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GENETIC SELECTION FOR EFFICIENCY

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Introduction

Efficiency has become a buzz word, often with many different interpretations. In simple terms, there is both biological efficiency and economic efficiency. Although these two broad categories are related, they are not the same. Indeed, the beef industry needs to focus more attention on selection for efficiency, but the "how" is often debated. The intent of this summary is to simply identify methods and tools by which producers could use breeding systems and genetics to improve overall production efficiency.

Breed Utilization

There is little scientific literature that clearly characterizes breed differences for feed intake and gain during feed intake test periods. One of the largest, and certainly the most recent, comes from data collected at the U.S. Meat Animal Research Center (USMARC) as part of their Germplasm Evaluation (GPE) project. Table 1 shows breed differences in average daily feed intake and average daily gain while on test as reported by Retallick et al. (2017). Interestingly, Retallick et al. (2017) also compared breeds based on a restricted (feed intake is not expected to increase when selection pressure is applied to gain while on test) and unrestricted index for feed efficiency. Beefmaster and Limousin were the most efficient compared to all other breeds based on the unrestricted index using steer data (significant breed differences at $P<0.05$).

Table 1. Breed Differences in grams (SE) of on-test average daily feed intake (ADFI) and on-test average daily gain (ADG) of steers and heifers relative to Angus[1]

Breed	Steer ADFI	Steer ADG	Heifer ADFI	Heifer ADG
Angus	0	0	0	0
Hereford	-788 (286)*	-35 (45)	-962 (266)*	-21 (44)
Red Angus	-310 (275)	-66 (52)	-684 (255)*	-86 (42)*
Shorthorn	-997 (320)*	-100 (61)	-1,021 (298)*	-98 (49)*
South Devon	-1,856 (666)	-274 (134)*	-1,576 (641)*	13 (109)
Beefmaster	-771 (346)*	72 (68)	-1,556 (641)*	-91 (56)
Brahman	-1,321 (350)*	-124 (68)	-1,351(319)*	-185 (53)*
Brangus	-173 (335)	-31 (65)	-585 (317)	-120 (53)*
Santa Gertrudis	-569 (334)	22 (63)	-1,039 (306)*	-113 (50)*
Braunvieh	-1,488 (351)*	-180 (68)*	-1,841 (305)*	-299 (50)*
Charolais	-521 (289)	-18 (55)	-876 (270)*	-75 (45)
Chiangus	-1,245 (334)*	-81 (64)	-1,049 (296)*	-118 (49)*
Gelbvieh	-1,051 (278)*	-72 (53)	-723 (253)*	-114 (42)*
Limousin	-1,238 (281)*	-5 (53)	-1,471 (255)*	-160 (42)*
Maine Anjou	-1,646 (334)*	-150 (64)*	-1,101 (302)*	-102 (50)*
Salers	-1,211 (333)*	-136 (63)*	-1,176 (306)*	-139 (51)*
Simmental	-43 (288)	-19 (55)	-530 (275)	-68 (45)
Tarentaise	-1,178 (678)	-150 (136)	-1,926 (566)*	-312 (96)*

[1] Significant breed differences ($P<0.05$) indicated by "*"

Within Breed Selection

Efficiency metrics, and indicators of efficiency, are indeed heritable and would respond favorably to selection (Table 2).

Table 2. Heritabilities (diagonal) and genetic correlations (off-diagonal) for feed efficiency traits[1]

	ADG	DMI	RFI	G:F
ADG	0.26	0.56	-0.15	0.31
DMI		0.40	0.66	-0.60
RFI			0.52	-0.92
G:F				0.27

[1]Adapted from Rolfe et al. (2011).

In addition to growth and dry matter intake EPD, some EPD do currently exist to select for partial efficiency. Examples of those are detailed below.

	Bull A	Bull B
Residual average daily gain	-0.1	0.05
Residual feed intake	-0.3	0.0
Maintenance energy	0	10

Residual average daily gain (Angus)- Calves sired by bull B should gain 0.15 pounds per day more when fed the same amount of feed during the post weaning phase.

Residual feed intake (Gelbvieh)- Calves sired by bull A would consume 0.3 lbs of feed per day less on average than calves sired by bull B to gain the same amount of weight.

Maintenance energy (Red Angus)- Daughters from bull B should require 10 Mcal/month less energy for maintenance. If average hay quality is 0.86 Mcal/lb. this equates to 11 lb. less forage per month.

Even though some EPD do exist for components of efficiency, feed intake phenotypes are expensive to collect and thus for the foreseeable future, wide-spread collection of individual intake data in the seedstock sector will remain sparse at best. Moreover, residual gain and residual feed intake are not phenotypes per se, but rather restricted selection indices. Although these residuals are biologically intriguing, they are suboptimal at generating response to overall profitability given that they only allow for improvement in either gain or feed intake and not both traits simultaneously.

Selection Methods for Efficiency

In terms of guidelines for the U.S. beef industry to follow relative to genetic selection for improved feed efficiency, Nielsen et al. (2013) recommend an index-based approach. From a total life-cycle perspective, maintenance energy costs are estimated to be about 70% of the total energy intake in the beef production system. Thus, a primary goal must be to decrease maintenance energy requirements while not reducing output. This means that profitable selection decisions must contemplate multiple traits simultaneously. Using selection index values will be very beneficial to achieve the overall goal of improved profitability. If constructed correctly, multiple-trait index tools can account for antagonisms that may exist between feed intake and other economically relevant traits, including cow-herd centric traits.

Rolfe et al. (2011) estimated selection response for three feed efficiency related phenotypes and four different selection indices (Table 3). From these results, it is clear that an economic index approach to selection is the most desirable.

Table 3. Expected response (selection intensity*lbs) to selection[1]

Selection Criterion[2]	Direction	DMI Response, lbs.	Gain Response, lbs.
DMI	Down	-125.0	-11.91
GAIN	Up	+57.98	+16.54
G:F	Up	-60.63	+5.29
I_1	Down	-98.33	+4.19
I_2	Down	-84.88	0
I_3	Down	-27.34	+11.91
I_4	Down	0	+16.98

[1] Adapted from Rolfe et al. (2011).

[2] DMI= Dry matter intake; GAIN = Weight gain; G:F = Gain to feed ratio; I_1 = Phenotypic RFI; I_2 = Genetic RFI; I_3= Economic index including DMI and Gain; I_4=Economic index including Gain and RFI.

Although Rolfe et al. (2011) illustrated that an economic index based approach was superior to single trait selection when considering both feed intake and gain, a more comprehensive approach is to consider feed intake as a cost in existing economic selection indices such as Angus's $B or Simmental's TI, therefore considering traits such as carcass merit, feed intake, carcass weight, survival, and other traits as dictated by the complete breeding objective.

The importance of feed intake in a terminal index is well documented. In example, Ochsner et al. (2017a) assumed a terminal breeding objective for Beefmaster cattle whereby all calves were born from mature cows, retained through the feedlot phase and sold on a grid-based system. The five objective traits considered for the terminal index included hot carcass weight (HCW), marbling score (MS), ribeye area (REA), 12^{th}-rib fat (FAT) and feed intake (FI), with the latter representing the only expense related phenotype among the objective traits. Relative economic values for the terminal objective traits HCW, MS, ribeye area REA, FAT, and FI were 91.29, 17.01, 8.38, -7.07, and -29.66, respectively.

Economic indices are the preferred tool for multiple trait selection. A bio-economic index is simply a collection of EPDs that are relevant to a particular breeding objective, whereby each EPD is multiplied by an associated economic weight. Consequently, a high index value does not necessarily mean that an animal excels in all EPD categories given that superiority in trait can compensate for inferiority in other traits depending on how the EPDs are weighted in the index. A high index value should be thought of as excelling in the ability to meet a breeding objective and ultimately net profit. It is important to note, however, that before proper use of an index can be ensured, a breeding objective must be clearly identified. For example, the use of an index such as the American Angus Association's Dollar Beef ($B) in an enterprise that retains replacement heifers can lead to adverse effects, given that sire selection pressure has been placed on terminal traits via $B.

An example of an all-purpose index (often called maternal in the beef industry because it contemplates the retention of females) that compares the importance of different weight traits comes from the Beefmaster breed. Ochsner et al. (2017b) developed a maternal selection index for use by Beefmaster breeders. The index assumed that Beefmaster bulls would be bred to British based cows and heifers and that heifers would be retained in the system and all cull heifers and steers would be sold at weaning. Six objective traits (the economically relevant traits that we wish to improve) were considered for the maternal index including calving difficultly direct (CDd), calving difficulty maternal (CDm), 205-day weaning weight direct (WWd), 205-day maternal growth (WWm), mature weight (MW) and heifer pregnancy (HP). Results showed that decreasing CDd, CDm and MW while increasing WWd, WWm and HP would increase profitability of the operation. Mature weight was the primary driver receiving 49.2% of the emphasis, implying that for the assumed parameters decreasing MW will do the most to improve profitability of operations with a maternal objective. Weaning weight direct was the second highest priority objective trait receiving 27.2% of the emphasis. These two traits are antagonistic to each other relative to the breeding objective, but since the genetic correlation between them is not unity progress can be made in both traits simultaneously.

Table 3. Breed association selection indexes, market progeny endpoints and breeding system[1]

Breed	Index Name	Progeny Endpoint	Breeding System
Angus	$W (Weaning)	weaned feeder calves	A
Angus	$EN (Maintenance Energy)	replacement heifers	M
Angus	$F (Feedlot)	live fed cattle	T
Angus	$G (Grid)	beef carcasses sold on a CAB grid	T
Angus	$B (Beef)	beef carcasses from retained ownership sold on a CAB grid	T
Charolais	TSPI (Terminal Sire Profitability Index)	beef carcass sold on grid	T
Gelbvieh	$Cow	replacement heifers	G
Gelbvieh	EPI (Efficiency Profit Index)	feedlot efficiency	T
Gelbvieh	FPI (Feeder Profit Index)	beef carcass sold on grid	T
Hereford	BMI$ (Baldy Maternal Index)	beef carcass sold on grid; replacement heifers retained	G
Hereford	BII$ (Brahman Influence Index)	beef carcass sold on grid; replacement heifers retained	G
Hereford	CHB$ (Certified Hereford Beef Index)	beef carcass sold on CHB grid	T
Limousin	MTI (Mainstream Terminal Index)	beef carcasses sold on grid	T
Red Angus	HerdBuilder	beef carcass sold on grid; replacement heifers retained	G
Red Angus	GridMaster	beef carcasses sold on grid	T
Simmental	API (All Purpose Index)	beef carcasses sold on grid; replacements retained	G
Simmental	TI (Terminal Index)	beef carcasses sold on grid	T

[1] Adapted from Weaber fact sheet available at www.eBEEF.org.
T=terminal, G=general-purpose, M=Maternal

Implications

There are clear breed differences for growth, feed intake, and proxies for maintenance energy (maternal weaning weight and mature weight). Moreover, well-structured cross-breeding programs that are able to exploit these differences between breeds and take advantage of heterosis for reproduction traits are well positioned to improve enterprise level efficiency. The goal of commercial producers should be profit, not simply the increase in revenue or the decrease in costs. In order to select for profit, both input and output traits must be considered simultaneously. To do so, the use of economic selection indices is advisable. The improvement in these indices will largely come from the development of additional EPD for traits of economic relevance at the commercial level aided by the collection of commercial level phenotypes.

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