

TECHNICAL BULLETIN





GENEMAX® ADVANTAGE™ REFRESH & EXPANSION MAKE MORE INFORMED COMMERCIAL ANGUS REPLACEMENT HEIFER DECISIONS WITH GENEMAX ® ADVANTAGE™

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KEY POINTS

- GeneMax[®] Advantage[™] is a genomic test for prospective commercial replacement females that are highpercentage Angus breed composition. GeneMax Advantage provides commercial users of Angus genetics with the most advanced genetic information available for making selection, breeding and marketing decisions.
- GeneMax Advantage predictions are based on marker effects derived from the single-step Angus National Cattle Evaluation (NCE), by Angus Genetics Inc. (AGI'), enabled by up to 1.8 million seedstock animals tested by Angus breeders.
- GeneMax Advantage delivers genomic predictions for 19 individual traits, including the newly added Early Summer Hair Shedding (HS) and Pulmonary Arterial Pressure (PAP). It also includes three economic index scores (Cow, Feeder and Total Advantage) and five Angus \$Value Indexes (Maternal Weaned Calf Value (\$M), Beef Value (\$B), Feedlot Value (\$F), Grid Value (\$G) and Combined Value (\$C)).
- The \$Values are directly comparable to those for registered Angus sires, and all the genomic predictions provided with GeneMax Advantage are benchmarked with percent ranks against nearly 120,000 tested commercial Angus replacement heifer candidates. This gives customers a clear indication of how their animals compare to the historic population of GeneMax tested females.
- GeneMax Advantage allows direct access to a customer's registered Angus bull battery's genomic profile for parentage determination, with no additional retesting.
- This latest version of GeneMax Advantage explains larger proportions of genetic variation across maternal, feedlot, management and carcass traits, and correlations between index values and component traits indicate favorable predicted correlated response.
- Simulated return-on-investment (ROI) in testing and selection based on \$Combined (\$C) or Total Advantage index scores as compared to traditional selection, indicated projected average ROI over 10 years of \$3.40: \$1 or \$3.23: \$1 respectively, assuming selected females produce an average of six calves.

INTRODUCTION

The availability of genetic predictions for beef **seedstock** versus **commercial** cow-calf producers is a "Tale of Two Worlds." Historically, seedstock producers have had an abundance of genetic information at their fingertips, while most commercial cow-calf producers only have sparse access to similar information about their cow herds and calf crops. Thanks to genomics, that began to change in the spring of 2014 with the introduction of GeneMax Advantage, designed jointly by Angus Genetics Inc. (AGI), the American Angus Association^{*} and Zoetis, and offered exclusively through AGI.

GeneMax Advantage is for commercial females that are high-percentage Angus breed composition, and its features are designed to better inform replacement heifer selection and breeding decisions. The traits, economic index scores, as well as Angus sire parentage components of GeneMax Advantage, were specifically developed to complement Angus bull-buying based on genomically-enhanced expected progeny differences (GE-EPDs) powered by HD 50K and Angus GS. The 2024 addition of \$Values to the GeneMax Advantage portfolio enables commercial cattlemen to confidently compare their commercial females to the seedstock Angus bulls they are targeting to use in their herds.

Replacement heifer selection and breeding decisions are challenging and economically impactful for commercial cow-calf producers. Replacement costs for heifers and bulls often rival annual feed costs as the two highest-ranking sources of expense. Yet typically, commercial producers select replacement heifers based on visual appearance and age (earliest born), which only provide limited insights regarding differences in genetic merit for economically important traits. With visual appraisal, there is also the tendency to select the biggest, highest growth heifers, which often translates into larger mature cow sizes, higher feed requirements and other related costs.

Since retained replacements comprise one-half of the genetic merit of future calf crops — and given heifer development and cow costs — it is economically beneficial to select heifers with genetic potential for sensible lifetime costs relative to their lifespan and the value of calves produced. Beyond selection, GeneMax Advantage predictions complement other sources of information for breeding decisions. These include GE-EPDs for selection of service sires and bull batteries, that complement strengths and correct weaknesses as documented by GeneMax Advantage. With \$Values available for tested commercial Angus females that are directly comparable to those for registered Angus bulls, commercial cow-calf producers can make more synergized and informed replacement heifer selection and bull buying decisions for added productivity.

To help ensure effectiveness over time, GeneMax Advantage predictions are periodically refreshed to reflect the most accurate aggregate marker effects, evolving economic assumptions, and an expanded reference population of tested commercial females. In summary, the latest enhancements incorporate new marker effects, adds five Angus \$Value Indexes that are congruent with those available for Angus seedstock, and reports scores for two additional traits - Pulmonary Arterial Pressure (PAP) and Hair Shedding (HS).

PRODUCT DEVELOPMENT, DESCRIPTION AND OVERVIEW

GeneMax Advantage trait predictions are based on marker effects derived from AGI's single-step Angus NCE, implemented April 1, 2024.¹ Generally, "Single Step" refers to streamlined methods for integrating genomic information into the NCE through use of truer genomic-informed pedigree relationships between animals across the evaluated population. While the previous single-step evaluation and derived set of marker effects for GeneMax Advantage included over one million seedstock Angus animals with high-density genotypes, the latest set of marker effects were derived from up to 1.8 million genotyped seedstock animals.

Genetic predictions, in the underlying form of Genomic Progeny Differences (GPD), for 19 individual traits are included in this latest version of GeneMax Advantage (table 1). For ease of interpretation, underlying GPDs are reported as normally distributed, transformed scores ranging from 1 to 100, where higher scores generally indicate more favorable genetic merit. Scores of 50 represent average genetic merit for each trait as benchmarked against the reference population of tested commercial Angus females.

Trait / Index	Acronym	Definitions for GeneMax Advantage Scores		
Birth Weight	BW	Higher BW Score = Genetics for Lighter BW		
Calving Ease Maternal	CEM	Higher CEM Score = Genetics for Higher CEM (easier calving)		
Weaning Weight	WW	Higher WW Score = Genetics for Heavier WW		
Heifer Pregnancy	HP	Higher HP Score = Genetics for Higher HP (more fertile)		
Milk	Milk	Higher Milk Score = Genetics for More Milk		
Yearling Height	ΥH	Higher YH Score = Genetics for Taller YH		
Mature Weight	MW	Higher MW Score = Genetics for Heavier MW (cows)		
Cow Cost	СС	Higher Cow Cost Scores = Lower Cow Cost (from cow size & milk)		
Docility	DOC	Higher DOC Scores = Genetics for Calmer Temperament		
Claw & Angle Composite	CAC	Higher CAC Scores = More Desirable CAC Soundness		
Gain	Gain	Higher Gain Scores = Genetics for Higher Gains		
Feed to Gain	F:G	Higher F:G Score = Genetics for Lower F:G (more desirable)		
Carcass Weight	CW	Higher CW Scores = Genetics for Heavier CW		
Marbling Score	Marb	Higher Marb Scores = Genetics for More Marb		
Ribeye Area	RE	Higher RE Scores = Genetics for Larger Carcass RE		
Fat Thickness	Fat	Higher Fat Scores = Genetics for Less Carcass Fat		
Tenderness	TND	Higher TND Score = Genetics for Lower Shear Force (more tender)		
Hair Shed ¹	HS	Higher HS Score = Genetics for More Heat Tolerance		
Pulmonary Arterial Pressure ¹	PAP	Higher PAP Score = Genetics for Lower Risk of High- Altitude Disease		

Table 1	. Traits,	acronyms,	and	definitions	for	scores	included	in	GeneMax	Advantage.
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¹New traits

It follows that underlying trait GPDs are drivers of Angus \$Values and Cow, Feeder and Total Advantage indexes that rank animals for combined genetic merit. Percentile rankings associated with \$Values and 1 to 100 Advantage score benchmarks are provided in Table 2. Percent ranks for Advantage indexes scores are similar to ranks associated with scores for individual traits, so the latter are not included in table 2.

%Rank	\$M	\$F	\$G	\$B	\$C	Cow Advantage	Feeder Advantage	Total Advantage
1%	85	128	82	187	296	89	90	91
2%	81	122	77	180	286	87	88	88
3%	78	119	74	175	280	85	86	86
4%	76	116	72	172	275	84	84	85
5%	75	114	70	169	271	83	83	83
10%	69	107	64	159	258	77	78	78
15%	66	102	60	153	249	73	73	74
20%	63	98	57	148	242	70	70	70
25%	60	95	54	143	236	66	66	66
30%	58	92	51	139	231	63	63	63
35%	55	90	49	136	226	60	60	60
40%	53	87	47	132	221	57	57	57
45%	51	85	45	129	216	54	54	54
50%	49	82	43	125	212	51	51	51
55%	47	80	41	122	207	48	48	48
60%	45	77	39	119	203	45	45	45
65%	43	75	37	115	198	41	42	41
70%	41	72	35	112	193	38	38	38
75%	38	69	33	108	188	35	35	35
80%	36	66	30	104	182	31	31	31
85%	32	62	27	99	175	28	28	28
90%	28	57	24	92	166	23	23	23
95%	22	50	18	82	153	18	17	18

Table 2. Minimum GeneMax Advantage index values and scores associated v	vith top
percentile rankings.	

GENEMAX ADVANTAGE MULTI-TRAIT INDEXES

GeneMax Advantage includes three economic index scores and five \$Value Indexes, that rank females for combined genetic merit across different phases of production. These index scores were derived using classic selection index methodology. Economic assumptions (i.e., input costs, output prices/value) were aligned with those used by AGI for dollar-value indexes for Angus seedstock and generally represent the most recent seven-year averages.²⁻⁸ The weights applied to trait predictions also considered genetic variances and correlations. Importantly, indexes are intended to properly simplify multiple traits select for net economic return.

ADVANTAGE INDEX SCORES

Like individual trait scores, underlying GeneMax Advantage Index dollar values were transformed to the normally distributed 1 to 100 scale for easy ranking, interpretation and use in selection (table 3). Higher scores equate to a more desirable net return, with scores of 50 representing an average combined genetic merit as benchmarked against the reference population of nearly 120,000 tested commercial Angus females. The three GeneMax Advantage index scores are:

- **Cow Advantage** index scores rank candidate replacements for net return from combined genetic merit for heifer pregnancy, maternal and direct calving ease (includes birth weight), direct and maternal weaning weight (milk), docility and foot soundness (claw and angle composite), as well as associated costs of production due to differences in mature cow size and milk production, while also accounting for variation in cull cow value.
- **Feeder Advantage** index scores rank candidate replacements for net returns from combined genetic merit transmitted to progeny for post-weaning gain, carcass weight and grade (USDA Quality and Yield Grades as predicted by component traits), and costs of gain due to genetic differences in dry matter intake and associated feed-to-gain.
- **Total Advantage** index scores rank candidate replacements for net returns from combined genetic merit across economically relevant traits captured in the Cow and Feeder Advantage indexes. As such, this is the one most **simple and comprehensive** prediction of system-wide production efficiency upon which to primarily base selection and breeding decisions.

Index	Acronym	Definitions for GeneMax Advantage Indexes
Cow Advantage Index	Cow	Higher Cow Advantage Scores = Genetics for Higher Net Returns – cow-calf segment
Feeder Advantage Index	Feeder	Higher Feeder Advantage Scores = Genetics for Higher Net Returns – feeding feeder and carcass segments
Total Advantage Index	Total	Higher Total Advantage Score = Genetics for Higher Net Returns – maternal, feeding and carcass

Table 3. Definitions and interpretation of Advantage Index scores.

GENEMAX \$VALUE INDEXES

This new and improved version of GeneMax Advantage includes the same \$Values used for the registered Angus seedstock population. The economic assumptions and weights used for the \$Values are essentially the same, with identical interpretation of values. This was possible by transforming the genetic merit of tested commercial animals estimated through the marker effects. The results aim to capture the differences between animals in the seedstock population, while respecting the observed genetic difference between commercial and seedstock animals.

The \$Values now available for animals tested with GeneMax Advantage include indexes focused on carcass: Beef Value (\$B), Grid Value (\$G); feedlot performance: Feedlot Value (\$F); maternal traits: Maternal Value (\$M); and overall profitability:

Combined Value (\$C). The traits and indexes included in the \$Values are the same as those used for seedstock:

- **Beef Value (\$B):** A terminal index, expressed in dollars per carcass, to predict profitability differences in progeny due to genetics for postweaning and carcass traits. This terminal index assumes commercial producers wean all male and female progeny, retain ownership through the feedlot phase and market animals on a carcass grid.
- **Grid Value (\$G):** Expressed in dollars per carcass, to predict profitability differences in progeny due to genetics for carcass grid merit compared to progeny of other parents. The underlying objective assumes producers will market cattle on a marbling-based carcass grid.
- Feedlot Value (\$F): Expressed in dollars per carcass, to predict profitability differences in progeny due to genetics for postweaning feedlot merit compared to the progeny of other parents. The underlying objective assumes producers will retain ownership through the feedlot phase and sell fed cattle on a carcass weight basis, but with no consideration of premiums or discounts for quality and yield grade.
- Maternal Weaned Calf Value (\$M): Expressed in dollars per head, predicts profitability differences from conception to weaning, with the underlying breeding objective of producers retaining their own replacement females, selling cull females and all male progeny as feeder calves. The model assumes commercial producers replace 20% of their breeding females in each generation.
- **Combined Value (\$C):** Expressed in dollars per head and includes all traits that make up both Maternal Weaned Calf Value (\$M) and Beef Value (\$B), with the assumption that commercial producers replace 20% of their breeding females per year with replacement heifers retained within their own herds. The remaining cull heifer and steer progeny are assumed to be sent to the feedlot, with retained ownership and marketing of fed cattle an on a quality-based carcass merit grid.

The \$Values can be used to compare tested animals and Angus seedstock in a standardized way, considering economic drivers in the industry for profitability. The \$Values have the same interpretation as in the seedstock population, as measured as dollars per head or dollars per carcass (Table 4). It follows that this standardization more readily enables complementary A.I. sire or natural service breeding to females of similarly evaluated genetic merit.

\$Value	Acronym	Definitions for GeneMax Advantage \$Values
Maternal Weaned Calf Value	\$M	Higher \$M = More profitable females
Feedlot Value	\$F	Higher \$F = More profitable postweaning feedlot performance
Grid Value	\$G	Higher \$G = More profitable carcass grid merit
Beef Value	\$B	Higher \$B = More profitable postweaning and carcass traits
Combined Value	\$C	Higher \$C = More profitable commercial herd

Table 4. Definitions for \$Values included in GeneMax Advantage

The traits and relative contributions to \$Value and Advantage indexes are provided in table 5 and figures 1, 2 and 3. This information helps users of GeneMax Advantage understand the differences between \$Value and Advantage indexes that encompass similar sets of traits – namely \$M and Cow, \$B and Feeder, \$C and Total. For historic GeneMax customers, this information helps evaluate tradeoffs between continuity of selection via continued use of primarily Advantage indexes, versus added congruency of selection using indexes that are aligned across registered Angus bulls and tested commercial females.

Table 5. Traits in \$Value and Advantage indexes.

Trait included	\$Value					Advantage Index		
Trait	\$M	\$F	\$G	\$B	\$C	Cow	Feeder	Total
CED	Х				Х	Х		Х
WW	Х				Х	Х		Х
Gain		Х		Х	Х		Х	Х
CEM	Х				Х	Х		Х
MILK	Х				Х	Х		Х
MW	Х				Х	Х		Х
MHT						Х		
YHT								Х
DOC	Х				Х	Х		Х
HP	Х				Х	Х		Х
CAC	Х				Х	Х		Х
DMI		Х		Х	Х		Х	Х
CW		Х	Х	Х	Х		Х	Х
RE			Х	Х	Х		Х	Х
MARB			Х	Х	Х		Х	Х
FAT			Х	Х	Х		Х	Х

Figure 1. Relative contributions of trait groupings to Maternal Weaned Calf Value (\$) and Cow Advantage index scores



Figure 2. Relative contributions of trait groupings to Beef Value (\$) and Feeder Advantage index scores

Figure 3. Relative contributions of trait groupings to Combined Value (\$) and Total Advantage index scores

INDEX USE

Producers often ask, "What index should I use?" The intention of economic indexes is to simplify proper multiple trait selection and breeding decisions to optimize tradeoffs between traits that impact costs versus those that generate revenues from different phases of production. The increased number of indexes is not intended to add complexity, but rather is designed to enhance alignment between indexes used to select registered Angus bulls and indexes available to select commercial Angus replacement heifers.

Given the diversity of commercial cow-calf operations, it's not a matter of "one size (index) fits all." Rather, there's financial beneficials to using the index option(s) that best fit individual producers' breeding objectives. As genetic information becomes more available for commercial cattle, and bridges across industry segments, a strong case can be made for commercial cow-calf producers to primarily use broadly inclusive indexes, namely \$C or Total Advantage.

Focusing first on \$Value indexes, \$C can be used to simplify selection of females and sires that provide overall economic returns from combined maternal, production and carcass trait genetic merit (table 7). On some occasions, \$Values tailored for specific segments of the supply chain can be targeted for selection in tandem with \$C, across females and bulls. For example, if cow-calf operations wish to enhance their pools of maternally strong replacement females and profitability up to weaning (maternal traits), while not overly compromising feeding and carcass traits, bulls and heifers with higher combinations of \$M and \$C are advised for selection.

Correlations between \$Value and Advantage indexes are provided in table 8. While \$C and Total Advantage are moderately correlated (.62), and both are positively related to maternal, feeding and carcass merit, the components are not equally weighted. Total Advantage index scores are more highly correlated to Cow Advantage (.79 with maternal set of traits) as compared to Feeder Advantage (.57 with feeding and carcass set of traits) – table 6. Conversely, as indicated in table 7, \$C is more highly correlated with \$B (.90) as compared to \$M (.33). Relative to the maternal set of traits included in Cow Advantage and \$M, neither of these indexes are strongly or favorably correlated respectively, with feedlot and/or carcass indexes.

It follows that for GeneMax customers, it's handy to have two all-inclusive index options, one that's more influenced by maternal traits (Total Advantage – although not aligned with what's available for bulls) and another that's more driven by feedlot and carcass performance (\$C – aligned with bulls), while both are anticipated to yield across-the-board improvements in genetic merit for net returns.

Table 6. Pearson correlation between Cow, Feeder and Total Advantage economicIndex.

	Feeder Advantage	Total Advantage
Cow Advantage	0.05	0.79
Feeder Advantage		0.57

	\$F	\$G	\$B	\$C
\$M	-0.26	0.12	-0.12	0.33
\$F		0.11	0.80	0.65
\$G				0.70
\$B				0.90

Table 7. Pearson correlation between Maternal Weaned Calf (\$M), Feedlot (\$F), Grid (\$G) and Beef (\$B) economic indexes.

Table 8. Pearson correlation between \$Values (Maternal Weaned Calf - \$M, Feedlot - \$F, Grid - \$G and Beef - \$B economic Index) and Advantage Scores indexes (Cow, Feeder and Total Advantage).

Index	Cow Advantage	Feeder Advantage	Total Advantage
\$M	0.54	-0.17	0.45
\$F	0.08	0.63	0.30
\$G	0.09	0.50	0.38
\$B	0.11	0.77	0.45
\$C	0.34	0.65	0.62

USE OF GENEMAX ADVANTAGE IN BREEDING DECISIONS

GeneMax Advantage provides flexibility in replacement heifer selection and a wealth of information for mating and marketing decisions. While \$C or Total Advantage provides a simple and comprehensive assessment of an individual heifer's future contribution to supply chain profitability, there are instances where other indexes and individual trait predictions may be more applicable and used to inform mating.

For example, in instances where environmental constraints put a premium on cow adaptability, use of \$M or Cow Advantage Scores coupled with Hair Shed or Pulmonary Arterial Pressure outliers to inform bull buying based on GE-EPDs for these traits, will help match genetic potentials of future heifer calf crops to specific environments. Alternatively, for producers with abundant feed resources and the opportunity to benefit directly from feedlot and carcass performance or from special feeder cattle marketing programs, emphasis on \$B or Feeder Advantage will enhance post-weaning and carcass profitability.

SIMULATED VALUE RETURN FROM INVESTMENT IN GENEMAX ADVANTAGE

Value-return from selection of replacement heifers based on \$C and Total Advantage index scores were simulated over a 10-year period⁹. The simulation included the following assumptions: 500 head cow herd; 92% weaned calf crop; an initial replacement rate of 20% and the testing of two heifers for every one selected (200 tested, 100 retained); testing cost per selected heifer of \$56 (\$28 per head); 25% annual replacement rate and continuous index (\$C) advancement for purchased bulls.

The simulation evaluated use of \$C and Total Advantage versus traditional selection of replacement heifers and associated impacts on the cowherd and calf-crops over time. Traditional replacement heifer selection and genetic gain was defined as equivalent to parent-average \$C index values for simulated calf crops.

Depending upon the time horizon and assuming the average number of calves produced from selected replacement heifers was six, projected returns on investment (ROI) from selection based on \$C as compared to traditional selection ranged from a high of \$4.07 in year-10 to a low of \$2.57 in year-1, per \$1 invested in testing. Similarly, selection based on Total Advantage as compared to traditional selection yielded projected ROI that ranged from a high of \$3.89: \$1 in year-10 to a low of \$2.46: \$1 in year-1.

As \$C and Total Advantage indexes were used year-over-year, the pool of heifers for selection improved more rapidly than traditional selection, resulting in increased ROI over time. This doesn't include unquantified benefits related to smarter Angus bull buying and mating decisions that more effectively accentuate genetic strengths and correct weaknesses of the cowherd, better identified through use of GeneMax Advantage. As well, avoidance of inbreeding and labor savings due to anticipated reduction in problems related to traits such as calving ease, docility, foot and claw soundness, brisket disease in high altitude environments, are at least somewhat unaccounted for in this simulation.

Overall, simulated use of GeneMax Advantage and selection based on \$C or Total Advantage indicated a \$32 or \$30 per calf advantage, respectively, as compared to traditional selection. The strategy of testing two heifers for every one selected – ideally the earliest born and visually acceptable – means that most all viable candidates are evaluated and competitively considered, but costs are saved from not testing the entire heifer crop.

Based on customer experiences, this strategy also sometimes enables identification of excess heifers that possess documented genetic merit for value-added marketing as either open or bred replacements – rather than as feeder cattle. It follows that this testing strategy also provides insights about feedlot and carcass performance of steer mates, as benchmarked by the average \$F, \$G, \$B and Feeder Advantage indexes. These insights may be used to inform retained ownership decisions or help with feeder cattle price discovery through programs such as AngusLinkSM.

SIRE MATCH ENABLED WITH HD50K AND ANGUS GS

GeneMax Advantage matches potential Angus sires to tested heifer progeny (with no re-testing of bulls). This feature requires Angus bulls to be registered with the Association and transferred at the time of sale to the GeneMax Advantage customer's AGI account. This feature enables producers with HD 50K and Angus GS-tested bulls to find effective sires and proactively manage inbreeding, or avoidance of closely related common ancestors among sires of tested heifers and service sires, especially through AI. Sire Match verification enables knowledge of sires with the flexibility of multi-sire breeding systems. Inbreeding has generally been documented to adversely affect reproductive, survival and fitness traits. Ideally, customers are advised to designate candidate sires with their AAA registration numbers at the time of order submission. In cases where candidate sires have not yet been genomic tested, or if ownership has not yet been transferred at the time heifers are tested, Sire Match may be requested following the initial delivery of GeneMax Advantage results.

LIMITATIONS TO USE OF GENEMAX ADVANTAGE

GeneMax Advantage is a collaborative effort between AGI and Zoetis, designed for use in high-percentage Angus commercial replacement females. This primarily includes progeny of genomic tested, registered Angus bulls mated to half-blood or greater Angus cows. It is not intended for use in registered Angus females or bulls. Regarding the latter, genomic determination of female sex is required for reporting – genomic males do not receive results. The predictions obtained with GeneMax Advantage are not incorporated into the AGI's NCE and do not influence the GE-EPDs of registered Angus animals.

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