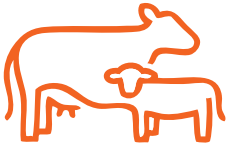


TECHNICAL BULLETIN

November 2022



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 Angus replacement females that are 75% or greater Black Angus breed composition
- GeneMax Advantage predictions are based on marker effects derived from the single-step Angus National Cattle Evaluation (NCE) implemented August 17, 2021 by Angus Genetics Inc. (AGI), enabled by over one million seedstock animals tested by Angus breeders
- GeneMax Advantage delivers three economic index scores (Cow, Feeder and Total), genomic predictions for seventeen individual traits benchmarked against 95,257 tested commercial Angus replacement heifer candidates, as well as Sire Match to registered and transferred HD50K and Angus GS tested bulls
- The seventeen individual trait scores include ten historically reported, and now updated traits as of January 2022: Calving Ease Maternal (CEM), Weaning Weight (WW), Heifer Pregnancy (HP), Milk, Mature Cow Weight (MW), Post-Weaning Gain (Gain), Carcass Weight (CW), Marbling (Marb), Ribeye Area (RE) and Fat Thickness - and scores for seven added traits, including: Birth Weight (BW), Feed-to-Gain (F:G), Yearling Height (YH), Foot Claw & Angle Composite (CAC), Docility (Doc), Cow Cost and Tenderness (TND)
- This refreshed version of GeneMax Advantage explains notably larger proportions of genetic variation across maternal, feedlot and carcass traits, and correlations between index values and component traits indicate favorable predicted response to selection
- Simulated return-on-investment (ROI) in testing and selection based on Total Advantage index scores as compared to traditional selection, indicated that ROI increases from year-one (\$2.36 : \$1) to year-ten (\$3.64 : \$1) following adoption, assuming selected females produce an average of six calves
- Along with GE-EPDs used to inform effective Angus bull buying, GeneMax Advantage provides commercial users of Angus genetics with advanced genetic information for genetic information available for making whole-herd selection, breeding and marketing decisions

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 the American Angus Association and Zoetis, and offered exclusively through AGI.

GeneMax Advantage is for commercial females that are 75% and greater black Angus breed composition, and its features are designed to better inform replacement heifer selection and breeding decisions. The trait and economic index scores, as well as Angus sire parentage components of GeneMax Advantage, were specifically developed to complement Angus bull-buying based on genomic enhanced expected progeny differences (GE-EPDs) powered by HD50K and Angus GS. Since 2014, there have been several product updates, the latest of which is significant.

Table 1 - Traits, indexes, acronyms and definitions for scores included in GeneMax Advantage.

Trait / Index	Acronym	Definitions for GeneMax Advantage Scores
Birth Weight ¹	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 ¹	YH	Higher YH Score = Genetics for Taller YH
Mature Weight	MW	Higher MW Score = Genetics for Heavier MW (cows)
Cow Cost ²	CC	Higher Cow Cost Scores = Lower Cow Cost (from cow size & milk)
Docility ²	DOC	Higher DOC Scores = Genetics for Calmer Temperament
Claw & Angle Composite ¹	CAC	Higher CAC Scores = More Desirable CAC Soundness
Cow Advantage Index ³	Cow	Higher Cow Advantage Scores = Genetics for Higher Net Returns
Gain	GAIN	Higher Gain Scores = Genetics for Higher Gains
Feed to Gain ¹	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 ²	TND	Higher TND Score = Genetics for Lower Shear Force (more tender)
Feeder Advantage Index ⁴	Feeder	Higher Feeder Advantage Scores = Genetics for Higher Net Returns
Total Advantage Index ⁵	Total	Higher Total Advantage Score = Genetics for Higher Net Returns

¹New trait

²Previously reported as SMART Outlier trait

³Combined genetic merit for maternal traits, including predicted revenues & costs, with weaned calf end-point

⁴Combined genetic merit for feedlot & carcass traits, including predicted revenues & costs, with carcass end-point

⁵Combined genetic merit for maternal, feedlot & carcass traits, including predicted revenues and costs, with carcass end-point

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's also the tendency to select the biggest, highest growth heifers, which typically translates into larger mature cow size, higher feed requirements and 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 effectively select heifers with genetic potentials for sensible lifetime costs relative to lifespan and 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. To help ensure effectiveness over time, GeneMax Advantage predictions are periodically refreshed to reflect the most accurate aggregate marker effects available, evolving economic assumptions and expanded reference population of tested commercial females.

Product Development and Description

GeneMax Advantage trait predictions are based on marker effects derived from AGI's single-step Angus National Cattle Evaluation (NCE) implemented August 17, 2021¹. Generally, Single-Step refers to streamlined methods for integrating genomic information into 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 335,000 seedstock Angus animals with high-density genotypes, the the January 2022 updated set of set of marker effects were derived from over one million genotyped seedstock animals.

Genetic predictions - in the original form of Genomic Progeny Differences (GPD) - for seventeen individual traits are included in this latest version of GeneMax Advantage. These underlying GPD are drivers of the Cow, Feeder and Total Advantage indexes. Trait and index definitions are included in Table 1. For easier interpretation, the GPD are reported as normally distributed, transformed scores ranging from 1 to 100. Scores of 50 represent average genetic merit for each trait as benchmarked against the reference population of tested commercial Angus females (n > 95,000). More specific percentile

Table 2. Minimum GeneMax Advantage trait and index scores associated top percentile rankings¹.

Top Percentile Ranking	Minimum Score
1	88
5	82
10	77
20	68
30	61
40	55
50	49
60	37
70	30
80	22
90	22
95	16

¹Relatively consistent across all traits and indexes

rankings associated with 1 to 100 score benchmarks are provided in Table 2, which are relatively consistent across all traits and indexes.

As compared to the previous Angus NCE used for derivation of aggregated marker effects for GeneMax Advantage, the January 2022 updated evaluation included updated genetic parameters (i.e., heritability and genetic correlation estimates) and modernized multiple-trait genetic evaluation models.

The models now incorporate more genetically correlated post-weaning gain records in the evaluation of dry matter intake, mature cow weight and carcass weight predictions. Together, single-step integration of nearly three times more animals with genomic information, updated genetic parameters and modernized multiple-trait models, resulted in more explained genetic variation. This is evidenced through notable increases in the standard

Table 3. Contrasts in the standard deviations of Genomic Progeny Differences (GPD) for trait predictions from the previous (2017) and refreshed (2021) Angus evaluations.

	GPD Standard Deviations ¹		Percent Increase	Average Percent Increase
	Year			
Maternal Traits	2017	2021		
Calving Ease Maternal (CEM)	8.7	10.2	17%	36%
Weaning Weight (WW)	24.0	32.5	35%	
Heifer Pregnancy (HP)	5.0	5.5	10%	
Milk	12.0	15.6	30%	
Mature Weight (MW)	44.0	81.4	85%	
Feedlot & Carcass Traits				
Dry Matter Intake (DMI)	0.24	0.45	88%	54%
Carcass Weight (CW)	27.2	41	51%	
Marbling Score (Marb)	0.50	0.73	46%	
Ribeye Area (RE)	0.44	0.64	45%	
Fat Thickness (FAT)	0.05	0.07	40%	

¹ Underlying Genomic Progeny Differences (GPD) prior to transformation into 1 to 100 scores

deviations of GPD that underpin trait scores for this version of GeneMax Advantage (Table 3).

With more explained variation across previously evaluated traits (Table 3) – as well as with the addition of new traits to the indexes (Table 1) - updated GeneMax Advantage index scores rank commercial Angus females somewhat differently as

compared to the previous version of each of the indexes. Updated marker effects for trait predictions weighted according to refreshed versus previous Advantage indexes, indicated greater potential for re-ranking for post-weaning and carcass traits and the Feeder index, as compared to the Cow and Total Advantage indexes (Table 4).

Table 4. Correlations between GeneMax Advantage index scores for refreshed and previous trait weightings using updated marker effects.

		Previous Advantage Indexes		
		Cow	Feeder	Total
Refreshed Advantage Indexes	Cow	0.90	-0.11	0.89
	Feeder		0.38	0.15
	Total			0.82

GeneMax Advantage Economic Index Scores

As discussed above, GeneMax Advantage includes three economic index scores that rank females for combined genetic merit across three phases of production, Cow, Feeder and Total. Index scores were derived using classic selection index methodology, intended to *simplify* multiple-trait selection. 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.

Like individual trait scores, underlying GeneMax dollar index values were transformed to the normally distributed 1 to 100 scale for easy ranking, interpretation and use in selection. As mentioned, higher scores equate to more desirable net return, with scores of 50 representing average combined genetic merit as benchmarked against the reference population of 95,257 tested commercial Angus females. The three GeneMax Advantage index scores include:

- **Cow Advantage** index scores rank candidate replacements for net return from combined genetic merit for heifer pregnancy, calving ease maternal and direct (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

FIGURE 1. Relative contributions of trait groupings to Cow Advantage index scores

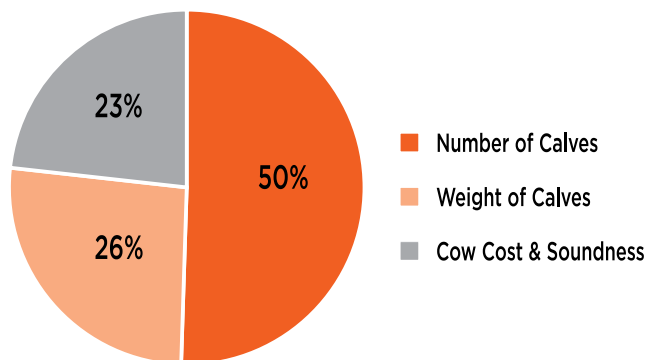


FIGURE 2. Relative contributions of trait groupings to Feeder Advantage index scores

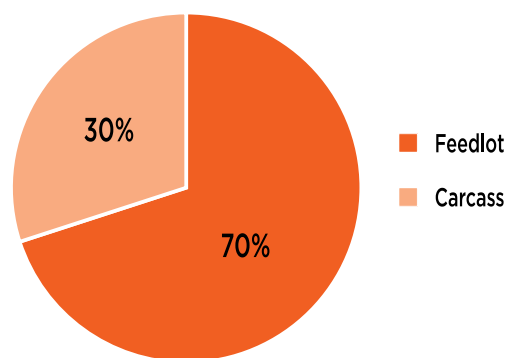
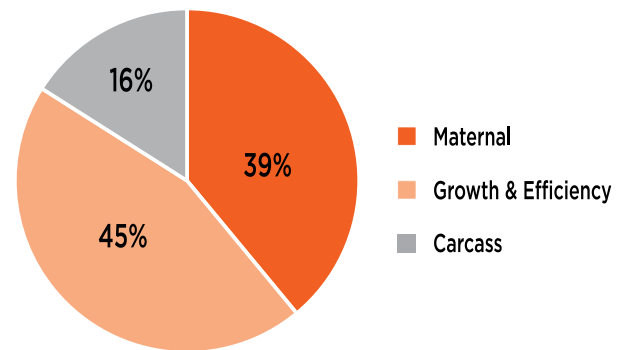


FIGURE 3. Relative contributions of trait groupings to Total Advantage index scores



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 all economically relevant traits captured in the Cow and Feeder Advantage indexes. As such, this a simple and comprehensive prediction of system-wide production efficiency upon which to primarily base selection and breeding decisions.

The relative contributions of different trait groupings to each index are illustrated in Figures 1, 2, and 3⁹. Cow, Feeder and Total index scores were calculated separately and independent from one another, although both Cow and Feeder traits contribute to Total. Total Advantage index scores are more highly correlated to Cow Advantage as compared to Feeder Advantage scores (.77 versus .60). The relationship between Cow and Feeder index scores is notably lower (.05), because other than growth, notably different traits drive costs, revenues, and net returns for these separate phases of production. Predictions for cow cost were more negatively (unfavorably) associated with Feeder and Total Advantage (-.39, and -.20, respectively)

as compared to Cow Advantage (-.06), because of stronger associated trait weightings to maintain moderate cow size, milk, and related costs. The intention of these indexes is to simplify proper multiple trait selection and breeding decisions that help optimize revenues and help lower the costs of production.

When using indexes, it is beneficial to understand relationships between index scores and correlated responses in individual traits. The correlations provided in Table 5 help breeders gauge the direction and magnitude of response in individual trait performance that is expected from selection based on the various indexes. For example, Cow Advantage is most highly correlated with maternal traits, while Feeder Advantage is most strongly related to growth and carcass performance. The Total Advantage index seeks to help breeders optimize performance across most all evaluated traits - while managing genetic antagonisms - to dependably identify differences in net return throughout the supply chain. These correlations can also help to inform breeders where more or less selection and/or mating attention may be needed using individual trait predictions along with indexes.

Table 5. Correlations among GeneMax Advantage indexes and with individual traits.

Trait Scores	GeneMax Advantage Indexes		
	Cow	Feeder	Total
Cow	1.00	0.05	0.77
Feeder	0.05	1.00	0.60
Total	0.77	0.60	1.00
BW	-0.04	0.29	0.08
CED	0.12	-0.16	0.06
CEM	0.69	-0.03	0.40
WW	0.26	0.47	0.48
HP	0.60	0.06	0.51
SC	0.08	0.16	0.17
Milk	0.07	0.04	0.08
YH	0.07	0.28	0.09
MH	0.03	0.42	0.15
MW	0.02	0.57	0.27
Cow Cost	-0.06	-0.40	-0.21
DOC	0.11	0.17	0.22
Claw	-0.03	0.09	0.04
Angle	-0.05	-0.08	-0.10
Gain	0.11	0.85	0.56
YW	0.20	0.69	0.55
DMI	0.17	0.48	0.43
CW	0.18	0.53	0.34
Marb	0.06	0.37	0.35
RE	0.08	0.34	0.13
FAT	0.06	-0.23	0.05

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 Total Advantage provides a simple and comprehensive assessment of an individual heifer's future potential contribution to supply chain profitability, there are instances where

other Advantage 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 Cow Advantage Scores coupled with heifer pregnancy and close attention to Cow Cost outliers to inform bull buying based on GE-EPDs for these traits, will help match genetic potentials of future heifer calf crops

to feed resources. 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 Feeder Advantage will enhanced post-weaning and carcass profitability.

Simulated Value Return from Investment in GeneMax Advantage

Value-return from selection of replacement heifers based on Total Advantage index scores were simulated over a 10-year period¹⁰. 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 - Combined) advancement for purchased bulls. The simulation evaluated use of 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 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 the Total Advantage index as compared to traditional selection ranged from a high of \$3.64 in year-10 to a low of \$2.36 in year-1, per \$1 invested in testing. As the Total Advantage index was used year-over-year, the pool of heifers for selection improved more rapidly than traditional selection, resulting in increased ROI over time.

Overall, simulated use of GeneMax Advantage and selection based on

the Total Advantage index indicated a \$28 per calf advantage 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 value-return modeling using customer results, this can also enable 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 Feeder Advantage index and component traits. These insights may be used to inform retained ownership decisions or help with feeder cattle price discovery through programs such as Angus LinkSM.

Sire Match Enabled with HD50K and Angus GS

GeneMax Advantage matches potential Angus sires to tested heifer progeny. This feature requires bulls to be registered with the American Angus Association and transferred at the time of sale to the AGI account of the GeneMax Advantage customer. This feature enables producers with HD50K and ANGUS GS tested Angus bulls to proactively manage inbreeding, or avoidance of closely related common ancestors among sires of tested heifers and service sires (especially through A.I.). 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 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 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.

Thanks go out to the team that worked to execute the January 2022 updated evaluation including: Dr. Tom Short - Zoetis Outcomes Research; Kelli Retallick – President of AGI, and her colleagues; Dr. Steve Miller – former AGI Director of Genetics Research; Dr. Tony McNeel and Dr. Kent Andersen, Zoetis Genetics Global Technical Service.

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