Are there sacrifices in the chase for carcass merit?

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Introduction:

As the beef complex has become more consumer focused and more cattle are individually priced through various value-based marketing systems or grids, seed-stock and commercial producers have been motivated to place more selection pressure on carcass traits by downstream industry partners. A number of grid pricing systems exist that significantly reward cattle that grade in average Choice or better and meet other production specification for branded beef programs. Economic incentives and the publicity surrounding branded programs have raised industry awareness of the value of carcass merit. At least a portion of this motivation for selection to improve end-product quality and consistency comes from the National Beef Quality Audit (NCBA, 2000) which identified a variety of attributes that needed improvement to expand beef demand. Among the top ten challenges identified in the strategies portion on the audit were inappropriate carcass size and weight, inadequate tenderness, excess external fat cover, insufficient marbling and inappropriate USDA Quality Grade mix.

The above deficiencies were selected by the author as they each have a genetic component that may contribute to the problem. A wide range of carcass traits, or their live animal indicator traits measured via ultrasound, have been shown to be moderately to highly heritable (Shackleford et al., 1994; Dikeman et al., 2005; Minnick et al., 2004; Crews et al., 2003) and lowly to moderately correlated with production traits including cow body condition score, direct and maternal weaning weight (Eborn, 2007). Many breed association sponsored genetic evaluation systems now include routine production of Expected Progeny Differences (EPD) for carcass traits including: carcass weight, marbling, rib-eye area, 12th rib fat thickness and yield grade or percent retail cuts. Several breed organizations include either ultrasound based indicator traits of carcass merit which consist of scan weight, percent intramuscular fat, rib-eye area and 12th rib fat thickness or include this data in a multiple trait genetic evaluation. Seedstock producers are utilizing these EPD to change genetic merit of seedstock animals and their germplasm as evidenced by the genetic trends within breeds (Am. Angus Assn., 2007; Am. Simmental Assn., 2007).

Increased emphasis on phenotypic performance has motivated commercial producers to seek out animals with enhanced genetic merit for carcass traits. Seedstock producers have responded by implementing carcass testing programs, ultrasound data collection systems and the use of DNA markers to differentiate their products. Considerably more selection pressure is placed on carcass traits today, by a wider range of seedstock and commercial producers, than ever before. The increased selection pressure is justified to some extent by the increased relative economic importance of carcass traits for commercial producers that decide to retain ownership of their calves through harvest. Melton (1995) states than for an integrated production firm reproduction is twice as important as growth or carcass traits. So, as value differences in beef carcasses widen due to further market differentiation, it is sensible to investigate the changes in genetic merit of other economically important production traits due to correlated responses when selecting for carcass traits. The purpose of this work is to investigate the potential genetic and economic consequences of selection for increased carcass merit, particularly increased intramuscular fat or marbling.

Materials and Methods:

To simulate realistic changes in phenotypic marbling scores associated with varying percentages of cattle grading USDA Choice and higher, mean marbling scores were derived by finding the truncation points for right tail areas 50%, 60%, 70%, 80%, and 90% of a standard t distribution with mean equal zero and variance equal to one. Then the typical equation for computing critical values of t distributions;

$$t_{crit} = \frac{X - \overline{x}}{S_X}$$

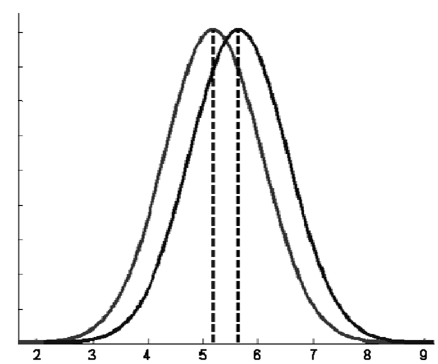
was solved for the mean, such that,

$$\overline{x} = X - S_X \cdot t_{crit}$$

Where, $\overline{x}$ = mean pen marbling score, S_X = marbling phenotypic standard deviation (0.7744), t_{crit} is the truncation point for the specified right tail area, and X is 5.00, the minimum marbling score required to grade USDA Choice. The solutions for the required average marbling score pens to grade varying levels of percent USDA Choice and higher are reported in Table 1.

The resulting average marbling scores were deviated from 5.0 (the minimum marbling score required to grade USDA Choice equivalent to Small 00) to determine the increase in average marbling score required to move from a 50% USDA choice and higher to 60%, 70%, 80%, and 90% USDA Choice and higher. These phenotypic deviations were divided by the marbling genetic standard deviation of 0.5196 (h^2 = 0.35) to compute the number of genetic standard deviations required to move the pen to the various levels of percentage of cattle grading USDA Choice or higher. Then incremental requirements were computed to determine the genetic improvement required at each 10% increase in percentage of cattle grading Choice or higher from 50-90% Choice. These results are presented in Table 2. Figure 1. illustrates the shift in the distribution of phenotypic pen average marbling score as the percentage of choice cattle in a pen increases from 60% to 80%.

Figure 1. Simulated differences in mean marbling score for pen of cattle grading 60% USDA Choice and higher (left most) with mean marbling score = 5.196, and a pen of cattle grading 80% Choice and higher (right most) with mean marbling score = 5.652.



Genetic variances and covariances for a variety of beef production traits used to construct selection indexes were obtained (W. Shafer, personal communication). The genetic variances and covariances were for traits included in either the breeding objective or selection criteria of the all-purpose selection index (API) computed for the American Simmental Association and constructed by Dr. Mike MacNeil, USDA-ARS-LARRL. The API index is used to describe economic differences due to genetic merit in a production system that sells calves at harvest on a grid pricing system and keeps replacement females from the herd. The genetic covariances between traits in the breeding objective and selection criteria are reported in Table 3. The genetic (co)variances between traits in the selection criteria are reported in Table 4. A description of each trait is provided in Table 5. Additive genetic correlations between traits in the breeding objective and selection criteria and among traits in selection criteria are reported in Table 6 and 7, respectively.

Two sets of genetic multiple regressions were computed. One set of regression coefficients were computed for the regression of traits in the breeding objective on those in the selection criteria. The other regression was among traits in the selection criteria. All regressions took the form of b_{YX} = (cov(X,Y)/var(X). Coefficients for the regression of traits in breeding objective on those in the selection criteria are reported in Table 8, while coefficients for regressions among traits in selection criteria are in Table 9.

Predicted responses for traits in the selection criteria and breeding objective were computed for perturbed values of marbling associated with the proportional increases in marbling score for each level of percentage of cattle grading USDA Choice or better computed earlier.

The predicted values of the traits in the breeding objective were weighted by breeding objective economic value weightings for the API indexes produced in 2006 and 2007 by MacNeil (Shafer, personal communication). Likewise, the predicted selection criteria values were weighted by the selection index economic weights for the 2006 and 2007 API. Note that only the 2006 index values have been implemented by the American Simmental Association. The 2007 values represent a new simulation model with added stochastic elements for several trait complexes including BWT-CE(d)-SURV and carcass traits and evaluates the revenues and costs of a sires daughter during her productive life, discounting revenues and costs to the point in time when a replacement females is selected. Relative economic values in the 2006 API place considerably more emphasis on STAY, FERT, SURV and CE(d) and CE(m) than does the 2007 API which places considerably more weight on growth and carcass traits that other traits in objective.

Results and Discussion:

Predicted genetic responses for correlated traits in breeding objective to selection for marbling are reported in Table 10, while predictions for traits in selection criteria are reported in Table 11. In each case Marbling predictions are percentage increases above a base of 5.0 (Small 00) and relate to the 50-90% USDA Choice and higher pen averages. In general, the changes the correlated traits in the breeding objective and selection criteria were small in magnitude. When moving pen percent USDA Choice and higher from 50-90%, MWT decreased by nearly 7 pounds, WW(m) was nearly unchanged, marginal improvements in FERT and SURV. ADG, FI, and DP increased numerically. For traits in selection criteria, response in correlated to traits to selection for MRB reveals a 1 unit decrease in STAY, a small increase in CE(d) and small decrease in CE(m) and WW(d). WW(m) increased approximately one pound while YW increased 5 pounds. YG was only marginal increased.

These predicted responses to selection for marbling are not equivalent to the traditional computation of correlated response to selection as they have not been scaled by either accuracy of prediction, selection intensity or generation interval. The computations assume the accuracy of prediction of 1.0 and that the genetic differences are fully expressed in phenotypes.

Once the predicted genetic changes were weighted for their economic contributions to profit using either the economic values for the 2006 or 2007 API changes in Net Merit (measured in dollars) due to increases in marbling were computed and are reported in Tables 12 and 13. Under the 2006 API index, the 40% increase in % USDA Choice and higher resulted in a nearly $5.00 change in Net Merit while using the 2007 API revealed a $43.70 increase per progeny. The changes in Net Merit using traits in the selection criteria and weighted by economic weights used in either the 2006 or 2007 API were ($ 3.05) and $ 31.29, respectively. Value changes between the weighting of traits in breeding objective and selection criteria are expected as not all traits in selection criteria are in breeding objective and vice-versa. Economic weights for the selection criteria, which include some traits in breeding objective and some indicator traits, are the regressed contributions to profit for correlated traits in the breeding objective.

The changes in Net Merit observed here reveals that there are typically only small changes in correlated traits even when significant selection pressure is applied to MRB. The small changes in Net Merit and underlying expression of traits in the breeding objective and selection criteria are a result of the small additive genetic correlations between marbling and the other traits ($-0.20 \leq r \leq 0.20$). Minimal changes in correlated traits should be expected when placing heavy selection pressure on marbling. Any potential genetic antagonism should be countered by inclusion of those traits in the breeding objective or selection decisions. Effective multiple trait selection including marbling and other economically important traits should result in improvement Net Merit.

It appears that little negative impact, and in fact, some positive results in additive genetic merit and resulting phenotypic performance can be achieved through selection for significant increases in MARB. However, these additive genetic gains must be weighed against potential compromises in non-additive genetic merit. In many instances improvements in MARB are achieved through selection of subsequent generations of animals of high merit from within a single breed making use of the breed's superiority. For instance, one might harvest the core strengths of the Angus or Red Angus breeds for MARB by increasing the percentage of one of those breeds in progeny. This process is likely to increase average genetic merit for MARB, but will reduce heterosis or hybrid vigor. Even though heterosis has little impact on MARB it has large positive effects on lowly heritable, but economically important, traits such as cow longevity, reproductive rate, and productivity (Cundiff and Gregory, 1999; Gregory and Cundiff, 1980). Decreases in economic performance due to reduced heterosis must be rationalized against improvements in additive merit. These potential adverse conditions may be partially mitigated through the effective use of a well designed, structured crossbreeding system that optimizes breed complementarity and heterosis to produce cows best suited for their production environment and market targeted progeny

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Table 1. Percentage of cattle grading USDA Choice or higher quality grade, t distribution truncation point and required pen average marbling score for pen to achieve state percentage USDA Choice and higher quality grade.

% Choice and Higher	Truncation Point	Pen Average Marbling Score[1]
50	0.000	5.000
60	-0.253	5.196
70	-0.524	5.406
80	-0.842	5.652
90	-1.282	5.992

[1]4.00 = Slight 00, 5.00 = Small 00 degrees of marbling

Table 2. Percentage of cattle grading USDA Choice and higher, the required pen average marbling score to achieve stated percentage of choice and higher, the needed increase in genetic merit to achieve percentage choice and higher from a base of 5.00 (50% Choice and higher), the number of genetic standard deviations required to reach each grade level from a base of 50%, the incremental genetic standard deviations required to move from one grade percentage level to next, and the incremental genetic merit increase needed between grade percentage levels.

% Choice and Higher	Pen Average Marbling Score	Needed Increase in Genetic Merit	Genetic Std Dev Required to Achieve Increase	Incremental Genetic Std Dev	Incremental Genetic Merit
50	5.000	--	--	--	
60	5.196	0.196	0.378	0.378	0.196
70	5.406	0.406	0.782	0.404	0.210
80	5.652	0.652	1.254	0.473	0.246
90	5.992	0.992	1.910	0.656	0.341

Table 3. Genetic covariances between traits in the API breeding objective and selection criteria.

	MWT	WW(m)	FERT	SURV	WW(d)	ADG	FI	DP	YG	MRB
STAY	-278.500	-22.100	290.170	53.700	0.000	0.000	0.000	0.000	-0.550	-1.470
BWT	290.800	-21.532	-12.400	-22.968	96.549	0.325	3.275	-0.864	-0.118	0.000
CE(d)	-245.788	-55.508	64.000	88.814	-76.192	-0.524	-1.299	0.000	-0.305	0.405
CE(m)	248.939	-18.740	129.700	77.959	128.615	0.531	1.316	0.000	-0.309	-0.410
WW(d)	1667.298	-247.162	0.000	0.000	1060.200	2.789	18.166	6.816	-2.547	-2.538
WW(m)	-186.870	562.700	-48.700	0.000	-247.162	-0.080	1.975	0.000	0.000	1.233
YW	2648.385	-257.644	0.000	0.000	1498.807	7.296	33.593	8.859	-5.058	-5.380
YG	-7.704	0.000	-0.800	0.000	-2.547	-0.007	-0.080	0.037	0.153	0.041
MRB	-10.241	1.230	-2.130	0.000	-2.537	0.009	0.043	0.079	0.041	0.270

Table 4. Genetic variances and covariances among traits in the API selection criteria.

	STAY	BWT	CE(d)	CE(m)	WW(d)	WW(m)	YW	YG	MRB
STAY	200.000	-8.600	44.100	89.400	0.000	-22.100	0.000	-0.550	-1.470
BWT	-8.600	36.620	-38.705	13.386	96.549	-21.532	147.102	-0.118	0.000
CE(d)	44.100	-38.705	243.360	86.268	-76.192	-55.508	-80.684	-0.305	0.406
CE(m)	89.400	13.386	86.268	249.640	128.615	-18.740	245.155	-0.309	-0.411
WW(d)	0.000	96.549	-76.192	128.615	1060.200	-247.162	1498.807	-2.547	-2.537
WW(m)	-22.100	-21.532	-55.508	-18.740	-247.162	562.700	-257.644	0.000	1.233
YW	0.000	147.102	-80.684	245.155	1498.807	-257.644	2675.000	-5.058	-5.375
YG	-0.550	-0.118	-0.305	-0.309	-2.547	0.000	-5.058	0.153	0.041
MRB	-1.470	0.000	0.406	-0.411	-2.537	1.233	-5.375	0.041	0.270

Table 5. Description of trait abbreviations listed in Table 1 and 2.

Trait	Description
ADG	Average Daily Gain
BWT	Birth Weight
CE(d)	Calving Ease - Direct
CE(m)	Calving Ease - Maternal
DP	Dressing Percentage
FERT	Fertility
FI	Feed Intake
MRB	Marbling Score
MWT	Mature Cow Weight
STAY	Stayability
SURV	Survival at Birth
WW(d)	Weaning Weight - Direct
WW(m)	Weaning Weight - Maternal
YG	Yield Grade
YW	Yearling Weight

Table 6. Additive genetic correlations between traits in API breeding objective and selection criteria.

	MWT	WW(m)	FERT	SURV	WW(d)	ADG	FI	DP	YG	MRB
STAY	-0.25	-0.10	1.00	0.50	0.00	0.00	0.00	0.00	-0.10	-0.20
BWT	0.61	-0.15	-0.10	-0.50	0.49	0.32	0.65	-0.15	-0.05	0.00
CE(d)	-0.20	-0.15	0.20	0.75	-0.15	-0.20	-0.10	0.00	-0.05	0.05
CE(m)	0.20	-0.05	0.40	0.65	0.25	0.20	0.10	0.00	-0.05	-0.05
WW(d)	0.65	-0.32	0.00	0.00	1.00	0.51	0.67	0.22	-0.20	-0.15
WW(m)	-0.10	1.00	-0.10	0.00	-0.30	-0.02	0.10	0.00	0.00	0.10
YW	0.65	-0.21	0.00	0.00	0.90	0.84	0.78	0.18	-0.25	-0.20
YG	-0.25	0.00	-0.15	0.00	-0.20	-0.10	-0.25	0.10	1.00	0.20
MRB	-0.25	0.10	-0.20	0.00	-0.15	0.10	0.10	0.16	0.20	1.00

Table 7. Additive genetic correlations between traits in API selection criteria.

	STAY	BWT	CE(d)	CE(m)	WW(d)	WW(m)	YW	YG	MRB
STAY	1	-0.10	0.20	0.40	0.00	-0.10	0.00	-0.10	-0.20
BWT		1	-0.41	0.14	0.50	-0.15	0.47	-0.05	0.00
CE(d)			1	0.35	-0.15	-0.15	-0.10	-0.05	0.05
CE(m)				1	0.25	-0.05	0.30	-0.05	-0.05
WW(d)					1	-0.32	0.89	-0.20	-0.15
WW(m)						1	-0.21	0.00	0.10
YW							1	-0.25	-0.20
YG								1	0.20
MRB									1

Table 8. Coefficients for genetic regression of traits in API breeding objective on traits in API selection criteria.

	MWT	WW(m)	FERT	SURV	WW(d)	ADG	FI	DP	YG	MRB
STAY	-1.834500	-0.000099	1.446400	0.115030	0.000000	0.001494	0.012278	0.003941	0.000000	-0.000003
BWT	5.047000	0.000157	-0.022796	-0.570340	0.000000	-0.004221	0.075473	-0.063634	0.000000	-0.000005
CE(d)	0.281410	0.000066	-0.019023	0.205890	0.000000	-0.003102	0.017828	-0.005205	0.000000	-0.000009
CE(m)	0.689730	0.000016	0.009746	0.214260	0.000000	-0.000229	-0.020278	-0.002998	0.000000	0.000011
WW(d)	0.837910	0.000039	-0.018564	0.087902	1.000000	-0.006643	-0.000846	0.011349	0.000000	0.000008
WW(m)	0.332320	1.000000	-0.037740	0.036363	0.000000	-0.000591	0.012739	0.002234	0.000000	-0.000001
YW	0.103680	-0.000048	0.006538	-0.024068	0.000000	0.006856	0.013061	0.002258	0.000000	-0.000008
YG	-24.294000	0.002428	-0.208800	1.317300	0.000000	0.037554	-0.110130	0.346510	1.000000	-0.000120
MRB	-35.183000	-0.012830	0.188900	0.623540	0.000000	0.115850	0.380140	0.406700	0.000000	0.999960

Table 9. Coefficients for genetic regression among traits in API selection criteria.

	STAY	BWT	CE(d)	CE(m)	WW(d)	WW(m)	YW	YG	MRB
STAY	1	-0.234840	0.181210	0.358120	0.000000	-0.039275	0.000000	-3.594800	-5.444400
BWT		1	-0.159040	0.053621	0.091067	-0.038266	0.054991	-0.771240	0.000000
CE(d)			1	0.345570	-0.071866	-0.098646	-0.030162	-1.993500	1.503700
CE(m)				1	0.121310	-0.033304	0.091647	-2.019600	-1.522200
WW(d)					1	-0.439240	0.560300	-16.647000	-9.396300
WW(m)						1	-0.096316	0.000000	4.566700
YW							1	-33.059000	-19.907000
YG								1	0.151850
MRB									1

Table 10. Predicted genetic response via multiple genetic regression for traits included in API breeding objective when marbling genetic merit is increased through selection.

MWT	WW(m)	FERT	SURV	WW(d)	ADG	FI	DP	YG	MRB
-54.019	0.990	1.345	2.006	1.000	0.147	0.380	0.701	1.000	1.000
-55.398	0.989	1.352	2.030	1.000	0.152	0.395	0.717	1.000	1.039
-56.876	0.989	1.360	2.057	1.000	0.156	0.411	0.734	1.000	1.081
-58.603	0.988	1.369	2.087	1.000	0.162	0.430	0.754	1.000	1.130
-61.003	0.987	1.382	2.130	1.000	0.170	0.456	0.782	1.000	1.198

Table 11. Predicted genetic response via multiple genetic regression for traits included in API selection criteria when marbling genetic merit is increased through selection.

STAY	BWT	CE(d)	CE(m)	WW(d)	WW(m)	YW	YG	MRB
-7.774	0.231	0.655	-2.362	-24.922	5.470	-51.966	1.152	1.000
-7.987	0.231	0.714	-2.422	-25.291	5.649	-52.747	1.158	1.039
-8.216	0.231	0.777	-2.486	-25.685	5.841	-53.583	1.164	1.081
-8.483	0.231	0.851	-2.561	-26.147	6.065	-54.560	1.172	1.130
-8.855	0.231	0.954	-2.664	-26.787	6.377	-55.918	1.182	1.199

Table 12. Changes in Net Merit ($) for traits in API breeding objective associated with increases in marbling score to achieve varying levels of cattle grading % Choice and higher when two different selection indexes are considered.

% Choice and Higher	Increase in Marbling Level	Change in Net Merit API 2006	Change in Net Merit API 2007
50	0.000	$ -	$ -
60	0.196	$ 0.98	$ 8.63
70	0.406	$ 1.05	$ 9.25
80	0.652	$ 1.23	$ 10.81
90	0.992	$ 1.71	$ 15.01
40	0.992	$ 4.98	$ 43.70

Table 13. Changes in Net Merit ($) for traits in API selection criteria associated with increases in marbling score to achieve varying levels of cattle grading % Choice and higher when two different selection indexes are considered.

% Choice and Higher	Increase in Marbling Level	Change in Net Merit API 2006	Change in Net Merit API 2007
50	0.000	$ -	$ -
60	0.196	$ (0.60)	$ 6.18
70	0.406	$ (0.65)	$ 6.62
80	0.652	$ (0.75)	$ 7.74
90	0.992	$ (1.05)	$ 10.75
40	0.992	$ (3.05)	$ 31.29