College of Tropical Agriculture
and Human Resources
University of Hawai‘i at Mānoa

Animal Sciences
June 2020
AS 1

DNA-Based Bull Selection and Artificial Insemination for Grass-Fed Beef Cattle Production

Jinzeng Yang, Michael DuPonte, Douglas Vincent, Kyle Caires, Yanghua He, Nicole Correa, Lehua Wall, Keala Cowell, Marla Fergerstrom
Department of Human Nutrition, Foods and Animal Sciences

Introduction

Identifying and utilizing the best breeds and genetic makeup of livestock animals for each individual operation is the foundation of a successful animal industry. Genetic improvement has been an effective means to increase animal growth, production efficiency, and product quality.

Historically, a variety of cattle breeds were brought to the Islands and unselectively used in most ranches. Breeds with large body frames that originate from cold climates (*Bos taurus*) have large mature sizes and do not adapt well to the local climates in the Islands, with their warm to hot temperatures and high humidity. Crossbreeding between *Bos taurus* and *Bos indicus* cattle, which originated in warmer and more humid southeast Asia, has been practiced by cattle producers to find cattle that are better adapted to Hawai‘i climates. Selections and studies of cattle breeds and crossbreeding for Hawai‘i grass-fed beef production are needed to support the transformation of the local cattle industry to a grass-fed beef production system.

At the Mealani Experiment Station of CTAHR, Angus and Hereford are the British breeds chosen for long-term experimentations because of their balance of production traits and their complementarity for crossbreeding in Hawai‘i's subtropical climate (Figure 1A–E).

Figure 1A–B. Examples of germplasm at Mealani Experiment Station of CTAHR. (A) Straight-bred Hereford cow–calf pair. (B) Straight-bred Angus cow–calf pairs. Photos by K. Caires.

Figure 1C–E. Examples of germplasm found at Mealani Experiment Station of CTAHR, cont'd. High-indexing (C) Angus, (D) Hereford calves, and (E) cross-bred calves from 2019 calf crop. Photos by K. Caires.

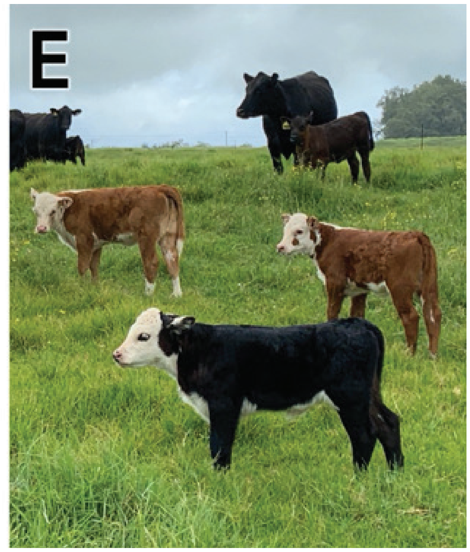

Table 1 demonstrates the common characteristics of British beef breeds. However, Angus represents the primary beef breed used at the Mealani Station.

Current studies in Hawai'i have successfully established protocols for semen collection, freezing, and AI technology to effectively improve beef cattle production. The DNA testing offered by commercial genotyping services such as Zoetis HD50K™, a platform developed in partnership with Angus Genetics, Inc. for Angus seedstock producers, has provided Molecular Value Predictions (MVP) of production traits and offered significant genetic makeup and assessment of the bulls at the Mealani Experimental Station of CTAHR. Economic Indexes and genomic predictions of each animal in the form of percentile ranks for 19 traits were calculated using GE-EPDs. The GE-EPD data pool was collected from a reference population of over 500,000 animals. Several Angus bulls at the Mealani Station were identified as having superior genetic potentials in terms of carcass quality and growth performance following DNA testing. A herd sire chosen from previous years of genomic testing for use in the Mealani herd is shown in Figure 2.

The application of traditional methods along with DNA technology developed from this genomic approach can be used for bull selection on ranches for the improvement of grass-finishing beef cattle genetics in the state. Outcomes of the Mealani beef herd's breeding programs focus on improving carcass traits in grass-finished beef are clearly demonstrated in recent carcass evaluations of steers and heifers harvested from Mealani Station (Table 2). Figure 3 shows a representative image demonstrating meat quality and yield traits in a Mealani steer carcass. Figure 4 provides a chart showing the relationship between marbling, maturity, and quality grades.

Animal geneticists and breeders have always tried to find ways to predict young animals' potential contribution of the traits of economic importance to their offspring. In addition to phenotypic selection, employing genomic

Table 1. Characteristics of Common British Breeds

Breed	Strengths	Weaknesses
Angus	Maternal ability, carcass quality, calving ease	Disposition, carcass fat
Hereford	Hardiness, maternal ability, disposition	Low milk, prolapses, predisposition to cancer eye
Shorthorn	Growth rate, carcass quality	Price discrimination due to color, diluted gene pool
South Devon	Growth rate, carcass quality, cuttability	High birth weights, later maturing, disposition

Figure 2: An Angus bull at CTAHR's Mealani Station. Photo by M. DuPonte.

markers such as single nucleotide polymorphisms (SNP) in the genome, molecular-based information holds promise to improve the quality of prediction of young animals, particularly with the discovery of ever-increasing densities of SNPs covering the whole genome. As sequencing the bovine genome becomes more affordable and widely used in various experiments and cattle species, millions of bi-allelic SNP, grouped to SNP subsets, have been discovered and further characterized for the genome in association with cattle performance traits. The use of haplotype analysis in future studies will further aid in the identification of interactions between SNPs for complex traits of economic importance in beef cattle, as a result of increased statistical power.

An expected progeny difference (EPD) is intended to provide estimates of the genetic value of an animal

Table 2. Representative Data Obtained Through Carcass Evaluations of Beef Cattle from Mealani Station

Animal ID	Breed	Sex	Age	Quality grade	Maturity	Marbling score	Fat thickness (in.)	Hot carcass weight (lb)	Ribeye area (sq. in.)
3032	Angus	Steer	20 months	C	A75	Mt 30	0.2	655	12.6
3008	Angus	Heifer	20 months	C-	A70	Sm 50	0.35	658	14
3052	Angus	Steer	20 months	C-	A75	Sm 20	0.2	630.5	10.5
3060	Angus	Steer	20 months	C	A80	Mt 10	0.2	711.5	13.3
3034	Angus	Steer	20 months	S	A80	Sl 70	0.15	543.5	11.1
3067	Angus	Heifer	20 months	C	A80	Mt 0	0.2	631	12.5
3004	Angus	Heifer	20 months	C+	A80	Md 60	0.2	571.5	11.2
3031	Angus	Heifer	20 months	C+	A80	Md 0	0.3	568	11.4
3057	Angus	Heifer	20 months	C	A80	Mt 90	0.3	653.5	14
3045	Angus	Heifer	20 months	C	A80	Mt 40	0.2	606.5	12.1
3009	Angus	Heifer	20 months	C-	A75	Sm 80	0.3	586	11
3050	Angus	Heifer	20 months	C-	A80	Sm 80	0.2	547.5	11.9

Note: The marbling score in beef is used to estimate intramuscular fat content by direct observation of adipose tissue, or fat, present in the loin/ribeye (longissimus dorsi) muscle. Graders evaluate the amount of intramuscular fat at the cut surface of the ribeye on the 12th rib surface. There are 9 marbling scores, each of which is divided into 100 subunits. They are assigned as subscripts to the scores ranging from 00 to 99, representing the least to greatest amount of marbling within the score. The marbling scores (least to greatest) are 1. Practically Devoid (PD), 2. Traces (TR), 3. Slight (SL), 4. Small (SM), 5. Modest (MT), 6. Moderate (MD), 7. Slightly Abundant (SLAB), 8. Moderately Abundant (MDAB), 9. Abundant (AB). **Quality grades** are used to segregate beef carcasses into palatability groups based on their expected eating quality. Quality grades are based on degree of marbling and carcass maturity (Figure 4). Carcass maturity groups range from A to E and are an estimate of the age of the animal from which the carcass was derived. Maturity group A cattle are estimated to be between 9 and 30 months old, while group E cattle are greater than 96 months. The quality grades (from most palatable to least) are Prime, Choice, Select, Standard, Commercial, Utility, Cutter, and Canner.

Figure 3: Ribeye cross-section from animal 3003. Photo by M. DuPonte.

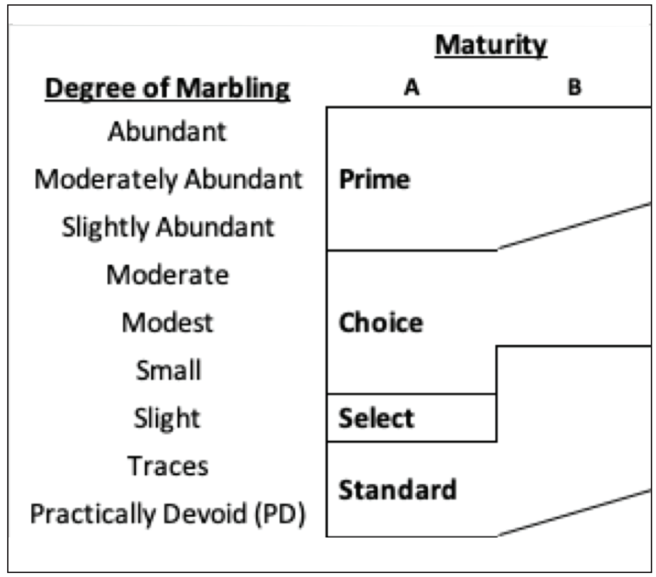

Figure 4. The relationship between marbling, maturity, and quality grades in beef carcasses.

as a parent. Differences in EPDs among individuals within one breed predict differences in the performance of their future offspring. Each EPD is an estimate of the individual's genetic merits for producing future progeny. EPDs are calculated by using complex statistical equations and models based on phenotypic data and additive genetic relationships between related individuals. Genetic predictions of animal performance are reported for as EPDs for world-wide use, these estimates of genetic merit are continually updated based on animal registrations and performance records submitted to breed associations, and other agencies such as the National Beef Cattle Evaluation Consortium (NBCEC), where researchers, producers, and beef industry leaders work together to continually update the genetic evaluations for multiple breeds of beef cattle.

The results for DNA testing are reported as Molecular Value Predictions (MVP) of production trait for each individual animal is summarized in Table 3. MVP is defined as a "molecular breeding value," which represents a portion or unit of expected genetic controls affecting the trait of interest. In evaluation of an individual animal's genetic contributions to their progeny, an MVP is similar to an EPD estimate to help a breeder to compare or rank the animals within one population or on a large scale with all animals tested by the SNP panels. The rank or reports of the MVP for all the traits of interests derived from animal genotype. The value and genetic evaluation by MVP are highly dependent upon the scale and data quality of association studies between MVP and the traits analyzed. As most beef cattle data is gathered on a feed-lot production system, there is a strong need to better evaluate the associations between MVP and traits in grass-fed commercial beef-production systems. A detailed report of MVP values and percentile rankings for various traits of economic importance following genomic testing of Angus bull calves (n = 17) at Mealani Station is provided in Table 4.

Objectives of the Mealani Cattle Breeding Project

- To organize and teach cattle breeding management and artificial insemination workshops.
- To utilize the latest DNA technology and genomic tools along with in-house performance testing, to identify and propagate genetically superior breeding stock to support Hawai'i's ranching industry.

Table 3. Trait Summary of Genomic Tested (HD50K) Angus Bull Calves (n = 17) in 2019 Calf-Crop

Traits	Calving Ease	Growth & Size			Efficiency		Maternal & Temperament				Carcass			Quality		Index
Parameters	CED	BW	WW	YW	DMI	RFI	CEM	MA	SC	DOC	CW	FAT	REA	MS	TND	$MVPFL
Angus Minimum MVPs	-29.7	-8.9	-37	-63	-5.24	-2.93	-17.3	-26	-2.37	-44	-25	-0.11	-0.79	-0.57	-1.02	-16
Angus Average MVPs	5.5	0.0	45	70	-0.22	-0.10	3.0	20	0.40	9	31	0.00	0.33	0.41	-0.39	125
Angus Maximum MVPs	22.9	9.1	107	173	4.30	2.75	17.5	49	3.16	59	81	0.12	1.54	1.73	1.09	284
Mealani Bull Minimum MVPs	3.0	-3.4		70	-0.62	-0.55	-0.6	19	-0.76	-1	34	-0.02	0.39	0.44	-0.56	138
Mealani Bull Average MVPs	9.6	-0.8	55	93	0.33	0.20	5.6	26	0.22	11	43	0.00	0.58	0.74	-0.38	171
Mealani Bull Maximum MVPs	15.7	2.2	69	118	1.08	0.77	11.2	34	1.30	21	53	0.01	0.85	0.95	-0.13	194
Average Reliability %	53	53	62	63	30	28	50	59	58	65	56	57	56	61	51	

Notes

Calving Ease Direct (CED) %
Describes differences in genetic merit in terms of the likelihood of unassisted births in first-calf heifers, expressed as a trait of the progeny. Higher MVP values and lower ranks are preferred, especially when selecting sires for use on replacement heifers for easier-calving progeny.

Birth Weight (BW), in Pounds
Quantifies genetic differences in birth weight, with lower and moderate MVP values and ranks generally desired for ease of calving.

Weaning Weight (WW), in Pounds
Measures differences in genetic merit for adjusted 205-day weaning weight, with higher MVP and lower rank values indicating heavier weights.

Yearling Weight (YW), in Pounds
Indicates differences in breeding value for adjusted 365-day weight, with higher MVPs and lower ranks equating to genetics for heavier yearling weights.

Yearling Height (YH), in Inches
Describes genetic differences in adjusted 365-day hip height, with higher MVP values and lower ranks translating to genetics for taller animals.

Dry Matter Intake (DMI), per Lb. of Feed (Dry Matter) Consumed per Day
Quantifies genetic differences for feed intake while on feedlot finishing rations. MVPs and ranks for DMI should be evaluated in relation to genetic merit for output traits, especially including MVPs and ranks for yearling and carcass weight (YW and CW).

Table 3, cont'd. Trait Summary of Genomic Tested (HD50K) Angus Bull Calves (n = 17) in 2019 Calf-Crop

Notes, cont'd.

Residual Feed Intake (RFI), per Pound of Feed (Dry Matter) Consumed per Day Compared to Expected Consumption
Describes genetic variation in weight of dry matter consumed per day, as compared to expected feed consumption based on body weight and growth rate. Lower MVP and rank values are desired, identifying genetics leading to the same amount of weight gain for less feed intake.

Calving Ease Maternal (CEM) %
Indicates differences in genetic merit for the likelihood of unassisted births in first-calf heifers, expressed as a trait of the heifer. Higher MVP and lower-rank values are preferred, indicating genetics for heifers that calve more easily.

Milking Ability (MA), in Pounds of Weaning Weight (WW)
Evaluates differences in genetic merit for the maternal component of calf weaning weight, predominantly due to the milking ability of dams (or daughters). Genetic potential for milking ability should be matched to available feed resources, which implies that intermediate MVP and rank values are likely optimum for many production systems.

Scrotal Circumference (SC), in Centimeters
Describes genetic differences in age at puberty as indicated by adjusted yearling scrotal circumference. Larger MVPs and lower ranks for scrotal circumference equate to genetics for earlier and more desirable age at puberty in both bulls and heifers.

Docility (DOC) %
Quantifies genetic differences in the probability of acceptable (calm) versus unacceptable (wild) temperament. Higher MVPs and lower ranks mean greater likelihood of more manageable disposition.

Carcass Weight (CW), in Pounds
Measures differences in breeding value for pounds of carcass weight at a constant age. Higher MVPs and lower ranks indicate genetics for heavier carcass weights, which are generally desired, as long as within heavy weight thresholds.

Fat Thickness (FAT), in Inches
Communicates genetic differences in fat thickness measured adjacent to the ribeye between the 12th and 13th rib, at a constant age. Higher MVPs and ranks indicate genetics for fatter carcasses and an adverse impact on USDA yield grades but may be desirable for maternal fleshing ability in breeding females.

Ribeye Area (REA), in Square Inches
Describes genetic variation in carcass muscularity as measured by ribeye area between the 12th and 13th rib, at a constant age. Larger MVPs and lower ranks for ribeye area favorably impact USDA yield grades and associated carcass premiums.

Marbling Score (MS), USDA Score Units
Quantifies genetic differences in USDA marbling scores at a constant age, with higher MVPs and lower ranks indicating higher levels of marbling and generally more desirable quality grades and associated carcass premiums.

Tenderness (TND), in Pounds of Shear Force
Evaluates differences in genetic merit for tenderness based on the amount of shear force required to slice through cooked steak samples. Lower MVP and rank values, indicating less shear force required, are preferred as measures of more desirable meat tenderness.

Molecular Value Prediction - Feedlot Index ($MVPFL), in US Dollars
Predicts net return from combined genetic merit for feedlot (FL) gain, dry-matter intake, and carcass weight, as well as USDA quality and yield grades (marbling, ribeye area, and fat thickness). The index assumes approximately 160 days on feed consuming concentrate rations and carcass value derived from a Certified Angus Beef (CAB) grid. Higher MVPs and lower ranks indicate more desirable combined genetic merit.

Table 4. Detailed report following genomic testing (HD50K) of Angus bulls at Mealani Station

Traits	Calving Ease		Growth & Size				DMI	Maternal & Temperament			Carcass			Quality		Index
Bull ID		CED	BW	WW	YW	YH	DMI	CEM	MA	SC	CW	FAT	REA	MS	TND	$ MVPFL
1	MVP	8.3	-3.0	54.0	92.0	0.0	0.8	6.8	20.0	0.6	47.0	0.0	0.5	0.6	-0.3	154.0
	% Rank	26.0	8.0	25.0	17.0	4.4	89.0	14.0	48.0	34.0	7.0	77.0	20.0	18.0	69.0	18.0
4	MVP	14.9	-2.0	54.0	107.0	-0.4	1.1	11.2	31.0	1.3	40.0	-0.0	0.5	0.8	-0.4	159.0
	% Rank	3.0	17.0	25.0	6.0	90.0	93.0	2.0	8.0	7.0	18.0	40.0	22.0	9.0	50.0	15.0
7	MVP	12.9	-0.7	64.0	107.0	-0.1	0.4	7.9	33.0	0.6	41.0	0.0	0.8	0.7	-0.4	171.0
	% Rank	7.0	37.0	8.0	6.0	60.0	79.0	9.0	5.0	34.0	16.0	61.0	5.0	16.0	44.0	9.0
12	MVP	4.7	0.7	47.0	90.0	0.3	0.2	1.7	19.0	0.3	37.0	0.0	0.4	0.4	-0.5	138.0
	% Rank	55.0	64.0	44.0	20.0	11.0	50.0	65.0	54.0	54.0	26.0	61.0	32.0	43.0	25.0	33.0
21	MVP	10.5	-0.2	64.0	105.0	0.0	0.0	10.0	29.0	0.9	53.0	0.0	0.6	0.7	-0.5	183.0
	% Rank	14.0	46.0	8.0	7.0	4.4	63.0	4.0	12.0	17.0	2.0	61.0	11.0	18.0	25.0	6.0
26	MVP	3.0	2.2	59.0	101.0	0.2	0.6	-0.6	24.0	-0.1	43.0	0.0	0.4	0.7	-0.3	186.0
	% Rank	70.0	86.0	15.0	10.0	19.0	33.0	86.0	28.0	85.0	12.0	61.0	32.0	13.0	89.0	5.0
37	MVP	10.3	-0.7	57.0	93.0	0.0	0.6	4.5	20.0	-0.3	47.0	-0.0	0.9	0.8	-0.4	180.0
	% Rank	15.0	37.0	19.0	16.0	4.4	84.0	32.0	48.0	92.0	7.0	40.0	3.0	8.0	63.0	6.0
38	MVP	7.7	-1.9	52.0	70.0	0.3	0.0	5.4	33.0	0.7	34.0	-0.0	0.4	0.8	-0.3	171.0
	% Rank	30.0	18.0	30.0	51.0	11.0	63.0	24.0	5.0	25.0	36.0	40.0	38.0	8.0	75.0	9.0
45	MVP	9.1	-0.6	43.0	74.0	-0.1	0.0	2.3	31.0	0.5	49.0	0.0	0.6	1.0	-0.6	190.0
	% Rank	21.0	39.0	57.0	44.0	60.0	61.0	58.0	8.0	39.0	6.0	61.0	14.0	4.0	10.0	4.0
46	MVP	5.7	0.8	52.0	82.0	0.1	0.1	2.6	23.0	0.1	51.0	0.0	0.4	0.6	-0.4	162.0
	% Rank	46.0	65.0	30.0	30.0	30.0	64.0	54.0	32.0	71.0	4.0	77.0	38.0	23.0	37.0	13.0
40	MVP	9.1	-1.4	52.0	90.0	0.0	0.5	5.4	24.0	-0.8	42.0	-0.0	0.9	0.7	-0.1	168.0
	% Rank	21.0	25.0	30.0	20.0	44.0	80.0	24.0	28.0	98.0	14.0	40.0	3.0	11.0	98.0	10.0
50	MVP	13.7	-2.3	64.0	107.0	0.1	0.7	7.2	31.0	0.3	49.0	0.0	0.7	0.8	-0.3	185.0
	% Rank	5.0	14.0	8.0	6.0	30.0	86.0	12.0	8.0	59.0	6.0	61.0	7.0	8.0	80.0	5.0
50	MVP	9.7	0.6	69.0	118.0	0.0	1.0	5.9	28.0	0.1	52.0	0.0	0.8	0.9	-0.4	194.0
	% Rank	18.0	62.0	5.0	3.0	44.0	92.0	20.0	14.0	70.0	4.0	61.0	5.0	5.0	63.0	4.0

Table 4, cont'd. Detailed report following genomic testing (HD50K) of Angus bulls at Mealani Station

Traits	Calving Ease		Growth & Size				DMI	Maternal & Temperament			Carcass			Quality		Index
Bull ID		CED	BW	WW	YW	YH	DMI	CEM	MA	SC	CW	FAT	REA	MS	TND	$ MVPFL
61	MVP	9.1	-0.3	66.0	100.0	-0.1	0.9	4.7	23.0	-0.6	38.0	-0.0	0.6	0.9	-0.4	180.0
	% Rank	21.0	44.0	7.0	10.0	60.0	90.0	30.0	32.0	96.0	23.0	21.0	12.0	6.0	60.0	6.0
63	MVP	15.7	-3.4	43.0	72.0	-0.2	0.1	9.0	25.0	0.1	36.0	0.0	0.6	0.9	-0.5	176.0
	% Rank	3.0	6.0	57.0	47.0	75.0	58.0	6.0	24.0	70.0	29.0	61.0	12.0	6.0	15.0	8.0
64	MVP	6.6	0.5	60.0	98.0	0.0	1.1	3.2	19.0	-0.3	38.0	-0.0	0.5	0.8	-0.4	162.0
	% Rank	38.0	60.0	13.0	12.0	44.0	93.0	47.0	54.0	90.0	23.0	21.0	18.0	10.0	63.0	13.0
66	MVP	11.7	-1.6	43.0	78.0	0.1	0.5	8.6	34.0	0.2	38.0	0.0	0.4	0.5	-0.4	147.0
	% Rank	10.0	22.0	57.0	37.0	30.0	39.0	7.0	4.0	64.0	23.0	77.0	38.0	32.0	40.0	24.0

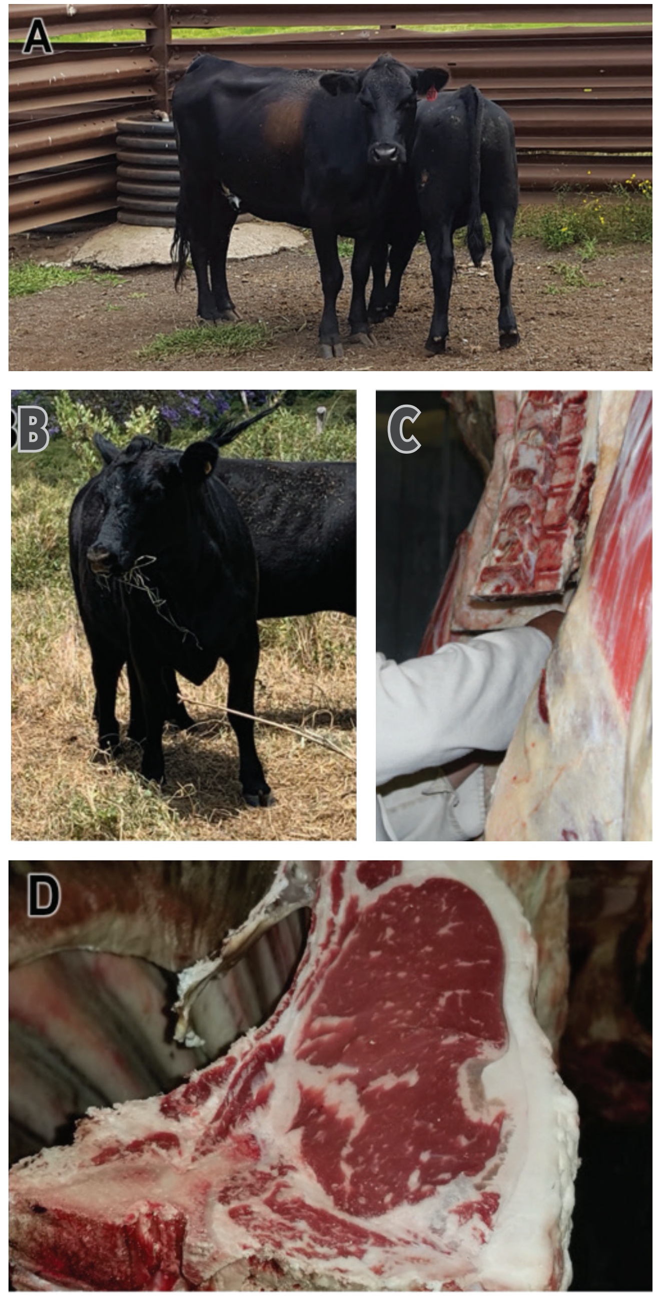

Figure 5. Real-world performance of Mealani Angus genetics in Hawai'i's commercial beef industry yields favorable results for all aspects of the beef supply chain. (A) First-calf heifer pictured with her steer-calf at weaning in Maui County; calf was sired by a purchased Mealani bull, born unassisted, with excellent performance for weaning weight. (B) That same steer calf is shown during the later stages of a grass-finishing program. (C,D) Post-harvest carcass evaluation demonstrates superior meat quality and yield traits resulting from a grass-finishing program. Photos by K. Caires.

- To offer advanced reproductive technologies (ARTs) such as bull semen collection, freezing, and AI programs to cattle ranches, and conduct progeny testing of offspring to improve the consistency and performance of grass-fed beef production in Hawai‘i.

Current challenges of local grass-finished beef production in Hawai‘i

- Product is still inconsistent in quality as to marbling and tenderness
- Poor post-weaning growth, and late maturity, as animals are being finished later than at the suggested 25–30 months of age
- Limited supply is available, so more animals are needed to satisfy the growing demand of young cattle for grass-finished beef production.

Impacts

Artificial insemination, or AI technology, was developed for cattle more than 60 years ago. It has been used for dairy cattle industry but has not been used widely in the beef cattle industry. In recent years, genetic evaluation of beef bulls by DNA testing and genomic analysis from animal blood or hair samples has improved considerably, and the cost of the DNA analysis has become affordable with the advancement of DNA sequencing and genomic technologies. Based on DNA testing results, a cattle producer can make bull selections for specific traits without conducting the expensive and time-consuming traditional animal breeding and mating systems for progeny testing. The MVP data from DNA markers are increasing the need for and use of AI in beef cattle production, and they will increase operational profits by fostering a better and uniform animal production system.

This project at the College of Tropical Agriculture and Human Resources of the University of Hawai‘i at Mānoa is ongoing, with the goal of demonstrating that the use of superior bulls, identified through genetics, DNA selection, and recordkeeping and bred through artificial insemination, can help to confront and answer the current challenges of quality and quantity demands of grass-finished beef. Real-world feedback from cattle producers across the state that have utilized Mealani genetics through bull purchases remains favorable, as superior growth and carcass performance is observed in following progeny testing (Figure 5). We are open to collaborating with cattle producers and working together to improve growth rates, reproductive performance, carcass quality, and recordkeeping for grass-fed cattle-production systems in Hawai‘i.

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Acknowledgements

Thanks for the funding support by the USDA-Hatch program administrated by College of Tropical Agriculture and Human Resources of the University of Hawai‘i at Mānoa.