research was to develop breeding objectives for Angus and Charolais terminal sires to be used in breeding Afrikaner, Bonsmara, and Nguni cows. An aggregated simulation model that is reliant on user inputs for the phenotypic characterization of the germplasm and economic characterization of the production environment was developed. Relative economic values were calculated by approximating partial derivatives of simulated profit with respect to economically relevant traits. Correlations among the breeding objectives calculated from simulations of Angus and Charolais bulls bred to Afrikaner, Bonsmara and Nguni cows were consistently > 0.9. Thus, an average index could be used for all six scenarios with little loss of selection efficiency. On average, relative emphasis given to breeding values for survival, direct weaning weight, postweaning daily gain, postweaning daily feed intake, dressing percent, and fat depth were 31.1, 31.0, 17.3, 1.4, 19.1, 0.2%, respectively. These breeding objectives may be viewed as an appropriate step in the evolution of multi-trait selection to facilitate poverty alleviation among cattle producers in the emerging sector through wealth creation resulting from their production of calves for industrial feeding.

Keywords: Beef cattle, genetic evaluation, selection strategy, crossbreeding, cow-calf production system
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Introduction

An agricultural development objective was established by the South African government as a means to poverty alleviation through wealth creation. To achieve this objective, many poor farmers should evolve from subsistence farming to commercial production and “emerge” from the subsistence agriculture. The cattle population of the subsistence sector accounts for approximately 4 million animals of a total population of some 14 million. It is estimated that 80% of cattle slaughtered in South Africa go through feedlots. However, currently animals from the subsistence sector do not meet requirements of the feedlots. In commercializing emerging cattle producers, breeding objectives and efficient use of breed resources can facilitate improved production for market requirements.

Hazel & Lush (1942) established the utility of a linear function of traits as a basis for multiple trait selection. Hazel (1943) put forth the concept of aggregate genotype based on weighting the gain to be made in each trait by the relative economic value of that trait. Following Henderson (1963), maximum improvement in the aggregate genotype can be achieved by evaluation on the sum of products of breeding values for traits in a breeding objective and their relative economic values. In a business context, profit maximization has been a long standing goal and it has been suggested that the breeding objective be defined by profitability of future progeny (Harris, 1970). 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 & Newman, 1994). Therefore, a consistently applicable breeding objective related to traits that influence profitability in commercial production is needed.

Commercial beef production is generally most economically efficient when heterosis is captured (MacNeil & Newman, 1991). 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 complimentarity (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 specialized sire lines (Scholtz, 1988; 1990a). This strategy for using breed resources may aid emerging cattle producers entering into the commercial beef production.

Thus, objectives of this research were to: 1) put forth a process for defining breeding objectives, and 2) predict relative economic values for Angus and Charolais specialized sire lines to be used in breeding Afrikaner, Bonsmara, and Nguni cows. The breeding objectives developed here are intended to assist farmers in selecting sires for breeding indigenous females when the resulting progeny are to be marketed through an industrial feeding system.

Materials and Methods

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 is similar in some respects to the simulation model described by MacNeil *et al.* (1994) and 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. In this research, Angus and Charolais sires are bred to 50% of the Afrikaner, Bonsmara, and Nguni females in separate simulations. It is assumed that young cows are bred to bulls of the maternal breeds for the production of replacements. Performance was simulated on a group mean basis (i.e. separately for each breed combination), except that upon attaining the harvest endpoint traits needed to derive the value of individual animals were simulated from the first and second moments of the respective phenotypic distributions assuming constant coefficients of variation for each trait. The general structure of the model specific to this research is given below.

A specific-cross production system using specialized sire and dam lines was simulated. Thus, an individual phenotype (P) of a progeny sired by the specialized sire breed was modeled as:

$$P = 0.5G^I_A + 0.5G^I_B + h^I + 1.0G^M_B$$

The G^I_A and G^I_B represent direct effects of the specialized sire and dam breed, respectively; h^I is the average heterosis effect taken from literature summaries; and G^M_B is the maternal effect of the specialized dam breed. In this study, maternal genetic effects only influenced growth from birth to weaning.

Phenotypic characterizations of breed resources used in this study were derived data tabled by Bergh & Gerhard in Scholtz *et al.* (1999) and are given Table 1.

Table 1 Phenotypic means of traits used in the simulation of performance attained by top-cross progenies of Angus or Charolais sires bred to Afrikaner, Bonsmara, or Nguni dams[a]

	Traits[b]										
Breed	CW, kg	MM, kg	FF, %	MF, %	SV, %	WW(d), Kg	DG_2, Kg/d	DF, D	FI, kg/d	DP, %	FD, Mm
Afrikaner	453	966	77	na	90	185	1.57	95	8.3	55	5
Bonsmara	493	1102	86	na	90	214	1.91	68	9.6	55	4
Nguni	364	825	87	na	90	155	1.45	107	7.5	55	6
Angus	na	na	na	80	75	215	2.10	56	10.3	55	4
Charolais	na	na	na	80	75	218	2.24	50	10.4	55	3
Heterosis[c], %	na	na	na	na	7	4	5	na	3	1	2

[a] after Bergh & Gerhard (1999)
[b] CW - cow weight; MM - total milk production; FF - female fertility; MF - male fertility; SV - calf survival; WW(d) - direct weaning weight; DG_2 - average daily gain during finishing period; DF - duration of finishing period; FI - daily feed intake during finishing period; DP - dressing percent; FD - fat depth
[c] Heterosis derived from MacNeil *et al.* (1988) and Marshall (1994)

Cow weights taken at calving and weaning were averaged to derive the value of cow weight (CW) used in this study. Weaning weight (W) was assumed to be affected by direct and maternal effects in the manner of an arbitrary base value (200 kg) multiplied by (1 + d + m), where d and m are proportional value for direct and maternal effects. Breed-specific values of d and m were derived by solving W = 200(1 + d + m) and D = 200(d – m) simultaneously, where D is the 1997 difference in direct and maternal EBV for weaning weight from the national genetic evaluation system as presented by Bergh & Gerhard (1999). Milk production of breed i was assumed proportional to m_i and based on milk production of Hereford (H) cows (1062 kg/lactation) from MacNeil & Mott (2000); Thus, for the i'th maternal breed $MM_i = 1062(1 + (m_i - m_H)/0.5)$. Therefore, the number of cows in production was:

$$N_{cows} = 1000 \cdot CFI(CW_i, MM_i)/CFI(454, 1000),$$

where, CFI represents a function of cow weight and milk production that yields annual feed required to sustain a cow given her body weight and milk production. For this study, CFI followed Anderson *et al.* (1983) and number of cows was subject to a resource constraint of 1000 stock units, with a stock unit defined as a cow weighing 454 kg and producing 1000 kg milk per lactation.

For each maternal breed, female fertility (FF) was related to its reported intercalving period (ICP) as: ICP = 365FF + 730(1 – FF) and thus cows were simulated to calve at least every other year. Owing to a lack of data, male fertility was assumed constant at 80%. Likewise, calf survival was assumed constant at 90% for the presumably adapted maternal breeds and 75% for the specialized sire breeds. This difference in survival under South African conditions is arbitrary and taken to reflect differences in adaptation between Bos taurus and Sanga cattle (Mason & Buvanendran, 1982; Blackburn *et al.*, 1998). However, Du Plessis *et al.* (2006) report an 11% advantage in calf survival for Bonsmara cross, Afrikaner, and Nguni herds over Simmentaler cross herds; a result that is approximately consistent with the differences in breed-specific survival assumed here. Thus, number of calves produced as a result of breeding the terminal sire to indigenous cows was:

$$N_{calves} = 0.5 \cdot N_{cows} \cdot MF \cdot FF \cdot SV$$

The feedlot phase of production was simulated in two phases. The first phase was a 28-d adaptation period when a ration of moderate energy density was fed. Average daily gain (DG_1) and feed intake during this phase were assumed similar to that attained in standardized (Phase C) bull tests. This was followed by a longer second phase during which a more energy dense ration was fed, with average daily gain (DG_2) increasing by 0.3 kg/d and feed conversion decreasing by 25% accordingly. Final weight (FW) was simulated as:

$$FW = WW + 28 \cdot DG_1 + DF \cdot DG_2,$$

where, DF represents the duration of the second phase, and is optimized for each breed combination (see below). Dressing percentage was assumed to be a constant 55% across all breeds. Parameter values for fat depth (FD, mm) were taken to be proportional to degree of maturity at 220 kg carcass weight and linearly adjusted (b = 0.037) for deviations in carcass weight from this value.

Phenotypes of individual animals were simulated at harvest. Initially, samples were drawn from a bivariate (r = 0.315) normal distribution for fat depth (SD = 0.46 mm) and carcass weight (SD = 13 kg). Samples from the bivariate normal distribution resulting in a predicted fat depth less than 0.01 mm were discarded. In setting up the base simulations for each breed combination, DF was optimized to minimize the number of animals that would have carcass weights less than 185 kg or greater than 245 kg and fat depths less than 1.0 mm or greater than 5.0 mm. This parameterization assumes animals were managed as a group rather than as individuals and resulted in simulations for each breed combination that minimized the number of animals in the group that were subject to discounts in price per kg carcass. Carcasses were valued relative to a base price of 12.6 R/kg (Germishuis, 2004) with price discrimination factors shown in Table 2. Thus, income (I) derived from each simulated calf was:

$$I = 0.55 \cdot FW(12.6 + D)$$

where, D represents the sum of any discounts appropriate to the animal given its simulated carcass weight and fat depth. Income was accumulated over the N_{calves} produced to derive total income (TI).

Costs of producing calves to weaning were assumed insensitive to sire selection and thus independent of genetic attributes of the Angus and Charolais sires. Costs for rations fed during the receiving and finishing phases were RC_1 = 0.93 and RC_2 = 0.80 R/kg, respectively. A yardage cost of 0.92 R/head/d was also incurred in the feedlot. Thus, total expense (TE) was simulated as:

$$TE = N_{calves} \cdot (0.92 \cdot (28 + DF) + 28 \cdot RC_1 \cdot FI_1 + DF \cdot RC_2 \cdot FI_2)$$

Table 2 Factors contributing to price discrimination (/kg) among beef carcasses

Base carcass price = R12.6				
Trait		Discounts (D)		
Carcass weight	< 185 kg = -2.1R		> 245 kg = -1.6R	
Fat thickness	< 1 mm = -0.6R	5 to 10 mm = -0.7R		> 10 mm = -1.2R

Finally, the partial budget that yielded simulated profit (P) derived from terminal sired calves was:

$$P = TI - TE$$

Relative economic values for survival, growth, feed intake, and carcass related traits were then calculated by approximating partial derivatives of simulated profit with respect to each of the traits.

A baseline economic analysis was conducted with breed characterizations given in Table 1. Then, in separate simulations, the phenotypes for each of the economically relevant traits was perturbed a single unit. The difference between simulated profit with a phenotype perturbed and profit in the baseline simulation was taken to be the relative economic value for that trait. Relative 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:

$$r_A = \mathbf{a_1'Qa_2} / \sqrt{(\mathbf{a_1'Qa_1})(\mathbf{a_2'Qa_2})} \text{ (James 1982a)}$$

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).

Table 3 Genetic variances (on diagonal), covariances (above diagonal) and correlations (below diagonal) among traits (ERT) in the breeding objective

ERT	SV	WW_d	ADG	FI	DP	FD
Calf survival (SV), %	5.38	-2.98	0.0089	0.0	0.0	0.0118
Direct weaning weight (WW_d), kg	-0.20	41.34	0.1761	0.949	1.042	0.0623
Finishing average daily gain (ADG), kg/d	-0.07	0.50	0.0030	0.0093	0.0033	0.0015
Postweaning daily feed intake (FI), kg/d	0.0	0.61	0.70	0.0586	0.0189	0.0011
Dressing percent (DP)	0.0	0.27	0.10	0.13	0.36	0.0046
Fat depth (FD), mm	0.10	0.19	0.53	0.09	0.15	0.0026

Results and Discussion

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. This approach conceptually allows feed resources to be carried over from a season when there is a surplus to a season when there is a deficit relative to the requirements of the cow-herd. However, it does not allow for importation of feed from outside the system. While it was not the goal of this research to contrast differences in the use of breed resources, it is useful to recognize production system level differences in considering the relative economic values. Differences in cow weight and milk production influence the scale of the enterprise, but are unaffected by the use of the specialized sire breed. Thus, progeny from 1007 Afrikaner, 919 Bonsmara, and 1242 Nguni cows were simulated and numbers of progeny sired by the specialized sire breed were 274, 279, and 382, respectively. Numbers of progeny sired by the specialized sire breeds accounted for breeding 50% of females to maternal breed bulls for generating replacement females as well as effects of male and female fertility and calf survival. Whether breeding 50% of females to terminal sires can be sustained depends on criteria used for culling cows and their survival rate in the system. However, if all females that failed to become pregnant annually were culled, then a terminal sire system may not be viable. Our perception is that this level of managerial intervention is not presently in place. Results from the baseline economic analysis of the feedlot phase are presented in Table 4. The general advantage in income minus feed cost of the Nguni dam breed, irrespective of sire breed, is approximately consistent with differences in herd efficiency reported by Du Plessis *et al.* (2006). However, the simulated difference between Afrikaner and Bosmara dam breeds in income minus feed cost was smaller than the corresponding difference in herd efficiency observed by Du Plessis *et al.* (2006).

Table 4 Enterprise level net return (income minus feed cost), days on feed, and number (N) of carcasses marketed at the base carcass price from baseline simulations using alternative breed resources as specialized sire and dam breeds

		Sire breeds	
Dam breeds	Item	Angus	Charolais
Afrikaner	Income minus feed cost	621645	631345
	Days on feed	104	98
	N of carcasses not discounted	269	271
Bonsmara	Income minus feed cost	661060	656665
	Days on feed	90	85
	N of carcasses not discounted	271	274
Nguni	Income minus feed cost	819666	826785
	Days on feed	110	104
	N of carcasses not discounted	359	354

Presented in Table 5 are relative economic values for Angus bulls used as specialized sire breed on Afrikaner, Bonsmara, and Nguni females. Corresponding results for Charolais are presented in Table 6. The relatively subtle differences among objectives result from phenotypic differences between breeds. We reiterate the comment of Du Toit *et al*. (1995) that better characterization of breeds for economically relevant traits would be of considerable value; not only to this research but also to appropriate breed use throughout South Africa. Genetic correlations among the six breeding objectives were all greater than 0.9. Thus, discussion herein is limited to generalities apparent across the breed combinations. This result also suggests breeders need not consider breed of dam in evaluating Angus or Charolais bulls to use in producing top-cross progenies for the feedlot market.

The breeding objectives presented in Tables 5 and 6 indicate genetic effects on calf survival may be important. This result arises in part from the greater variance of survival when the mean is relatively low as in the present study compared to when the mean is greater and variance less as may be the case with more intensive management systems. Mass selection for survival occurs naturally, particularly in harsh environments (Simm *et al.*, 1996). Purebred stud breeders may invoke management practices to mitigate environmental factors that are detrimental to calf survival. These practices thus reduce opportunity for natural selection to occur and also may offset response to imposed selection detrimental to improvements in survival. However, the consistent and substantial relative economic value for survival found here supports the contention of Scholtz *et al.* (1990b) that animal breeding for meat production should not be based on selection for growth rate or size alone. Genetic differences in expected survival of progeny appear to be an important consideration in selection of terminal sires. In developing terminal sire selection indexes for use in the United Kingdom, Amer *et al.* (1998) using calving difficulty as a composite trait which included effects on calf survival also found it to have a substantial relative economic value *vis a vis* the production traits considered.

Table 5 Economic values (R) for Angus sires to be bred to Afrikaner, Bonsmara and Nguni cows to produce market progeny, measures of variability for economically relevant traits and magnitude of the respective economic values relative to genetic variation

Dam Breed	Economically Relevant Trait	Relative economic value (R1)	R1 per cow joined	Relative magnitude	Emphasis, %
Afrikaner					
	Calf survival, %	5227.6	10.4	12128.	31.8
	Direct weaning weight, kg	2590.6	5.1	16647.	43.6
	Finishing average daily gain, kg/d	80695.0	160.3	4406.	11.6
	Postweaning daily feed intake, kg/d	-2020.8	-4.0	489.	1.3
	Dressing percent	7049.5	14.0	4258.	11.2
	Fat depth, mm	-1071.0	-2.1	172.	0.5
Bonsmara					
	Calf survival, %	1795.1	3.9	4165.	29.4
	Direct weaning weight, kg	619.1	1.3	3978.	28.1
	Finishing average daily gain, kg/d	34478.1	75.0	1883.	13.3
	Postweaning daily feed intake, kg/d	-2286.1	-5.0	553.	3.9
	Dressing percent	5815.1	12.7	3512.	24.8
	Fat depth, mm	-410.8	-0.9	66.	0.5
Nguni					
	Calf survival, %	4281.9	6.9	9934.	28.8
	Direct weaning weight, kg	1294.1	2.1	8316.	24.1
	Finishing average daily gain, kg/d	155032.2	249.6	8465.	24.6
	Postweaning daily feed intake, kg/d	-2706.4	-4.4	655.	1.9
	Dressing percent	11626.3	18.7	7022.	20.4
	Fat depth, mm	-530.0	-0.9	85.	0.2

Direct effects on weaning weight were likewise consistently important (Tables 5 and 6) as a result of the sizeable part-whole relationship between weaning weight and weight at harvest which is transformed into carcass weight when dressing percent is held constant. In general, genetic effects on postweaning growth rate and dressing percent were important, but slightly less so than either survival or weaning weight.

On a genetic basis, feed intake and fat depth appear to be of almost negligible importance in the South African situation. Other studies have found the relative importance of growth vs. carcass traits to vary from 1:1 to 2:1 (Barwick *et al.*, 1994; MacNeil *et al.*, 1994; Nitter *et al.*, 1994; Phocas *et al.*, 1998). Given this managerial prescription and independent of changes in growth rate, dressing percentage, etc., small changes in fat depth of top-cross progenies had little effect on profitability of the beef production enterprise. Low cost of feed and a feedlot phase of relatively short duration both contribute to the relatively minor importance of genetic effects on feed intake. In contrast, the relative economic value for feed intake is much more substantial in the U.S. where the feedlot phase is longer and feed more expensive (MacNeil, 2005a).

Table 6 Economic values (R) for Charolais sires to be bred to Afrikaner, Bonsmara and Nguni cows to produce market progeny, measures of variability for economically relevant traits and magnitude of the respective economic values relative to genetic variation

Dam Breed	Economically Relevant Trait	Relative economic value (R1)	R1 per cow joined	Relative magnitude	Emphasis, %
Afrikaner					
	Calf survival, %	5088.3	10.1	11805.	44.9
	Direct weaning weight, kg	992.0	2.0	6379.	24.2
	Finishing average daily gain, kg/d	72653.7	144.3	3996.	15.2
	Postweaning daily feed intake, kg/d	-453.9	-0.9	110.	0.4
	Dressing percent	6666.6	13.2	4027.	15.3
	Fat depth, mm	0.0	0.0	0.0	0.0
Bonsmara					
	Calf survival, %	2413.3	5.3	5599.	28.6
	Direct weaning weight, kg	1011.6	2.2	6505.	33.2
	Finishing average daily gain, kg/d	57119.4	124.3	3142.	16.0
	Postweaning daily feed intake, kg/d	-511.3	-1.1	123.	0.6
	Dressing percent	6965.2	15.2	4207.	21.5
	Fat depth, mm	-130.5	-0.3	21.	0.1
Nguni					
	Calf survival, %	3788.1	6.1	8788.	22.8
	Direct weaning weight, kg	1957.8	3.2	12589.	32.7
	Finishing average daily gain, kg/d	160196.2	258.0	8811.	22.9
	Postweaning daily feed intake, kg/d	-608.9	-1.0	147.	0.4
	Dressing percent	13515.8	21.8	8164.	21.2
	Fat depth, mm	-79.2	-0.1	13.	0.0

Specialized sire breed candidates for selection could be ranked using the sum of the products of the appropriate relative economic values derived here and the corresponding breeding values. When breeding values are not available for some economically important traits extension of the breeding objective to include genetic evaluations for indicator traits is straightforward, given appropriate estimates of genetic variances and covariances (Schneeberger *et al.*, 1992).

There has been a tendency to criticize breeding objectives developed from profit equations and empirical simulations because they fail to account for some complexities of the production system. These criticisms may be due to abstraction that is necessary to model the biological system and the dynamic nature of economic systems. However, James (1982b) argues the objective not be specified in too detailed a fashion and Bright (1991) suggested a simple profit equation may be sufficiently accurate in the short-term. Several authors (e.g., Phocas *et al.*, 1998; Ponzoni *et al.*, 1998; VanRaden, 2004) have suggested that breeding objectives be updated periodically in order to account for nonlinearity that was not modeled and changes in the assumed economic structure. However, Pearson (1982) presents a countervailing argument that economic values be changed infrequently, after substantial evidence for changing price relationships has accumulated. This latter line of reasoning has been supported by observations that efficiencies of indexes proposed for beef production are quite robust to changes in economic values for component traits (Amer *et al.*, 1998; Phocas *et al.*, 1998). This robustness is supported by the very high genetic correlations among breeding objectives across sire and dam breeds that were observed in this study. Thus, the indexes derived here are viewed as an appropriate step in the evolution of multi-trait selection to facilitate poverty alleviation among cattle producers in the emerging sector through wealth creation resulting from their production of calves for industrial feeding.

Management issues, both positive and negative, affect the rate at which technology is adopted. In this research, Angus and Charolais were chosen *a priori* as representatives of British and Continental breeds and as earlier and later maturing biological types, respectively. They were assumed to be less adapted to some South African production environments than indigenous breeds (Scholtz, 1988). This lack of adaptation may be mitigated by more intensive management of the bulls from the specialized sire breeds. In practice, the number of bulls from the specialized sire breed is small relative to the number of cows they may service and costs for the needed increase in their management should be substantially more than offset by the increased value of their progeny. If the Angus selected for use as the specialized sire breed are homozygous black, then both Angus and Charolais calves from Afrikaner, Bonsmara, and Nguni cows will be readily identifiable by their color patterns. This easy identification should facilitate use of specialized sire breeds and appropriate marketing of their calves to the feedlots. Unambiguous identification of the various progenies permits concurrent use of bulls from the specialized sire breeds with bulls of the indigenous breeds, or their replacing bulls of the indigenous breeds part way through the breeding season, in addition to sorting of females as is typically suggested (e.g., Kress & MacNeil, 1999; MacNeil, 2005b) for use of specialized sire and dam lines in beef cattle.

Conclusions

Breeding objectives were developed to facilitate appropriate selection of terminal sires for mating with indigenous cows to produce progeny for commercial feedlots. Results indicate all traits are not equally important to efficient selection decisions. The breeding objectives were relatively robust across the various breed combinations examined, suggesting that they need not be customized to each of the terminal sire production situations considered in this study.

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