Optimizing a beef production system using specialized sire and dam lines

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[1]*Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, Alberta Canada T6G 2P5;* [2]*College of Animal Science and Technology, Sichuan Agricultural University, Yaan 625014, China;* [3]*Beefbooster, Inc., Calgary, Alberta, Canada T1Y 5E4;* [4]*Alberta Agriculture and Rural Development, Lacombe Research Center, 6000 C and E Trail, Lacombe, Alberta, Canada T4L 1W1; and* [5]*United States Department of Agriculture, Agricultural Research Service, Miles City, Montana 59301, USA.* *Received 23 August 2010, accepted 4 April 2011.*

Tang, G., Stewart-Smith, J., Plastow, G., Moore, S., Basarab, J., MacNeil, M. D. and Wang, Z. 2011. **Optimizing a beef production system using specialized sire and dam lines**. Can. J. Anim. Sci. **91**: 353–361. Crossbreeding is an effective method for improving the efficiency of production in commercial cow-calf operations. It exploits available heterosis (hybrid vigour) and complementarity between different breeds or populations (lines). Before adopting a crossbreeding system, commercial cattle producers should evaluate available genetic resources and feasible crossbreeding systems, and choose one that is most beneficial for their own environment, resources, and management. This study compared profitability of alternative crossbreeding systems based on Beefbooster beef cattle breeding strains through computer simulation. Biological and economic data were collected from commercial customers of Beefbooster in Montana and western Canada, and breeding records from the database of Beefbooster, Inc. Three maternal strains (M1, M2 and M4) and two specialized paternal strains (M3 and TX), were evaluated with two simulated crossbreeding systems. System 1 uses a rotational cross between M1 and M4 with yearling crossbred heifers bred to M3 sires. System 2 is based on a three-strain rotation of M1, M2 and M4 with yearling crossbred heifers bred to M3 to facilitate ease of calving and crossbred cows bred to a classical terminal sire strain TX. Simulated base profit from system 2 was $29.57 greater (215.21 vs. 185.64 yr^{-1} per cow) than from system 1.

Key words: Beef cattle, breeding objective, crossbreeding, relative economic value

Tang, G., Stewart-Smith, J., Plastow, G., Moore, S., Basarab, J., MacNeil, M. D. et Wang, Z. 2011. **Optimisation d'un système de production du bœuf avec des lignées mâles et femelles spécialisées**. Can. J. Anim. Sci. **91**: 353–361. L'hybridation est une méthode efficace d'accroître la production dans les élevages commerciaux. En effet, elle mise sur l'hétérosis (vigueur hybride) et la complémentarité des races ou des populations (lignées). Avant de mettre en place un système d'hybridation, les éleveurs devraient néanmoins évaluer les ressources génétiques dont ils disposent et les systèmes réalisables, de manière à choisir celui qui s'avérera le plus profitable, compte tenu de l'environnement, des ressources et des méthodes de gestion. Les auteurs ont comparé la rentabilité de divers systèmes d'hybridation reposant sur les lignées de bovins de boucherie Beefbooster par simulation sur ordinateur. Les données biologiques et économiques ont été recueillies de clients commerciaux de Beefbooster du Montana et de l'ouest du Canada, et les registres d'hybridation, de la base de données de Beefbooster inc. Trois lignées maternelles (M1, M2 et M4) et deux paternelles (M3 et TX) spécialisées ont été évaluées dans le cadre de deux systèmes d'hybridation virtuels. Le premier recourait au croisement rotatif des lignées M1 et M4 avec accouplement des génisses hybrides d'un an avec des mâles M3; le second reposait sur la rotation des trois lignées M1, M2 et M4 avec accouplement de génisses hybrides d'un an avec des mâles M3 pour faciliter le vêlage, les vaches hybrides étant accouplées à la lignée terminale mâle classique TX. La rentabilité de base obtenue par simulation avec le deuxième système dépassait celle du premier de 29.57 $ (215.21 $ c. 185.64 $ par année et par vache).

Mots clés: Bovins de boucherie, hybridation

Crossbreeding systems are used in beef cattle production to take advantage of heterosis (non-additive effects) and to exploit breed differences for specific characteristics (additive effects) to improve performance and value of the progeny (Gregory and Cundiff 1980; Bennett 1987a Bennett 1987b Bennett 1987c). This approach allows breeders to more effectively match maternal biological type with their specific climatic and nutritive environment, and market requirements. Crossbreeding can also capitalize on potential differences in additive genetic merit for growth rate and carcass quality of specific terminal sire breeds.

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Abbreviations: **CW**, carcass weight; **QG**, quality grade; **YG**, yield grade

Strain development, by Beefbooster, Inc., was predicated on an envisioned production system using rotational crossing of three specialized maternal strains that generated replacement females to maintain herd size. Surplus females were to be bred to one of two specialized sire strains; one to minimize dystocia in first-calf heifers and the second to older females to optimize growth and carcass characteristics of progeny destined for harvest. This system was intended for use by commercial producers in western Canada and Montana in the United States. Recently, a simpler system, using two of the three maternal strains and the specialized sire strain for heifers, has come into vogue.

A well-organized breeding program requires a breeding objective, a method of evaluating selection candidates, a mating scheme, a way to validate the program design and a measurement of genetic improvement (MacNeil and Newman 1994). Defining a breeding objective is the first step in deriving a structured breeding program (Harris et al. 1984). A breeding objective represents each animal's genetic value for true economic merit. It is usually written as a linear function of breeding values of traits of economic importance weighted by their marginal economic values. Properly defining the breeding objective involves identification of which traits should be included and derivation of their respective economic values. Breeding objectives are customarily expressed in economic units and comparisons among animals reflect differences in genetic potential for profit.

Approximately 20 years ago, MacNeil et al. (1994) developed breeding objectives for the Beefbooster strains based on then current phenotypic characterizations and economic statistics. These objectives were put into place, in the form of phenotypic selection indexes (MacNeil and Newman 1994), and later revised for use with EPD based on phenotypic data submitted by Beefbooster breeders. However, neither the phenotypic characterization of Beefbooster strains nor the economic characterization of the production environment used for developing these selection tools has been updated since that time.

The objectives of this study were: (1) to assess the cost associated with the production system that was originally designed based on five strains to a simplified production system that made use of only three of the five strains by the breeders in their actual practices; and (2) to update relative economic values for the specialized sire and dam lines as envisioned by Beefbooster members and customers in their original design, while respecting their roles in a vertically integrated crossbreeding system using the most up to date biological and economic parameters.

MATERIALS AND METHODS

Crossbreeding Production System

Two available production systems were simulated based on the five Beefbooster strains.

System 1

The two-strain rotational cross of M1 and M4 formed the base production herd. Crossbred replacement females were produced from this rotation, and surplus steers and heifers were sold. Crossbred replacement heifers were bred to M3 bulls and all offspring were sold (Fig. 1). Breed and heterosis affected the expression of driving variables. Heterosis effects were adapted from MacNeil et al. (1994), and are presented in Table 1. All calves produced by multiparous females in the two-strain rotation had an assumed equilibrium breed composition of ½(M1 + M4). Calves from primiparous females sired by M3 bulls had an assumed breed composition of ½M3 + ¼(M1 + M4). Expression of strain-specific direct and maternal additive effects was assumed to be in proportion to the breed composition. Two-thirds of direct and maternal heterosis effects were assumed to be expressed by all individuals, except those calves sired by M3 bulls were assumed to express 100% of direct heterosis effects.

System 2

The three-strain rotation of M1, M2 and M4 generated the base cow herd. Replacement heifers were produced from this rotation, and surplus steers and heifers were marketed. Yearling replacement heifers were bred to M3 bulls, cows 2 through 4 years of age were bred in a three-breed rotation, and cows of 5 years of age and older were bred to TX bulls (Fig. 2). All M3- and TX-sired calves were sold. All calves produced in the three-strain rotation were assumed to have breed composition of 1/3 (M1 + M2 + M4). Calves from M3 (or TX) bulls had assumed breed composition of ½M3 (TX) + 1/6 (M1 + M2 + M4). Expression of strain-specific direct and maternal effects was proportional to breed composition of the individual and its dam, respectively. For those calves produced in the three-strain rotation, 86% of both individual direct and maternal heterosis effects were expressed. Complete (100%) expression of direct heterosis and 86% expression of maternal heterosis were hypothesised for calves sired by M3 or TX bulls (MacNeil and Newman 1994).

Biological Model Description

The data-driven empirical model used in this research was similar to the model described by MacNeil et al. (1994). As such, it is aggregated to the herd level (MacNeil and Harris 1988) and model inputs characterize herd-average levels of performance. A comparative static equilibrium analysis was conducted without discounting. Biological phenomena are mathematically described below with driving variables indicated in bold.

Feed intake by cow-calf (pre-weaning) =
$$3.834 \times \textbf{cow weight}^{0.75}\ (\text{kg}) + 0.3041 \times \text{milk production (kg)},$$

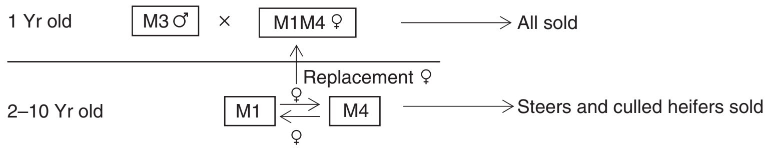

Fig. 1. Crossbreeding system 1.

$$\text{Milk production (kg)} = 1497 + 19.5 \times (\textbf{maternal effect}\ (\%) - 0.04),$$

as milk production is not measurable in beef cattle on a practical basis, the above regression equation (MacNeil, personal communication) was used to convert maternal effect, expressed as a percent of mean weaning weight to milk production. The maternal effect for weaning weight expressed as an EBV (kg) was rescaled to the percentage of mean weaning weight.

$$\text{Weaning weight} = \text{mean weaning weight (kg)} \times (1 + \textbf{direct effect}\ (\%) + \textbf{maternal effect}\ (\%))$$

where the direct (expressed on the calf) and maternal (expressed on the cow raising the calf) effects of weaning weight were rescaled to the percentage of mean weaning weight based on their EBV.

$$\text{Pregnancy rate} = \textbf{male fertility}\ (\%) \times \textbf{female fertility}\ (\%),$$

$$\text{Weaning rate} = \textbf{pregnancy rate}\ (\%) \times \textbf{calf survival to weaning}\ (\%)$$

where pregnancy rate was calculated by calves born per number of cows exposed to breeding; male and female fertility were calculated as the square root of pregnancy rate.

$$\text{Replacement rate} = \text{cow culling rate}$$

where culled cows included open, old and dead. Culling of cows was obligatory after they weaned their calf at 10 years of age. Involuntary death losses for cows were assumed to be equal across all age classes and a constant 0.9% of the cow herd. A population transition matrix approach (Leslie 1945; Searle 1966; Pang et al. 1999) was used to calculate the equilibrium age distribution.

At weaning, sexes were coded separately. The sex ratio was assumed to be 1:1. Replacement heifers were chosen to replace culled cows. Steers and surplus heifers were finished and harvested. Two types of finishing regimes are conducted in western Canada; calf-fed and yearling-fed. In the former, animals enter the feedlot in the fall as weaned calves at 6–7 mo of age and are fed a high forage, low grain starter ration for approximately 60–100 d prior to finishing on a high grain ration for 150–200 d. For simplification, in the present study a finishing diet is fed in both phases (J. Basarab, personal communication). In the latter regime, yearling-fed animals when weaned at the same time as the calf-fed animals and were backgrounded on lower cost growing

Table 1. Biological characterization of Beefbooster strains and heterosis for driving variables required to predict profitability

	Strain					
Trait	M1	M2	M4	M3	TX	Heterosis (%)
Cow weight (kg)	545	574	568	432	622	3
Male fertility (%)	93.82	94.64	94.16	94.83	94.75	10
Female fertility (%)	93.82	94.64	94.16	94.83	94.75	10
Calving difficultly	10	10	10	5	15	−10
Calf survival (%)[z]	96.57	97.14	97	93.4	92.45	7.5
Weaning weight direct effect (%)	−3.66	10.69	6.07	−12.46	2.82	5
Weaning weight maternal effect (%)	−0.25	0.57	0.22	−0.72	0.04	8
Backgrounding daily gain in grazing (kg d^{-1})	0.7	0.7	0.7	0.65	0.75	5
Backgrounding daily gain in feedlot (kg d^{-1})	1.02	1.02	1.02	0.9	1.08	5
Backgrounding feed conversion in grazing (kg feed DM kg^{-1} gain)	15.6	15.6	15.6	15.8	14.6	−2
Backgrounding feed conversion in feedlot (kg feed DM kg^{-1} gain)	9.5	9.5	9.5	9.8	8.6	−2
Finishing daily gain (kg d^{-1})	1.51	1.6	1.64	1.37	1.7	5
Finishing feed conversion (kg feed DM kg^{-1} gain)	10.1	10.5	10.3	11	9.5	0
Dressing percentage (%)	58	58	58	58	58	0
Carcass quality grade[y]	2.49	2.49	2.49	2.49	2.49	0
Carcass yield grade	1.49	1.49	1.49	1.49	1.49	0

[z]Calf survival means the ratio calves survived to weaning of calves born alive.
[y]Carcass quality and yield grade are defined based on the Canadian beef grading program (Canada Beef Export Federation, 2005). Here, for simulation, the carcass quality grade and yield grade are recoded based on Table 3 and the values in Table 1 are the mean values of the recoded values for all strains.

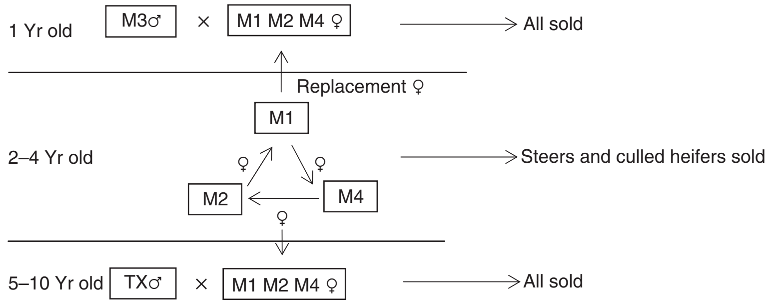

Fig. 2. Crossbreeding system 2.

rations in the feedlot for approximately 200 d, pastured for 90–120 d, and fed a feedlot finishing diet for 90–100 d. The approximate proportions of calf- and yearling-fed cattle in Alberta are 45 and 55%, respectively (Basarab et al. 2009). Calculations for the different components are presented below for steers with modification for heifers noted in brackets.

Gain during backgrounding (G1) = days during backgrounding × [0.95] **backgrounding daily gain** (kg d^{-1}),

Feed consumed during backgrounding = G1 × **feed conversion ratio during backgrounding** (kg feed DM kg^{-1} gain),

Gain on pasture (G2) = days on pasture × [0.95] **pasture daily gain** (kg d^{-1}),

Feed consumed during pasturing = G2 × **feed conversion ratio during pasturing** (kg feed DM kg^{-1} gain),

Gain during finishing (G3) = days during finishing × [0.95] **finishing daily gain** (kg d^{-1}),

Feed consumed during finishing = G3 × **feed conversion ratioduring finishing** (kg feed DM kg^{-1} gain),

Slaughter weight (calf fed) = weaning weight + G1 + G3,

Slaughter weight (yearling fed) = weaning weight + G1 + G2 + G3,

Carcass weight = slaughter weight × **dressing percentage** (%),

The previous biological model expressed profit through grouping terms by class of cattle (steers, heifers and cows) and calculated revenue and cost per cow per year (one production cycle). Table 1 lists the driving variables affecting revenues and costs in all production systems. Costs of production are shown in Table 2 and factors used in valuation of product are shown in Table 3. Profitability was calculated as:

Profit = total revenue − total cost.

For revenue:

Income from cull cows = number of cows × cowculling rate (%) × cow weight (kg) × cow price ($/cow).

Income from youthful (surplus progeny through a finishing system) cattle = number of cows × weaning rate (%) × (1 − death loss from weaning to finishing (%)) × carcass weight (kg) × carcass rail price ($ kg^{-1}).

Total income = income from cull cow + income from youthful cattle

where carcass rail price was generated by a random simulation in the following manner. Firstly, the carcass weight (CW), quality grade (QG) and yield grade (YG) were sampled from their corresponding normal distributions $N(m, \sigma^2)$ with mean m, and variance σ^2. Carcass weight, QG and YG were assumed uncorrelated. In this study, the mean of QG and YG is listed Table 1**,** and means of CW were calculated based on average weaning weight and dressing percentage of all five strains according to previous formula. The standard deviations for CW, QG and YG were assumed to be 22.3 (kg), 0.57 and 0.68 and the same across five strains (Nkrumah et al. 2007). The price for each individual was deter-

Table 2. Economic characterization of beef production in western Canada based on a survey of Beefbooster members

Costs	$
Cow feed cost ($ cow^{-1})	430.19
Non-feed cost ($ cow^{-1})	175.1
Fixed cost ($ cow^{-1})	59.27
Backgrounding feed price during grazing ($ kg^{-1})	0.02
Fixed cost during grazing backgrounding ($ head^{-1} d^{-1})	0.04
Backgrounding feed price prior finishing in feedlot ($ kg^{-1})	0.07
Fixed cost during feedlot backgrounding ($ head^{-1} d^{-1})	0.1
Finishing feed price ($ kg^{-1})	0.1
Fixed cost during finishing ($ head^{-1} d^{-1})	0.11

Table 3. Carcass price system in Alberta based on a survey from Canfax

Base price		\$159.33/cwt
Discounts		
Carcass weight <550 lbs		\$ −15.00
950 <carcass weight <1000		\$ −7.5
Carcass weight ≥1000		\$ −15.00
Quality grade	Code	\$/cwt
Prime	1	6.00
AAA	2	2.00
AA	3	−2.50
A	4	−13.00
Yield grade	Code	\$/cwt
YG 1	1	3.00
YG 2	2	0.00
YG 3	3	−10.00

mined based on its CW, QG and YG by a carcass price system (Table 3). A random sample of 10 000 was generated, and then an average carcass price was calculated. For expense:

Total cowcosts = number of cows× [(feed intake by cow (kg/cow)× cow feed price (\$/kg)) +non-feed cost + dystocia cost+ fixed cost]

where feed intake by cow includes cow feed intake prior to weaning including maintenance requirements and milk production of the cow. Feed intake of the calf prior to weaning was not considered.

Cost of backgrounding = number of cows× weaning rate (%)× [feed consumed during backgrounding (kg)× backgrounding feed price (\$ kg^{-1})+ days backgrounding × fixed costduring back grounding (\$ head^{-1} d^{-1}))].

For yearling fed:

Pasturing = yearling fed proportion (%)× [number of cows × (weaning rate (%)− replacement rate (%))]× [feed consumed during pasturing (kg)× pasturing feed price (\$/kg) + days pasturing× fixed costduring pasturing (\$/herd/day)]

Finishing = yearling fed proportion (%)× [number of cows×(weaning rate (%)− replacement rate (%))]×[feed consumed during finishing (kg)×finishing feed price (\$/kg)+ days finishing × fixed costduring finishing (\$/head/day)].

For calf fed:

Finishing = the calf fed proportion (%)× [number of cows×(weaning rate (%)− replacement rate (%))]×(feed consumed during finishing (kg)×finishing feed price (\$/kg)+ days finishing × fixed costduring finishing (\$ head^{-1} d^{-1})).

Biological and economic data used in the simulations were collected from members of the Beefbooster group breeding scheme in Montana and western Canada and from concurrent analyses of Canfax (www.canfax.ca) and Beefbooster survey data and production records. These survey results provide a baseline for analysis, and do not represent a basis for comparison among Beefbooster strains or of Beefbooster strains with other seedstock sources.

Dystocia cost was also generated by stochastic simulation. The calving difficultly score for each individual was sampled from a normal distribution $N(m, \sigma^2)$ where m is the average calving difficultly score (Table 1), and σ^2 is the variance. The standard deviation of calving difficultly score (16.8) was assumed to be the same across all five strains. The dystocia cost of each individual was determined by its calving difficultly score based on a calving difficultly scoring system (Table 4; J. Basarab, personal communication). A sample of size 10 000 was generated and an average dystocia cost was calculated.

Estimation and Standardization of Economic Values

Economic values for traits can be estimated by using two methods: partial differentiation of the profit model with respect to the trait of interest, and by partial budgeting (i.e., accounting for unit changes in marginal returns and costs arising from the improvement in the trait of interest; Rewe et al. 2006). In this paper, an approximate partial derivative was used to calculate economic values of all driving variables. The model was parameterized and a base profit calculated. Each driving variable was then perturbed upward 0.1 standard deviation in a separate simulation. The differences between profit observed in these latter simulations and the profit from the baseline simulation were the relative economic values for respective driving variables (MacNeil et al. 1994).

Table 4. Calving difficultly cost

Calving difficultly	Score	\$
Unassisted	0	0
Easy pull	3	10
Difficult/hard pull	60	350
C-section	100	500

Table 5. Genetic standard deviation and genetic correlation used in calculating genetic correlation between different crossbreeding systems

Trait	Genetic SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. cow weight (kg)	61.93	1																	
2. Male fertility (%)	12.37	0	1																
3. Femal fertility (%)	12.37	0	0.16	1															
4. Calving difficultly	10.2	−0.22	0	0	1														
5. Calf survival (%)	13.37	0	0	0	−0.81	1													
6. weaning weight direct (%)	17.08	0.65	0	0	−0.16	0	1												
7. weaning weight maternal (%)	5.42	−0.15	0	0	0	0	−0.3	1											
8. backgrounding daily gain using grazing (kg)	0.11	0.5	0	0	−0.33	0	0.38	0.09	1										
9. backgrounding daily gain using feedlot (kg)	0.11	0.6	0	0	−0.33	0	0.38	0.09	0.88	1									
10. backgrounding feed conversion using grazing (kg kg^{-1})	0.81	−0.14	0	0	0	0	0.15	0	−0.53	−0.53	1								
11. backgrounding feed conversion using feedlot (kg kg^{-1})	0.81	−0.14	0	0	0	0	0.15	0	−0.53	−0.53	0	1							
12. finishing daily gain (kg)	0.12	0.64	0	0	−0.33	0	0.38	0.09	0.61	0.71	−0.53	−0.53	1						
13. finishing feed conversion (kg kg^{-1})	0.81	−0.14	0	0	0	0	0.15	0	−0.53	−0.53	0	0	−0.53	1					
14. dressing percentage (%)	1.17	0	0	0	0	0	0.22	0	0.12	0.12	0.33	0.33	0.12	0.33	1				
15. carcass Quality Grade	0.36	0	0	0	0	0	0	0	0.32	0.32	0	0	0.32	0	0.26	1			
16. carcass yield Grade	0.55	0	0	0	0	0	0	0	0.41	0.41	−0.02	−0.02	0.41	−0.02	0.48	0.48	1		
17. percent A grade	0.25	0	0	0.21	0	0	−0.13	0	0	0	0	0	0	0	0.31	0.65	0.32	1	
18. cutability (%)	0.89	0.25	0	0	0	0	0.42	0	0.25	0.25	0	0	0.25	0	0	−0.45	−0.82	−0.75	1

Genetic correlations between breeding objectives were calculated as (James 1982; MacNeil 2005):

$$r_A = a_1^{'} G a_2 / \sqrt{(a_1^{'} G a_1)(a_2^{'} G a_2)}$$

where, a_1 and a_2 are vectors of relative economic values, and **G** is the genetic variance covariance matrix, as derived from information given in Table 5, among traits in the breeding objective.

RESULTS

In this simulation study, the biological model was parameterized, and the base profits for the two crossbreeding systems were calculated. The base profit of systems 1 and 2 were \$185.64 and \$215.21 yr^{-1} per cow, respectively. System 2 resulted in \$29.57 yr^{-1} per cow more profit than system 1, which represents the opportunity cost that producers incur by choosing to utilize the simpler breeding system. The opportunity cost must be offset by reductions in cost of production that were not included in these simulations for this choice of production system to be economically rational. For example, implementation of either crossbreeding system was considered to be free. However, natural mating system 2 requires more pastures for breeding with presumably greater cost for fencing, etc. Revenue and expense for the nucleus breeders producing seedstock males were ignored in this analysis because the number of seedstock males was very small relative to the number of females in the crossbreeding system. With equitable transfer of the benefits among the segments of the industry, incremental costs of seedstock production above commercial production should be compensated with premiums paid by the commercial sector for the seedstock (MacNeil et al. 1994). This is commonly referred to as value-based marketing (Harris and Newman 1994).

All feed inputs, including pasture, were purchased (or had opportunity costs). Changes in feed consumed were priced on a per-unit of energy basis relative to their base cost. This approach reflects the situation faced by individual producers in an environment when there are no economies to scale in prices for inputs and products (MacNeil et al. 1994). Standardized economic values are presented in Table 6 for the crossbreeding system 1, system 2 with current data and old system 2 with 1994 data (MacNeil et al. 1994). For the maternal strains of both systems, relative economic values of driving variables were identical due to the herd level of organization used, which assumed equilibrium genetic contribution for each strain in the rotational cross. The economic values of cow weight, calving difficultly, feed conversion ratio, carcass quality grade and carcass yield grade were negative, while the economic values for fertility, calf survival, direct and maternal effects on weaning weight, postweaning daily gains and dressing percentage were positive. For paternal strains, economic values were zero for cow weight, female fertility and weaning weight maternal (i.e., milk), because these phenotypes are not

Table 6. Relative economic values for Beefbooster strains under crossbreeding system 1^z with current data, system 2^y with current data and old system 2 with 1994 data (Macneil et al. 1994)

	Maternal strains			Paternal strains				
	System1 (M1 M4)	System2 (M1 M2 M4)	Old system 2 (M1 M2 M4)	System1 (M3)	System2 (M3)	Old system 2 (M3)	System2 (TX)	Old system 2 (TX)
Cow weight (kg)	−0.555	−0.370	−5.96	0	0	0	0	0
Male fertility (%)	5.455	1.521	10.07	1.326	1.365	8.8	6.623	31.67
Female fertility (%)	6.124	4.199	13.79	0	0	0	0	0
Calving difficultly	−0.135	−0.059	–	−0.019	0.005	–	−0.054	–
Calf survival (%)	6.083	3.037	10.42	0.715	0.735	6.48	3.582	14.83
Weaning weight direct effect (%)	3.196	1.631	2.08	0.472	0.528	2.08	2.131	3
Weaning weight maternal effect (%)	1.158	0.521	2.08	0	0	0	0	0
Backgrounding daily gain using grazing(kg)	0.502	0.176	–	0.086	0.250	–	0.316	–
Backgrounding daily gain using feedlot(kg)	0.567	0.543	0.11	0.061	0.194	0.11	−0.124	0.11
Backgrounding feed conversion using grazing (kg kg^{-1})	−0.031	−0.011	–	−0.002	−0.002	–	−0.011	–
Backgrounding feed conversion using feedlot (kg kg^{-1})	−0.344	−0.186	−0.04	−0.042	−0.043	−0.03	−0.203	−0.07
Finishing daily gain (kg)	0.864	0.550	1.03	0.152	0.630	0.6	0.514	1.46
Finishing feed conversion (kg kg^{-1})	−0.874	−0.421	−0.04	−0.118	−0.121	−0.03	−0.593	−0.07
Dressing percentage (%)	1.089	0.639	2.31	0.129	0.462	1.53	0.250	3.41
Carcass quality grade	−0.574	−0.445	–	−0.008	−0.201	–	−0.210	–
Carcass yield grade	−0.664	−0.325	–	−0.073	−0.228	–	−0.353	–
Percent A grade	–	–	3.32			2.21		5.03
Cutability (%)	–	–	3.14			2.18		4.79

^{z}Two-strain rotation of M1 and M4, yearling heifer bred to M3 based on current data.
^{y}Three-strain rotation of M1, M2 and M4, yearling heifer bred to M3, mature cow bred to TX.

expressed in the crossbreeding systems modeled in the present study. As in the old system 2, the economic importance of fitness traits (fertility and survival) was still, in aggregate, greatest, followed by direct effects on weaning weight, and then other carcass and growth traits in systems 1 and 2. The relative economic values of female fertility and male fertility were the highest in maternal strains and paternal strains, respectively. Due to fewer strain-specific expressions of the various traits, the relative economic values in system 2 were smaller than in system 1, and the economic values of TX were higher than M3.

Genetic correlations of breeding objectives between crossbreeding systems 1 and 2 are presented in Table 7. The average genetic correlation of the objectives for maternal strains (M1 and M4) in system 1 and in system 2 (M1, M2 and M4) was approximately 0.99. The average genetic correlation of the breeding objective for M3 strain in system 1 and the breeding objectives for paternal strains (M3 and TX) of system 2 approached 1.

To assess the need for updating the breeding objectives established in the early 1990s that potentially arose from changes in phenotypic characteristics of the Beef-Booster breeding stocks and economic characteristics of production environment, genetic correlations between old (MacNeil et al. 1994) and new breeding objectives (current production environment) based on crossbreeding system 2 were calculated. The genetic correlations between old and new objectives for M1, M2 and M4 were approximately 0.29 (Table 8). In contrast, the old and new breeding objectives for the two specialized sire strains (M3 and TX) were greater than 0.96 and 0.85, respectively (Table 8).

DISCUSSION

In this study, the simulated production system is similar, but not identical, to that studied by MacNeil et al. (1994). The latter calculated the relative economic values and selection indices for specialized sire and dam strains of Beefbooster based on specialized biological and economic parameters in western Canada in 1994 and prior years. However, in the past 10 yr, factors related to revenue and cost for beef cattle production have changed. The feed and non-feed cost ($430.19 and $175.1 per cow) for the cow-calf phase increased almost twice relative to their 1994 value ($216.35 and $68.39). In addition, the performance of beef cattle production has also improved in the Beefbooster populations as a result of long-term selection. Therefore, to incorporate the changes into the selection index for the current production system to meet the new situation, the breeding objective needed to be re-evaluated to reflect

Table 7. Genetic correlations of breeding objectives between crossbreeding system 1[z] and system 2[y]

		System 1	
Production system	Strain	M1 M4	M3
System2	M1 M2 M4	0.99	0.86
	M3	0.93	1.00
	TX	0.93	1.00

[z]Two-strain rotation of M1 and M4, yearling heifer bred to M3.
[y]Three-strain rotation of M1, M2 and M4, yearling heifer bred to M3, mature cow bred to TX.

Table 8. Genetic correlations of system 2[z] with current data and old system 2 with 1994 data (Macneil et al. 1994)

		Old system 2		
Production system	Strain	M1 M4	M3	TX
System2	M1 M2 M4	0.29	0.84	0.66
	M3	0.02	0.96	0.81
	TX	0.07	0.98	0.85

[z]Three-strain rotation of M1, M2 and M4, yearling heifer bred to M3, mature cow bred to TX.

the current production system and consumer demands, and the values of economically relevant traits needed to be re-assessed based on the most up to date biological and economic parameters available. Therefore, a new selection index should be constructed, which reflects the current market change in western Canada and Montana. Compared with the model described by MacNeil et al. (1994), three additional factors were considered in this study: (a) dystocia, (b) evolution to calf-fed and yearling-fed systems to reflect the current production situation in Alberta, and (c) carcass revenue was re-calculated based on the current pricing grid, with carcass quality and carcass yield grades considered simultaneously. These changes mean that the model better reflects the current real situation of beef production in western Canada. As with MacNeil et al. (1994), this model does not consider discounting of revenue and cost in the long term. The analysis of revenue and expense was based on 1 year, because it is simple and a consistently high correlation (>0.95) is found between breeding objectives with discount rates varying from 0 to 10% (Ponzoni and Newman 1989). Compared with the results of MacNeil et al. (1994), the relative economic values changed substantially. Despite these changes, old and new breeding objectives for the terminal strains were highly correlated (0.85–0.96) and old and new breeding objectives for the maternal strains were less correlated (approximately 0.29). The most important economic traits remain those for reproduction (Table 6), followed by carcass and growth traits. In this study, carcass quality grade was added to the biological model, and a random sampling method used to determine its economic value. The relative economic value of carcass quality grade was slightly lower than carcass yield grade. With the increase of importance for carcass quality, quality grade may become more important in the future as demand for marbled beef products increases, particularly in the United States. In this study, we have assumed that the carcass quality and yield grade are the same across lines as mentioned above. Ideally, it would be nice to have the carcass quality and yield grade parameters of these five different lines estimated from Beefbooster's actual data. Unfortunately, the carcass quality and yield grade data are unavailable; therefore, the average value of carcass quality grade and yield grade from the Canfax and literature were used in this study. Since the TX strain is a terminal strain, their carcass quality and yield parameters should be higher than the averages used in this study. Therefore, the real benefit to using the TX line in the system 2 breeding program is likely larger than is estimated here with the population as simulated.

As expected, system 2 was found to be more profitable than system 1 as it uses the three-strain rotation, which can utilize heterosis more effectively than the two-strain cross (86% vs. 67% expression of heterosis, respectively. In addition, system 2 used mature cows bred to TX, which leads to more yield advantage than system 1 because the TX line has faster growth ability and a better feed to gain ratio. It remains to be seen if the extra profit is enough to warrant implementation of system 2, as it also requires more management and capital resource inputs. As mentioned earlier, the producers are adopting the simpler breeding system (system 1), which is causing them to incur an opportunity cost. However, this opportunity cost must be offset by reduced cost of production for this choice of production system to be economically rational. However, for the existing Beefbooster seed stock breeding program, the paternal breeding strains of M2 and TX had already been in place for the past ten years. Therefore, crossbreeding system 2 should result in more profitable beef production and be a better choice for Beefbooster's commercial customers.

The breeding objectives for systems 1 and 2 were very similar, and there would be little merit in considering alternative objectives for the two breeding systems. Updating breeding objectives for the specialized maternal strains, while not markedly changing overall selection goals, appeared to have some merit. In contrast, old and new breeding objectives for the specialized paternal strains were remarkably similar and thus similar response to selection would be anticipated using either set of objectives for these strains.

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