UNIVERSIDADE FEDERAL DE UBERLÂNDIA
FACULDADE DE MEDICINA VETERINÁRIA

PAOLA PEREZ BÓSCOLLO

Economic values for fertility, growth, carcass, and meat quality traits for seedstock and cow-calf operations in the Southeastern United States

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Tese apresentada à Faculdade de Medicina Veterinária da Universidade Federal de Uberlândia, como requisito parcial à obtenção do título de doutora em Ciências Veterinárias.

Área de concentração: Produção Animal

Orientadora: Dra. Ricarda Maria dos Santos

Coorientador: Dra. Fernanda Marcondes de Rezende

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pelo apoio sem medidas ao longo dessa jornada!

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“Deus não quer que você entenda, Ele quer que você confie.”

“A mente que se abre a uma nova ideia jamais
voltará ao seu tamanho original.”
(Albert Einstein)

RESUMO

Objetivou-se, com este estudo, estimar valores econômicos para características específicas, a fim de utilizá-los como pesos em índices de seleção econômicos para sistemas de gado de corte Brahman e Angus-Brahman. Os valores econômicos (VEs) foram derivados a partir de características de fertilidade, crescimento e carcaça, utilizando os rebanhos Brahman Puro da UF (BRA) e Angus-Brahman Multirracial da UF (MAB) como populações de referência. Modelos bioeconômicos foram desenvolvidos utilizando custos variáveis do rebanho, receitas e dados de manejo coletados de fevereiro de 2024 a maio de 2025. O rebanho BRA é um sistema de produção de reprodutores que tem como base focar na criação e na comercialização de animais puros registrados e geneticamente superiores, para fornecer o material genético para a sustentabilidade a longo prazo na indústria de gado de corte. Além do rebanho BRA, um cenário simulado foi desenvolvido para representar uma gama mais ampla de sistemas de produção de reprodutores no sudeste dos Estados Unidos. Os bezerros do rebanho BRA e do cenário simulado de produção de reprodutores seguiram um dos cinco caminhos: vendidos ao desmame, com um ano de idade, mantidos como animais de reposição, abatidos para avaliação de carcaça ou vendidos para fins de reprodução. O rebanho MAB é uma sistema de cria que se concentra na reprodução de vacas para produzir um bezerro saudável e comercializável por vaca por ano, fornecendo à indústria da carne bovina carne suficiente e de alta qualidade. Além do rebanho MAB, três cenários simulados foram desenvolvidos para representar uma gama mais ampla de sistemas de cria de gado no sudeste dos Estados Unidos. Os bezerros do rebanho MAB e dos cenários simulados seguiram um dos quatro caminhos: vendidos ao desmame, com um ano de idade, mantidos como matrizes de reposição ou comercializados a um frigorífico. VEs foram estimados como a mudança esperada na lucratividade resultante da mudança de uma unidade no desempenho de uma característica específica, mantendo todas as demais constantes. Os VEs foram estimados para o sucesso de venda do parto (CS), idade na primeira gestação (AFP), peso ao desmame (WW), peso ao ano (WY), peso aos 15 meses de idade (W15), peso aos 18 meses de idade (W18), rendimento de carcaça (DP), classificação de qualidade do USDA (QG) e classificação de rendimento do USDA (YG). No rebanho BRA e no cenário simulado de reprodutores, o sucesso de venda do parto foi a característica economicamente mais importante, seguida por AFP, DP, QG, WY, YG, W15 e WW. No rebanho MAB e nos três cenários simulados, o sucesso de venda do parto também foi a característica mais valorizada, seguida por AFP, DP, QG, YG e características de crescimento. A importância relativa das características de crescimento no rebanho MAB e nos cenários simulados variou de acordo com o objetivo de comercialização, destacando a necessidade de alinhar a seleção para essas características conforme a estratégias de venda do sistema. Em conclusão, os valores econômicos específicos de cada característica permitem o desenvolvimento de estratégias de seleção para melhorar a eficiência do progresso genético. De modo geral, os resultados apoiam decisões de melhoramento genético baseadas em dados para otimizar a produtividade, a rentabilidade e o progresso genético por meio da seleção de múltiplas características.

Palavras-chave: decisões de melhoramento genético, índices de seleção, lucratividade, seleção de múltiplas características

ABSTRACT

This study aimed to estimate trait-specific economic values for use as weights in economic selection indexes for Brahman and Angus–Brahman beef cattle operations. Economic values (EVs) were derived for fertility, growth, and carcass traits using the UF Purebred Brahman and the UF Multibreed Angus–Brahman (MAB) herds as a reference population. Bioeconomic models were developed using herd variable costs, revenues, and management data collected from February 2024 to May 2025. The BRA herd is a seedstock production operation focused on the breeding and marketing of registered, genetically superior purebred animals, providing genetic material to support the long-term sustainability of the beef cattle industry. In addition to the BRA herd, a simulated scenario was developed to represent a broader range of seedstock operations in the Southeastern United States. Offspring from the BRA herd and the seedstock scenario were either sold at weaning or yearling, retained as replacements, slaughtered for carcass evaluation, or sold for breeding purposes. The MAB herd is a cow-calf operation that focuses on breeding cows to produce one healthy, marketable calf per cow per year, supplying the beef industry with enough and high-quality meat. In addition to the MAB herd, three simulated scenarios were developed to represent a broader range of cow–calf operations in the Southeastern United States. Offspring from the MAB herd and from the simulated scenarios were either sold at weaning or yearling, retained as replacements, or marketed to a meat processor. EVs were estimated as the expected change in profitability resulting from a one-unit change in performance of a specific trait, while holding all other traits constant. EVs were estimated for calving success-to-sale (CSS), age at first pregnancy (AFP), weaning weight (WW), yearling weight (WY), weight at 15 months of age (W15), weight at 18 months of age (W18), dressing percentage (DP), USDA quality grade (QG), and USDA yield grade (YG). In the BRA herd and the simulated seedstock scenario, calving success-to-sale was the most economically important trait, followed by AFP, DP, QG, WY, YG, W15, and WW. In the MAB herd and the three simulated scenarios, calving success-to-sale was also the most highly valued trait, followed by AFP, DP, QG, YG, and growth traits. The relative importance of growth traits in the MAB herd and simulated scenarios varied by marketing endpoint, highlighting the need to align selection for growth traits with revenue-generating sale strategies. In conclusion, trait-specific economic values enable selection strategies for improving the efficiency of genetic progress. Overall, the results support data-driven breeding decisions to optimize productivity, profitability, and genetic progress through multiple-trait selection.

Keywords: breeding decisions, multiple-trait selection, profitability, selection index

LISTA DE TABELAS

LISTA DE ABREVIATURAS E SIGLAS

ABNT	Associação Brasileira De Normas Técnicas
ADG	Average daily gain
AFP	Age at first pregnancy
AI	Artificial insemination
BRA	UF Purebred Brahman herd
CSS	Calving-to-sale success
cwt	100-pound carcass weight (hundredweight)
DMI	Daily total dry matter intake
DP	Dressing percentage
EV	Economic Value
QG	USDA quality grade
UFU	Universidade Federal de Uberlândia
UF	University of Florida
USDA	United State Department of Agriculture
WW	Weight at weaning
WY	Weight at yearling
W15	Weight at 15 months of age
W18	Weight at 18 months of age
YG	USDA yield grade

SUMÁRIO

CAPÍTULO 1 - CONSIDERAÇÕES GERAIS

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INTRODUCTION

When a single trait drives selection without consideration of its correlation with other economically important traits, negative and unintended consequences can arise (Richardson, 2023). Historically, beef cattle breeding programs have emphasized profit generation by selecting high-producing animals; for instance, faster-growing animals have typically been favored. However, the long-term sustainability of the beef cattle industry depends on cows consistently producing offspring capable of yielding sufficient quantities of high-quality beef in an efficient and environmentally responsible manner.

The United States (U.S.) beef industry includes numerous breeds selected to thrive in diverse environments across a wide geographic range, with Angus genetics present in over 80% of beef cattle, while many smaller breeds contribute to regional adaptation, heterosis, and specialized markets. Many cow–calf producers exploit heterosis to improve performance and adaptability (Van Eenennaam et al., 2014). In the Southern U.S., a significant proportion of cattle contain Brahman genetics to cope with summer conditions, as Bos indicus breeds are well adapted to tropical climates (Hansen, 2004; Scheffler, 2022). However, Bos indicus cattle generally produce carcasses with lower fat-to-lean ratios, reduced meat tenderness, and less intramuscular fat compared to Bos taurus animals (Thrift & Thrift, 2003). Despite the importance of breed composition on adaptation and production, there is limited information on the economic impact of key traits in purebred Brahman and Brahman influenced beef cattle operations.

It is noteworthy that because animals change ownership multiple times within the beef industry, phenotypic information on carcass and meat quality from packing plants frequently fails to return to the original seedstock operations (Van Eenennaam, 2014; Rowan, 2025). This lack of feedback limits breeders' ability to accurately evaluate the genetic merit of their animals' offspring for end-product quality, potentially slowing genetic progress and reducing the efficiency of selection decisions. As a result, there is a critical need for studies that provide economically grounded trait values to guide selection in systems where direct carcass and performance feedback is limited, such as those involving purebred Brahman and crossbred Angus × Brahman operations

An ideal genetic evaluation system in the beef industry should encompass all traits that contribute to overall industry profitability (Rowan, 2025). Seedstock and cow-calf operations must supply genetics that promote growth and carcass quality in feeder calves while also supporting strong, functional maternal performance in replacement heifers (Devani et al., 2021). As a result, the need to expand selection criteria to include other traits has become increasingly recognized (Cole & VanRaden, 2018). Doing so optimizes not only producer profitability but also long-term industry sustainability. Despite this, the U.S. beef industry still relies primarily on expected progeny differences for single traits rather than on comprehensive multi-trait selection tools (Garrick & Golden, 2009).

The economic selection index is considered the most efficient methodology for multiple-trait selection because it incorporates trait-specific economic values, thereby optimizing both genetic progress and overall profitability (Hazel, 1943). Multiple-trait selection has become the preferred strategy for enhancing aggregate genetic merit, as it allows simultaneous improvement across traits while accounting for their genetic correlations. Despite its advantages, practical implementation can be challenging because the economic importance of individual traits varies both within and across sectors of the beef cattle industry. Economic values can also differ between breeds and even between regions within the same breed (Hazel, 1943). Moreover, they should be periodically updated to reflect the evolving needs of farmers across different environments and payment systems, to incorporate new traits, and to account for changing economic conditions and genetic parameters both across and within traits (Cole & VanRaden, 2018). Nonetheless, multiple-trait approaches with appropriately derived economic values provide a robust framework for aligning financial, genetic, and production objectives, ultimately supporting a more sustainable beef cattle industry (Souza et al., 2022).

Decisions about which traits should be included in a breeding objective should be based strictly on their economic grounds rather than on how difficult or easy they are to measure or change genetically (Newman & Ponzoni, 1989). Factors such as management practices, animal performance, and economic components, including both revenues and costs, must be considered to define breeding objective traits and estimate their economic values. Economic values quantify the expected change in profit resulting from one unit of genetic improvement in a trait and serve as key parameters for guiding breeding decisions (Krupová et al., 2020). They ensure that each trait receives the appropriate emphasis within the breeding strategy (Konig & May, 2019), aligned with the specific priorities and production goals of individual herds.

The American Brahman Breeders Association (ABBA) provides breed-specific genetic selection indexes that assist breeders in making informed breeding decisions based on multiple traits of economic importance. ABBA currently offers two primary selection indexes: the

$Queen Index, a maternal index designed to rank animals for their ability to produce high-quality replacement females by combining multiple traits such as scrotal circumference, docility, and calving ease, and the $Bull Index, a terminal index focused on identifying cattle suited for market endpoints with emphasis on growth, frame, and carcass-related traits. $Queen Index helps breeders select females with superior reproductive and maternal potential without increasing mature cow size or milk beyond the intended breeding objective, whereas the $Bull Index tends to select bulls with larger frames and enhanced growth potential that perform well under grid market pricing systems. These indexes illustrate how ABBA remain primarily maternal or terminal rather than truly balanced indexes encompassing both maternal and terminal traits simultaneously, highlighting a gap that broader economic selection indexes aim to fill.

The International Brangus Breeders Association (IBBA) offers indexes tailored to common breeding goals in Brangus herds. Similar to the ABBA indexes, IBBA has a Maternal Economic Index to rank replacements and cows with superior fertility, milk production, and longevity potential, and a Terminal Economic Index to identify sires with greater growth, carcass merit, and market performance, providing a structured approach to multi-trait selection. Recently, the IBBA launched the Brangus Built Index, which placed equal emphasis on maternal and terminal traits, helping ranchers select animals that simultaneously contribute to herd productivity and end-product quality when those dual goals are desired. However, unlike some breed associations that publish fully standardized $Value indexes with explicit economic weights, the IBBA does not routinely report formal economic value coefficients for individual traits. Additionally, in the Brangus Built Index, maternal and terminal components are combined with equal emphasis rather than weighted by system-specific economic returns.

Objectives

This study aimed to estimate the economic values of fertility, growth, and carcass traits for a purebred Brahman seedstock operation and for a crossbred Angus x Brahman cow-calf operation in the Southeastern United States.

LITERATURE REVIEW

Beef Cattle Industry in the United States

In 2024, U.S. cattle production accounted for approximately 22% of total receipts from agricultural commodities. Additionally, the U.S. is the world's largest producer of fed cattle and the largest consumer of beef (USDA, ERS, 2025). Beef cattle are distributed primarily across the U.S. Central region (roughly 55%), followed by the Western and Southeastern regions with 20% each, with the remaining 5% located in the Northeast, Alaska, and Hawaii. Livestock grazing encompasses 41% of the total land area of the United States (USDA, ERS, 2025).

The United States beef industry is highly segmented, operating across multiple production stages and over a wide geographic area. Given the broad range of environments across the United States, beef production systems vary substantially, shaped by differences in climate, feed resources, and management practices. This heterogeneity is further reflected in cattle phenotype and production strategies. More recently, vertical alignment among production segments and with downstream markets such as wholesalers, retailers, and food services has become a defining feature of the industry, enhancing supply chain coordination and responsiveness to consumer demand (Drouillard, 2018).

Seedstock operations constitute a specialized segment of the beef cattle industry that focuses on producing genetically superior breeding animals, including bulls, replacement heifers, semen, and embryos, for sale to commercial cow-calf producers and other seedstock operations. These operations typically maintain purebred herds registered with breed associations and collect extensive pedigree and performance data to support formal genetic evaluations to the estimation of expected progeny differences, which guide genetic improvement and selection decisions. Although seedstock producers represent a relatively small proportion of U.S. beef cattle operations (approximately 5–6% according to national surveys), their role is fundamental in supplying the genetic base that influences the productivity and efficiency of downstream production segments, including cow-calf, stocker, and feedlot operations (USDA, 2020).

In the Southeastern seedstock operations, herds with 1 to 49 head account for 72.9% of operations, those with 50 to 99 head are 16.1%, and herds with more than 100 head account for 11% of all operators with a seedstock herd (Adkins & Riley, 2012). Additionally, variability in weaning weight and weaning rate is expected to be lower in seedstock herds than in commercial cow-calf herds, reflecting the genetic focus and higher management intensity characteristics of purebred seedstock programs (Adkins & Riley, 2012).

Cow-calf operations form the foundation of the beef cattle industry by producing weaned calves and are widely distributed across all 50 U.S. states. In the southeastern U.S., this production type is particularly prevalent due to regional climate, forage resources, and land use patterns. In this region, cow-calf enterprises are typically smaller in herd size and acreage compared with operations in other U.S. regions, with the majority of farms maintaining fewer than 50 cows and relying on extensive pasture grazing coupled with limited supplemental feeding. This production structure reflects both the natural resource base and land availability in the Southeast (McBride & Mathews, 2011).

Research indicates that approximately 70% of calves produced in the southeastern region are sold at weaning, highlighting the dominant marketing strategy among these producers and the importance of early growth and reproductive traits in their economic performance (Gillespie et al., 2023). Weaned calves can follow one of two primary pathways: they may be transferred directly to feedlots as ‘calf-feds,’ or they may enter a backgrounding or stocker program to grow being transferred to feedlots as ‘yearlings.’ Calf-fed cattle typically remain in the feedlot for an extended finishing period, whereas yearlings spend additional time grazing or being backgrounded on forage before finishing. The relative price of grain and forage also influences the timing of feedlot entry, since pasture and forage resources are used to grow calves after weaning, while high-energy grain diets are used in feedlots to achieve market weight (Drouillard, 2018).

Backgrounding and stocker operations represent an intermediate phase in U.S. beef cattle production, positioned between cow-calf weaning and feedlot finishing. During this phase, which typically lasts 60 to 300 days, weaned calves are raised on pasture, conserved forages, or supplemental rations to increase body weight (approximately 295 to 410 kg) and frame development. This growth prepares calves for the transition to the feedlot without excessive fat deposition. In some cow–calf systems, producers retain ownership of calves and manage this phase as an integrated component of their overall production strategy (USDA, APHIS 2012).

Although the backgrounding and stocker segment is smaller than cow-calf production in the Southeast, it remains an important value-adding opportunity for producers. This phase allows calves to develop immunity, adapt to feed, and achieve more uniform weights prior to feedlot entry, which can ultimately enhance feedlot performance and carcass outcomes (Anderson et al., 2003).

Feedlot operations feed cattle high-concentrate diets to promote rapid weight gain and fattening prior to slaughter (Drouillard, 2018). Over 72% of U.S. feedlot operations are located in five states: Nebraska, Texas, Kansas, Iowa, and Colorado (USDA-ERS, 2025), which is largely attributed to access to low-cost feedstuffs. Feedlot rations rely heavily on cereal grains and grain byproducts. Naturally, large slaughterhouses are also located in this region. As a result, cattle originating in the southeastern United States are often finished in feedlots outside the region following stocker or backgrounding phases. The feedlot phase usually lasts between 100 and 300 days, with cattle marketed at approximately 15 to 28 months of age (Drouillard, 2018).

The U.S. quality grading system applies price discounts for carcasses that are undersized (<250 kg) or oversized (>430 kg), as well as to carcasses assigned higher yield grade categories (4 or 5), thereby discouraging the over-fattening of cattle. Yield grade reflects the amount of fat in the subcutaneous, intermuscular, and peritoneal regions of the carcass. In contrast, premiums are awarded for carcasses exhibiting high levels of marbling, including those grading Choice, Certified Angus Beef®, and Prime. The USDA Agricultural Marketing Service currently recognizes more than 90 federal beef certification programs, approximately 80 of which were established in 2000 or later. Consumer demand is the primary driver of these carcass specifications. Given this, the objective of U.S. feedlots is to produce young cattle with carcass weights ranging from 250 to 430 kg, exhibiting ample tenderness and relatively high intramuscular fat content.

Artificial insemination (AI) is a relatively simple technology that intensifies selection through the use of genetically superior males. Although AI has been adopted by beef producers, overall usage remains low, especially in extensive beef production systems, due to challenges associated with synchronization protocols and estrus detection. To address this limitation, timed artificial insemination (TAI) protocols were developed, enabling scheduled insemination without the need for estrus detection (Van Eenennam, 2025). Despite these advancements, AI is currently used in only approximately 10% of U.S. beef females.

Overall, the U.S. beef cattle industry operates as a complex, vertically connected system in which decisions made at one stage affect performance and profitability downstream. Seedstock, cow–calf, stocker, and feedlot operations each play a distinct role in converting genetic potential into marketable beef, while regional differences, particularly in the southeastern United States, shape production practices and marketing strategies. As consumer preferences and carcass specifications continue to influence market outcomes, understanding the economic importance of key fertility, growth, carcass, and meat quality traits is critical for guiding selection decisions and supporting the long-term sustainability of the industry.

Brahman influence in the U.S. beef herd

The U.S. beef herd is highly heterogeneous, comprising more than 80 breeds and their crosses. However, the most used breeds include Angus, Hereford, Simmental, Red Angus, Charolais, Gelbvieh, Brangus, Limousin, Beefmaster, Shorthorn, and Brahman. Angus-influenced cattle account for more than 60% of animals harvested in the United States (National Pedigree Livestock Council). Producer profitability depends in part on the ability to identify appropriate breeds and select animals with desirable genetic and phenotypic traits.

Cattle have been selectively bred to meet the evolving needs of the beef industry. Modern cattle are descended from two species of wild cattle, *Bos taurus* and *Bos indicus*. The American Angus is a taurine beef cattle breed that originated in northeastern Scotland, specifically in the counties of Aberdeen and Angus (formerly Forfarshire), during the 18th century. Developed from native Scottish cattle, Angus genetics have since become among the most influential worldwide. Angus cattle are known for efficient feed conversion and strong reproductive performance, including calving ease and favorable maternal traits. Additionally, the breed is widely recognized for its superior meat quality, particularly its ability to deposit intramuscular fat, which enhances tenderness, flavor, and overall consumer acceptance.

The Brahman, or American Brahman, is an American breed of zebuine–taurine hybrid beef cattle developed in the United States beginning in 1885. Its foundation stock originated from cattle imported primarily from India, with additional imports routed through the United Kingdom, India, and Brazil. These imports consisted primarily of Gir, Guzerá, and Nelore cattle, with smaller contributions from Indu-Brasil, Krishna Valley, and Ongole breeds. Today, the Brahman breed is distributed worldwide, with significant populations in Australia, South America, and throughout the southern United States. In Australia, it is the most numerous cattle breed.

The American Brahman is characterized by its exceptional tolerance to heat, sunlight, and humidity, as well as resistance to parasites, traits that make it particularly suited to hot, humid environments and marginal feeding conditions. Its adaptive features include loose skin, a short coat that reflects solar radiation, and efficient thermoregulation, allowing Brahman cattle to thrive where many European breeds often struggle. Brahman cattle are primarily reared for beef production, especially in regions that demand resilience to environmental stressors, and they are frequently used in crossbreeding programs to enhance traits such as heat tolerance, hybrid vigor, and environmental adaptability in progeny. While Brahman meat is generally leaner than that of specialized European beef breeds, their contribution to composite breeds has enabled the combination of environmental adaptability with improved growth performance and carcass quality, making them a cornerstone of beef production in challenging climates worldwide.

The superiority of crossbred animals is attributed to the combination of complementary breed traits through additive genetic effects and heterosis (Elzo & Wakeman, 1998). Brahman cattle are more resilient to heat stress than Angus cattle (Hansen, 2004); however, they tend to exhibit less favorable productive traits, such as reduced feed efficiency, delayed reproductive maturity, and leaner and tougher beef (Cooke et al., 2020). Crossbreeding *Bos indicus* and *Bos taurus* cattle, such as Brahman × Angus, is therefore a common strategy to mitigate undesirable traits while enhancing overall productivity in tropical and subtropical regions (Lamy et al., 2012). The combination of environmental adaptability, resilience, and improved meat quality makes this crossbreed particularly valuable to the beef cattle industry.

Market incentives associated with carcass quality have accelerated the integration of Angus genetics into crossbreeding programs across the United States, including the southeastern region, where Angus is frequently combined with *Bos indicus* breeds such as Brahman to balance heat tolerance, environmental adaptability, and carcass quality (Garrick & Golden, 2009). Recent evidence suggests that moderate to moderately high levels of Brahman genetics (approximately 21% to 78%) are associated with greater productivity in subtropical Brahman × Angus cows (Martins et al., 2024).

Economically relevant traits

Economically relevant traits (ERTs) are defined as traits that directly influence the profitability of a production system by affecting either revenues or costs (Ponzoni & Newman, 1989). These traits form the basis of the breeding objective and determine the direction of genetic improvement within a given production environment (Hazel, 1943). Genetic improvement is a permanent and cumulative process and therefore represents one of the most effective approaches for achieving sustained profitability gains.

The underlying principle of genetic improvement is selecting above-average individuals as parents of the next generation, so that subsequent generations are expected to exhibit superior genetic merit. The history of genetic improvement in beef cattle reflects a transformation from informal, phenotype-based selection to highly quantitative, data-driven evaluation systems (Van Eenennam et al., 2014). Modern breeding programs leverage extensive phenotypic databases, advanced statistical models, and genomic information to estimate genetic merit for a broad range of economically relevant traits with precision. This progress allows for more accurate selection decisions and the intensified use of genetically superior parents across generations (Van Eenennam, 2025).

In beef cattle operations, ERTs typically include reproductive efficiency, growth performance, feed efficiency, carcass yield, and meat quality, as these traits collectively determine biological efficiency and economic return (Goddard, 1998). The economic importance of a trait depends on the production system, market structure, and management practices, meaning that ERTs may differ across regions, breeds, and sectors of the beef industry (Krupová et al., 2008; König & May, 2019). Because genetic resources are limited, emphasizing ERTs ensures that selection pressure is applied to traits that contribute most to long-term profitability and sustainability, rather than to traits chosen solely for ease of measurement or tradition (Cole & VanRaden, 2018).

Reproductive traits

The number of animals available for market mainly depends on herd reproductive ability, followed by overall health and survival rates. Poor reproduction and fertility are major contributors to on-farm inefficiencies and profit losses, serving as a primary reason for culling, reducing cow longevity, and increasing the need for replacements (Richardson et al., 2023). Additionally, reducing replacements and adjusting herd structure offer opportunities to reduce greenhouse gas emissions (López-Paredes et al., 2018). Therefore, selection for improved reproductive performance in females offers both sustainability benefits and conventional profitability gains.

According to Beef Improvement Federation (BIF) guidelines, the most common reproduction traits are calving interval, gestation length, heifer pregnancy, reproductive tract score, scrotal circumference, and stayability.

Calving interval is the number of days between consecutive calvings and is a crucial metric for herd productivity and profitability. The lifetime average calving interval is calculated as the total number of days between the first and last calving divided by the number of calvings. Cows with consistently short calving intervals are more likely to rebreed successfully within the breeding season. Genetic studies have consistently shown that calving interval has low heritability (heritability estimates for first calving interval range from approximately 0.01 to 0.15 in different beef cattle populations), indicating that environmental and management factors explain much of the observed variation, and direct selection for this trait yields slow genetic progress (Brzáková et al., 2020).

Gestation length, the period from conception to birth, varies by calf sex, breed, and genetic group. This emphasizes the relevance of tailoring breeding season length and nutritional management to genetic groups to maximize reproductive efficiency and economic returns in beef production (Inez Aniceto et al., 2025). Thus, monitoring gestation length in a herd and understanding these variations can be economically beneficial for producers.

Heifer pregnancy, or age at first conception, directly influences the retention of replacement heifers. It is defined as the probability of successful conception and predicts differences among individuals in their daughters' ability to conceive and calve at two years of age. Heifer pregnancy is a critical determinant of lifetime productivity and profitability in beef cattle systems. Heifers that conceive earlier in the breeding season not only enter the cow herd sooner but also tend to have improved long-term fertility outcomes, suggesting that selection for early fertility traits could enhance reproductive efficiency across generations (Wathes et al., 2014). Additionally, heifers born in the first 21 days of the calving period are more likely to cycle by the start of their breeding season once mature and are more likely to have better lifetime reproduction outcomes (Richardson et al., 2023). Pregnancy rate and related fertility measures often exhibit low heritability (0.02–0.18), while age at first calving and heifer pregnancy can show moderate heritability (0.17–0.33), indicating potential for genetic improvement with appropriate selection (Moorey & Biase, 2020).

Reproductive tract score evaluates heifer reproductive maturity on a scale from 1 to 5 based on ovarian follicular development and palpable size of the uterus four to six weeks before the breeding season. This timing provides a check on heifer development and allows time to make nutritional program adjustments when needed. A score of 1 indicates an infantile tract with tiny ovaries and no evidence of follicular development. A score of 2 is considered prepubertal, with slightly larger ovaries and very small follicles. A score of 3 reflects heifers prepubertal, characterized by increased uterine development and the presence of small follicles. A score of 4 suggests that the heifer is pubertal, with well-developed reproductive organs and either large follicles or the presence of a corpus luteum. Finally, a score of 5 corresponds to a pubertal state with a functional corpus luteum and strong uterine tone.

Scrotal circumference in yearling bulls (320 and 440 days old) is positively associated with sperm production, earlier puberty, and reproductive performance in daughters. Measurements are taken using a scrotal tape around the widest part of the fully extended scrotum. While scrotal circumference is an indicator of male fertility, it should be combined with semen quality traits, such as semen production (concentration, sperm count, and volume), quality (mass activity), motility (motility score and progressive motility), and morphology (percentage of live sperm) (Richardson et al., 2023).

Stayability, also called the length of productive life or productive longevity, reflects the probability of a cow surviving to her cost-breakeven age, typically six years, by which time five consecutive calves are needed to offset development and maintenance costs. Calving first as a two-year-old can indicate opportunity, and a calf every year through age six years may be required for success. Heritability estimates for stayability range from approximately 0.05 to 0.15 in both dairy and beef populations, suggesting slow genetic improvement (Ramos et al., 2020). Furthermore, stayability shows genetic associations with other economically important traits, including reproductive measures such as age at first calving in dairy cattle, and correlations with body weight and scrotal circumference in beef breeds, illustrating the interconnected nature of longevity and production traits in genetic evaluations (Ramos et al., 2021).

Growth traits

Increasing growth rate and then decreasing slaughter time can lower lifetime methane production per animal by 34-54% (Mccrabb et al., 1998), demonstrating that faster-growing animals require less total feed for maintenance during the growth period, which directly affects economic efficiency (Richardson et al., 2023).

According to the BIF guidelines, the most common growth traits are average daily gain, birth weight, weaning weight, yearling weight, mature weight, and hip height.

Average daily gain is calculated as the total weight gain between two measurements divided by the number of days between them. Because growth is non-linear, the time interval between measures should be sufficiently short, and comparisons should be made when animals are at the same phase of the growth curve.

Weight-related traits, including birth weight, weaning weight, yearling weight, and mature weight, are central to beef cattle breeding objectives because they directly influence productivity, biological efficiency, and profitability. These traits are generally moderately to highly heritable and genetically correlated, reflecting shared biological mechanisms underlying growth across different life stages. Understanding these correlations is therefore critical for informed breeding decisions, as selection on a single weight trait can generate unintended correlated responses in other traits (Arango et al., 2002).

Birth weight is a key indicator of calf viability and growth potential. However, there is a trade-off between birth weight and calving ease. Thus, it should be considered as an indicator trait for calving ease and should never be considered in a selection for a single trait because selection for lighter birth weight may reduce calf viability and growth rate from birth to maturity.

Weaning weight should never be estimated by averaging a group weight. Weaning weights are affected by the animal's age and should be adjusted accordingly, typically to a standard age of 205 days. Weaning weight is economically relevant in operations that sell calves immediately after weaning, as it directly affects revenue.

Yearling weight reflects both pre-weaning and post-weaning growth and may serve as the primarily economically relevant trait depending on the production system.

Mature weight affects the nutritional requirements of the cow herd, as heavier cows require more feed to maintain body condition. Mature weight is recorded annually and adjusted for age, particularly for young females who are still growing.

Hip height is used to determine the frame score, which predicts the animal's growth potential and lean-to-fat ratio, providing important information for breeding and selection decisions.

Carcass traits

Carcass traits directly influence saleable yield and pricing at harvest. Dressing percentage is a particularly important indicator of biological efficiency, as higher dressing percentages result in greater carcass weight and revenue per live animal. Variation in dressing percentage is influenced by genetic factors, body composition, and management practices, including fatness, muscling, and gut fill at slaughter (Coyne et al., 2019).

Improvements in meat quality, especially those associated with increased intramuscular fat, have been shown to enhance consumer acceptance and generate price premiums across retail and food service sectors (Lusk et al., 2018). Consequently, carcass traits are not only biologically but also economically relevant, reinforcing their inclusion in breeding objectives aligned with consumer-driven market demands.

According to the BIF guidelines, the most common carcass and meat quality traits include backfat thickness, carcass weight, dressing percentage, intramuscular fat, marbling score, ribeye area, and shear force.

Backfat thickness estimates external fat deposition and is measured at the 12th rib, perpendicular to the outside fat, approximately three-fourths of the length of the ribeye muscle from the backbone. It is the primary driver of yield grade, as increased external fat reduces the percentage of retail product. Backfat thickness is generally included in a multiple-trait selection model to prevent undesirable increases in fat deposition while ensuring adequate meat quality. Ultrasound measurements can be used as an indicator of traits for backfat thickness.

Carcass weight is the weight of the carcass as it leaves the slaughter floor and represents a direct source of revenue, especially for producers who retain ownership through finishing and market cattle carcass-weight basis.

Dressing percentage is calculated as the ratio of hot carcass weight to live weight multiplied by 100. Cattle with greater musculature at harvest tend to have a higher dressing percentage, whereas those with lighter musculature exhibit lower values. The typical range for dressing percentages is from 55 to 70%, with the current U.S. average at 63.24%.

Intramuscular fat (IMF) is strongly correlated with the USDA marbling score. Relationships between marbling scores and intramuscular fat percentages indicate that carcasses with *Slightly Abundant* marbling present on average 10.13% IMF, while those classified as *Moderate* and *Modest* marbling correspond to 7.25% and 6.72%, respectively. Carcasses with a *Small* marbling score contain around 5.04% IMF, whereas *Slight* and *Traces* marbling scores correspond to 3.83% and 2.76%, respectively.

Marbling refers to flecks of fat within the lean muscle and is the primary determinant of USDA quality grade once physiological maturity is established. Marbling is evaluated either visually or using camera-based systems in the ribeye muscle exposed between the 12th and 13th ribs. Increased marbling is associated with improved tenderness, juiciness, and flavor. USDA quality grades range from Prime, characterized by Abundant (9.0–9.9), Moderately Abundant (8.0–8.9), or Slightly Abundant (7.0–7.9) marbling; to Choice, characterized by Moderate (6.0–6.9), Modest (5.0–5.9), or Small (4.0–4.9) marbling; to Select, characterized by

Slight (3.0–3.9) marbling; and Standard, characterized by Traces (2.0–2.9) or Practically Devoid (1.0–1.9) marbling.

Ribeye area is an indicator of muscling and is measured on the longissimus or ribeye muscle at the 12th rib using a grid, ribeye tracing with a compensating polar planimeter, or ultrasound. Accurate measurement depends on three major items: clear and distinct medial and lateral end borders, not being over any portion of the 12th or 13th rib, and good transducer-animal contact. Ribeye area contributes to the yield grade equation, but to a lesser degree than does backfat thickness.

Shear force, an objective measure of tenderness, is used to predict the expected overall eating satisfaction. Beef with lower shear force is perceived by consumers as more tender, softer, and easier to chew, and is thus deemed more palatable (Destefanis et al., 2008).

Economic Selection Indexes

Genetic improvement is a powerful strategy for enhancing beef cattle production. However, the main challenge is ensuring that selection decisions translate into tangible economic benefits for producers. Because multiple traits influence profitability, often not equally, it is necessary to prioritize traits according to their economic importance. The need to balance genetic progress with economic efficiency has led to the development of economic selection indexes, which integrate biological performance and economic information to guide breeding programs toward long-term profitability and sustainability.

Originally proposed by Hazel (1943), the selection index method assigns appropriate weights to traits of interest based on both their economic value and genetic merit. The expected response to selection is expressed as the anticipated change in profit derived from genetic improvement in the selected traits. The initial step in constructing a selection index is defining the breeding objective, which consists of traits that directly affect revenue through product sales or help lower production costs (Spangler, 2019). Depending on the production system and the animals' abilities, it is essential to identify the primary sources of income and expenses. For instance, in cow-calf operations, major costs include reproductive management, feed, replacement of females, and veterinary expenses, while revenues are derived primarily from the value of the weaned calf. Traits such as feed intake and fertility influence costs, while calf survival and weaning weight affect revenue. Choosing a breeding objective that is poorly aligned with the production system or herd structure may compromise the effectiveness of genetic improvement (Ponzoni, 1986).

Economic values (EVs) quantify the relative importance of traits within the breeding objective. An economic value is defined as the change in system profit resulting from a one-unit increase in the genetic merit of a trait, while all other traits are held constant (Hazel, 1943). Economic values are derived from one or more profit equations that describe the biological and economic factors within a production system. The profit equation is a linear function designed to represent the relationship between production performance and system profitability. In this context, the economic value of a trait corresponds to the partial derivative of the profit function with respect to that trait in the breeding objective (Bourdon, 1998). These relationships are typically modeled using bioeconomic models, which integrate biological performance, management practices, revenues, and costs specific to the production scenario being evaluated (Krupová et al., 2008).

The economic value of trait i is calculated as:

$$EV = \frac{\Delta P}{\Delta G}$$

where ΔP is the change in profit following a change in trait i, and ΔG is the corresponding change in performance of that trait i.

The choice of traits to be included in the breeding objective should be based on their relative contributions. Thus, in addition to directly contributing to profit, they must also present sufficient genetic variation so that the genetic gain in the trait alters the system's profitability (Goddard, 1998). Therefore, the weighting of each trait is calculated as:

$$REV = v_i \, \sigma a_i$$

Where: REV = relative economic value of trait i; v_i = economic value of trait i; σa_i = additive genetic standard deviation of trait i. This approach also allows for comparing the economic values of traits expressed in different measurement units.

According to Pearson (1981), for a practical approach, only traits that account for a significant proportion in the production system should be included. The author cites an example threshold of 10% of relative economic value (REV):

$$ER = \frac{REV_i}{\sum REV} \, x \, 100$$

Although economically relevant traits define the breeding objective, they may be difficult or costly to measure routinely in breeding programs. As a result, measured traits that are genetically correlated with ERTs are often used as indicators of the objective. These traits are referred to as selection criteria and should exhibit favorable correlations with the objective traits, sufficient genetic variability, and moderate to high heritability (Hazel, 1943). When information on the ERT is directly measured, indicator traits are unnecessary, and the selection criteria coincide with the breeding objective traits (Oschner et al., 2017). For instance, ribeye area and backfat thickness ultrasound measurements are indicators of yield grade. Ultrasound measurements have the advantage of being non-destructive yet informative, allowing producers to select for higher-quality grades on live animals. Ribeye area is positively associated with retail product yield, whereas increased external fat reduces saleable product. Because carcass premiums depend on balancing muscling and fatness, both traits should be jointly considered within a selection index. Selection criteria should also be periodically updated to reflect changes in market conditions and production goals. Furthermore, when two ERTs exhibit strong and favorable genetic correlations, selection emphasis may be placed on the trait with greater genetic variability, thereby reducing index complexity while still achieving correlated genetic gains.

Once the breeding objective and selection criteria are clearly defined, the selection index can be constructed. Hazel (1943) introduced the concepts of the aggregate genotype (H), or breeding objective, and the selection index (I), or selection criterion. The H is defined as a linear combination of the true breeding values of the objective traits, weighted by their respective economic values. In contrast, the I is a linear combination of phenotypic information (or predicted genetic values) for the selection criteria, weighted by regression coefficients (b), which are estimated to maximize the correlation between the I and the H. Thereby, ensuring that selection is directed toward the greatest possible improvement in overall economic merit. To estimate these coefficients, the inverse of the phenotypic (co)variance matrix of the selection criteria (P), the genetic (co)variance matrix between selection criteria and objective traits (G), and the vector of economic values for the objective traits (v) are used ($\mathrm{b} = \mathrm{P}^{-1}\mathrm{Gv}$).

In practice, Expected Progeny Differences (EPDs), estimated using Best Linear Unbiased Prediction (BLUP) methodology, are commonly used in beef cattle breeding programs. BLUP incorporates pedigree information (i.e., relationships among animals), phenotypic performance, and adjustments for environmental effects, enabling comparisons both within and across contemporary groups (Schneeberger et al., 1992). Building on this, Schneeberger et al. (1992) proposed the construction of the selection index using EPDs, in which the required information includes the EPDs themselves, the genetic (co)variances, and the economic values.

$$H = ev_1EPD_1 + ev_2EPD_2 + ... + ev_nEPD_n = ev'EPD$$

$$I = b_1EPD_1 + b_2EPD_2 + ... + b_mEPD_m = b'EPD$$

$$b = G_{11}^{-1} G_{12}\, ev$$

where ev represents economic value for each trait, b the index weights, G_{11} the matrix of genetic (co)variances among the selection criteria traits, and G_{12} the matrix of genetic (co)variances between selection criteria and breeding objective traits.

The properties of the selection index include achieving the maximum correlation between the aggregate genotype (H) and the selection index (I), maximizing the probability of selecting the individual with the highest total merit according to the weighting of traits, and ensuring maximum genetic progress in the first generation of selection (Rönnigen and Van Vleck, 1985). To this end, the correlation between I and H is estimated, which represents the selection accuracy, or the reliability of the proposed selection index.

$$r_{HI} = \frac{\sigma_{HI}}{\sigma_I \sigma_H} = \frac{b'G_{12}v}{\sqrt{(b'G_{11}b)(v'Cv)}}$$

Where: σ_{HI} is the covariance between the aggregate genotype and the selection index; σ_I represents the variance of the index; σ_H is the variance of the aggregate genotype; C represents a matrix of genetic (co)variances among the breeding objective traits.

To predict the response to selection, expressed in monetary units (e.g., $), after one generation of selection:

$$R_H = i\, \frac{b'G_{12}v}{\sqrt{(b'G_{11}b)}}$$

where i is selection intensity applied. The expected change in the additive genetic value for each breeding objective trait (**g**) after one generation of selection, according to the unit of each trait, is given by:

$$R_g = \frac{b'G_{12}}{\sqrt{(b'G_{11}b)}}$$

To ensure the reliable practical application of selection indexes in animal breeding programs, sensitivity analyses are essential. The development of a selection index assumes that genetic and phenotypic parameters, as well as their (co)variances, are known without error. In practice, however, the accuracy of these estimates depends on several factors, including the estimation method, data structure, and sample size (Oschner et al., 2017). Consequently, an index that is robust to changes in parameters and (co)variances is more efficient than one that is highly sensitive to such variations (Smith, 1983).

Index sensitivity (**E**) is calculated as the proportion of the maximum expected response to selection in the aggregate genotype if a set of variances or economic values (**u**) were used to derive the index coefficients, relative to the response obtained using the true set of variances and economic values (**t**), expressed as:

$$E = \frac{R_{Hu}}{R_{Ht}}$$

where: R_{Hu} represent the response to selection using coefficients derived from altered values; R_{Ht} the response to selection calculated using the true index values. The true correlations used in the index can be individually modified by ±0.2 or ±0.4 to assess the sensitivity of the index (Smith, 1983).

In this context, large changes in economic weights may or may not reduce index efficiency. When a single breeding objective trait dominates the relative emphasis, the index efficiency will be most sensitive to changes in the price or economic value of that trait (Smith, 1983). Variations of ±20% relative to the original values can be applied to feed costs, management, husbandry, and meat prices, using the base scenario with a constant number of animals to evaluate the index efficiency. Changes are implemented one at a time, keeping all other parameters constant (Kosgey et al., 2003).

Implications for the U.S. beef cattle industry

Overall, the literature highlights the complexity and interconnected nature of the U.S. beef cattle industry, in which genetic decisions made at the seedstock and cow–calf levels have cascading effects on productivity, profitability, and sustainability throughout stocker, feedlot, and carcass sectors. Regional differences, particularly in the southeastern United States, shape production systems and emphasize the importance of adaptability, reproductive efficiency, and early growth performance. The widespread use of crossbreeding strategies, especially Brahman × Angus, reflects the need to balance environmental resilience with carcass traits that are rewarded by the market. Across production systems, reproductive, growth, carcass, and meat quality traits emerge as the primary economically relevant traits, although their relative importance varies with management conditions and market incentives. The development and application of economic selection indexes provide a robust framework for integrating these traits into coherent breeding objectives, allowing producers to optimize genetic progress while accounting for economic trade-offs. Together, the literature underscores the need for regional appropriate, economically focused selection strategies to attend to dynamic market demands and ensure the long-term profitability and sustainability of the U.S. beef cattle industry.

REFERENCES

Adkins, T. S., & Riley, J. M. (2012). Cow-Calf Operations in the Southeastern United States: An Analysis of Farm Characteristics and Production Risks. *Southern Agricultural Economics Association Meeting*, AL, Feb 5-8.

American Brahman Breeders Association (ABBA). (2025). Available from: ABBA: American Brahman Breeders Association - The World is Better with Brahman

Anderson, J. D., Lacy, C., & Little, R. (2003). Stocker Cattle Ownership vs. Contract Grazing: a Comparison of Risk-Adjusted Returns. *Southern Agricultural Economics Association Meeting*, AL, Feb 2-5.

Arango, J. A., Cundiff, L. V., & Van Vleck, L. D. (2002). Genetic parameters for weight, weight adjusted for body condition score, height, and body condition score in beef cows. *Journal of animal science*, *80*(12), 3112-3122.

Bourdon, R.M., 1998. Shortcomings of current genetic evaluation systems. Journal of Animal Science, 76, 2308-2323. https://academic.oup.com/jas/article-abstract/76/9/2308/4625326

Brzáková, M., Čítek, J., Svitáková, A., Veselá, Z., & Vostrý, L. (2020). Genetic parameters for age at first calving and first calving interval of beef cattle. *Animals*, 10(11), 2122. https://doi.org/10.3390/ani10112122

Cole, J. B., & VanRaden, P. M., 2018. Symposium review: Possibilities in an age of genomics: The future of selection indices. *Journal of Dairy Science*, 101(4), 3686-3701. https://doi.org/10.3168/jds.2017-13335

Cooke, R. F., Daigle, C. L., Moriel, P., Smith, S. B., Tedeschi, L. O., & Vendramini, J. M. (2020). Cattle adapted to tropical and subtropical environments: social, nutritional, and carcass quality considerations. *Journal of Animal Science*, *98*(2). https://doi.org/10.1093/jas/skaa014

Coyne, J. M., Evans, R. D., & Berry, D. P. (2019). Dressing percentage and the differential between live weight and carcass weight in cattle are influenced by both genetic and non-genetic factors. *Journal of Animal Science*, *97*(4), 1501-1512.

Destefanis, G., Brugiapaglia, A., Barge, M. T., & Dal Molin, E. (2008). Relationship between beef consumer tenderness perception and Warner–Bratzler shear force. *Meat Science*, *78*(3), 153-156. http://doi:10.1016/j.meatsci.2007.05.031

Devani, K., Quinton, C. D., Archer, J. A., Santos, B. F., Martin-Collado, D., Amer, P., Pajor, E. A., Orsel, K., & Crowley, J. J., 2021. Estimation of economic value for efficiency and animal health and welfare traits, teat and udder structure, in Canadian Angus cattle. *Journal of Animal Breeding and Genetics*, 138(3), 314-325. http://doi/10.1111/jbg.12540

Drouillard, J. S. (2018). Current situation and future trends for beef production in the United States of America—A review. *Asian-Australasian Journal of Animal Sciences*, *31*(7), 1007. https://doi.org/10.5713/ajas.18.0428

Elzo, M. A., & Wakeman, D. L., 1998. Covariance components and prediction for additive and nonadditive preweaning growth genetic effects in an Angus-Brahman multibreed herd. *Journal of Animal Science,* 76(5), 1290-1302. https://doi.org/10.2527/1998.7651290x

Garrick, D. J., & Golden, B. L., 2009. Producing and using genetic evaluations in the United States beef industry of today. Journal of Animal Science, 87(suppl_14), E11-E18. http://doi:10.2527/jas.2008-1431

Gillespie, J., Whitt, C., & Davis, C. (2023). Structure, management practices, and production costs of U.S. beef cow-calf farms. *United States Department of Agriculture, Economic Research Service*, Report Number 321.

Goddard, M.E., (1998). Consensus and debate in the definition of breeding objectives. *Journal of Dairy Science*, 81, 6-18. https://doi.org/10.3168/jds.S0022-0302(98)70150-X

Hansen, P.J., 2004. Physiological and cellular adaptations of zebu cattle to thermal stress. Animal Reproduction Science. 82-83(2-83):349–360. http://doi:10.1016/j.anireprosci.2004.04.011

Hazel, L. N., 1943. The genetic basis for constructing selection indexes. *Genetics*, 28(6), 476-490. https://doi.org/10.1093/genetics/28.6.476

Inez Aniceto, J. B., do Couto, S. R. B., de Almeida Mattos, T. F., de Mello, M. R. B., Dias Barbero, M. M., & Barbero, R. P. (2025). Gestation length and growth performance in beef heifers: comparative analysis of genetic groups during first pregnancy. *Tropical Animal Health and Production*, 57(7), 305. https://doi.org/10.1007/s11250-025-04551-z

International Brangus Breeders Association (IBBA). (2025). Available from: IBBA Brangus | The International Brangus Breeders Association>

König, S., & May, K., 2019. Invited review: Phenotyping strategies and quantitative-genetic background of resistance, tolerance and resilience associated traits in dairy cattle. *Animal*, 13(5), 897-908. http://doi:10.1017/S1751731118003208

Kosgey, I.S., Van Arendonk, J.A., Baker, R.L., 2003. Economic values for traits of meat sheep in medium to high production potential areas of the tropics. *Small Ruminant Research*, 50, 187-202. http://doi:10.1016/S0921-4488(03)00102-0

Krupová, Z., Krupa, E., Zavadilová, L., Kašná, E., & Žáková, E. (2020). Current challenges for trait economic values in animal breeding. *Czech Journal of Animal Science*, 65(12). https://doi.org/10.17221/161/2020-CJAS

Krupová, Z., Oravcová, M., Krupa, E., Peškovičová, D., (2008). Methods for calculating economic weights of important traits in sheep. Slovak *Journal of Animal Science*, 41, 24-29. https://sjas.ojs.sk/sjas/article/view/428/416

Lamy, E., Van Harten, S., Sales-Baptista, E., Guerra, M. M. M., & De Almeida, A. M. (2012). Factors influencing livestock productivity. In *Environmental stress and amelioration in livestock production* (pp. 19-51). Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-29205-7_2

López-Paredes, J., Pérez-Cabal, M. A., Jiménez-Montero, J. A., & Alenda, R. (2018). Influence of age at first calving in a continuous calving season on productive, functional, and economic performance in a Blonde d'Aquitaine beef population. *Journal of Animal Science*, 96(10), 4015-4027. http://doi/10.1093/jas/sky271

Lusk, J. L., Tonsor, G. T., Schroeder, T. C., & Hayes, D. J. (2018). Effect of government quality grade labels on consumer demand for pork chops in the short and long run. *Food Policy*, *77*, 91-102. https://doi.org/10.1016/j.foodpol.2018.04.011

Martins, T., Rocha, C. C., Driver, J. D., Rae, O., Elzo, M. A., Mateescu, R. G., Santos, J. E. P., & Binelli, M. (2024). Influence of proportion of Brahman genetics on productivity of Brahman–Angus cows at weaning. *Translational Animal Science*, 8, txae093. https://doi.org/10.1093/tas/txae093

McBride, W. D., & Mathews Jr, K. H. (2011). Beef cow-calf production a lifestyle choice among many farmers. *Amber Waves*, *9*(2), 3.

McCrabb, G. J., & Hunter, R. A., (1999). Prediction of methane emissions from beef cattle in tropical production systems. *Australian Journal of Agricultural Research*, 50(8), 1335-1340. https://doi.org/10.1071/AR99009

Moorey, S. E., & Biase, F. H. (2020). Beef heifer fertility: importance of management practices and technological advancements. *Journal of Animal Science and Biotechnology*, *11*(1), 97. https://doi.org/10.1186/s40104-020-00503-9

National Pedigreed Livestock Council. (2016). Beef Breeds Registration Statistics. Available from: http://www.nplc.net/aws/NPLC/pt/sp/resources

Ochsner, K.P., MacNeil, M.D., Lewis, R.M., Spangler, M.L. (2017). Economic selection index development for Beefmaster cattle I: terminal breeding objective. *Journal of Animal Science*, 95, 1063-1070. https://doi.org/10.2527/jas.2016.1231

Ponzoni, R.W. (1986). A profit equation for the definition of the breeding objective of Australian Merino sheep. *Journal of Animal Breeding and Genetics*, 103, 342-357. https://doi.org/10.1111/j.1439-0388.1986.tb00096.x

Ponzoni, R. W., & Newman, S., (1989). Developing breeding objectives for Australian beef cattle production. *Animal Science*, 49(1), 35-47. https://doi.org/10.1017/S0003356100004232

Pearson, R.E., Miller, R.H. (1981). Economic definition of total performance, breeding goals, and breeding values for dairy cattle. *Journal of Dairy Science,* 64, 857-869. https://doi.org/10.3168/jds.S0022-0302(81)82659-8

Ramos, P. V. B., e Silva, F. F., da Silva, L. O. C., Santiago, G. G., Menezes, G. R. D. O., Soriano Viana, J. M., ... & Brito, L. F. (2020). Genomic evaluation for novel stayability traits in Nellore cattle. *Reproduction in Domestic Animals*, *55*(3), 266-273. https://doi.org/10.1111/rda.13612

Ramos, P. V. B., da Silva, L. C., da Costa Perez, B., Junior, R. A. D. A. T., de Oliveira Menezes, G. R., Alvarenga, L. C., ... & e Silva, F. F. (2021). Stayability and consecutive rebreeding ability associated to carcass and growth traits in Brazilian Nellore cattle: A Bayesian framework. *Livestock Science*, *245*, 104416. https://doi.org/10.1016/j.livsci.2021.104416

Richardson, C. M., Crowley, J. J., & Amer, P. R., (2023). Defining breeding objectives for sustainability in cattle: challenges and opportunities. *Animal Production Science*, 63(11), 931-946. https://doi.org/10.1071/AN23021

Rönningen, K., Van Vleck, L.D. Selection index theory with practical applications. IN: Chapman, A.B. (Ed.). World Animal Science. Amsterdam: Elsevier, 1985, p. 187- 222.

Rowan, T., 2025. Exploring Next-Generation Phenotyping that Drives Commercial Profitability. Angus Genetics Inc. *Imagine Forum White Paper*, 1-12. https://cd.angus.org/-/media/project/american-angus-association/angus/pdf/agi/agi_phenotyping_white_paper_final.pdf

Scheffler, T.L. (2022). Connecting heat tolerance and tenderness in bos indicus influenced cattle. *Animals* (Basel) 12(3):220. http://doi/10.3390/ani12030220

Schneeberger, M., Barwick, S.A., Crow, G.H., Hammond, K., 1992. Economic indices using breeding values predicted by blup. *Journal of Animal Breeding and Genetics*, 109, 180-187. https://doi.org/10.1111/j.1439-0388.1992.tb00395.x

Smith, C. (1983). Effects of changes in economic weights on the efficiency of index selection. *Journal of Animal Science*, 56, 1057-1064. https://doi.org/10.2527/jas1983.5651057x

Souza, F. M., Lopes, F. B., Rosa, G. J., & Magnabosco, C. U. (2022). Economic values of reproductive, growth, feed efficiency and carcass traits in Nellore cattle. *Journal of Animal Breeding and Genetics*, 139(2), 170-180. http://doi/10.1111/jbg.12652

Thrift, F. A., & Thrift, T. A. (2003). Longevity attributes of Bos indicus× Bos taurus crossbred cows. *The Professional Animal Scientist*, 19(5), 329-341. https://doi.org/10.15232/S1080-7446(15)31438-8

United States Department of Agriculture (USDA) and Animal and Plant Health Inspection Service (APHIS). (2012). The Foreign Animal Disease Preparedness and Response Plan (FAD PReP) cow-calf industry manual. *Iowa State University of Science and Technology, College of Veterinary Medicine.*

United States Department of Agriculture (USDA). (2020). Beef Cow-calf management practices in the United States, 2017, report 1. USDA–APHIS–VS–CEAH–NAHMS. Fort Collins, CO.

United States Department of Agriculture (USDA). (2025). Cattle & beef – sector at a glance. *Economic Research Service*. <Cattle & Beef - Sector at a Glance | Economic Research Service>

Van Eenennaam, A. L., Weigel, K. A., Young, A. E., Cleveland, M. A., & Dekkers, J. C., 2014. Applied animal genomics: results from the field. Annual Review Animal Bioscience, 2(1), 105-139. https://doi.org/10.1146/annurev-animal-022513-114119

Van Eenennaam, A. L. (2025). Current and future uses of genetic improvement technologies in livestock breeding programs. *Animal Frontiers*, *15*(1), 80-90. https://doi.org/10.1093/af/vfae042

Wathes, D. C., Pollott, G. E., Johnson, K. F., Richardson, H., & Cooke, J. S. (2014). Heifer fertility and carry over consequences for life time production in dairy and beef cattle. *Animal*, *8*(s1), 91-104. https://doi.org/10.1017/S1751731114000755

CAPÍTULO 2

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ECONOMIC VALUES OF FERTILITY, GROWTH, AND CARCASS TRAITS IN BEEF CATTLE SEEDSTOCK OPERATION

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Abstract

Economic values (EVs) for fertility, growth, and carcass traits were derived using the University of Florida purebred Brahman (BRA) herd as the reference population. Bioeconomic models were constructed using herd-level variable costs, revenues, and management data collected from May 2024 to May 2025. In addition to analyses based on the BRA herd, a simulated scenario was developed to represent a broader range of seedstock operations in the southeastern United States. Offspring from both the reference herd and the simulated seedstock scenario were allocated to alternative production pathways, including sale at weaning or yearling, retention as replacement breeding animals, harvest for carcass evaluation, or sale for breeding purposes. Economic values were defined as the expected change in system profitability resulting from a one-unit improvement in the performance of a specific trait, while all other traits were held constant. Economic values were estimated for calving-to-sale success (CSS), age at first pregnancy (AFP), weaning weight (WW), yearling weight (WY), weight at 15 months of age (W15), dressing percentage (DP), USDA quality grade (QG), and USDA yield grade (YG). Across both the BRA herd and the simulated seedstock scenario, calving success-to-sale exhibited the highest economic value, followed by AFP, DP, QG, WY, YG, W15, and WW. Overall, these findings support the use of data-driven, multiple-trait selection strategies to enhance productivity, profitability, and long-term genetic progress in seedstock breeding programs.

Keywords: breeding decisions, multiple-trait selection, profitability, selection index

1 | INTRODUCTION

Seedstock herds play a critical role in supplying genetic material to the beef cattle industry. The U.S. beef cattle industry comprises multiple interconnected segments, including seedstock, cow-calf, stocker/backgrounder, feedlot, packer, retailer, and consumer. Seedstock producers register purebred animals with their respective breed associations to provide high-quality genetics, including bulls, cows, replacement heifers, semen, and embryos, to improve the performance and efficiency of commercial cattle operations. According to the U.S. Department of Agriculture, approximately 5.9% of U.S. beef cattle producers operate seedstock herds (USDA, ERS, 2025). Although seedstock producers represent the smallest segment of the industry, they are the primary source of genetic improvement that drives productivity and quality throughout the beef supply chain (Koch et al., 1986). This role extends beyond increasing animal numbers and focuses on enhancing economically and biologically important traits.

Brahman cattle are known for their exceptional heat tolerance, longevity, and hybrid vigor, making them particularly valuable for improving herd performance in challenging environments (ABBA, 2026). Despite these advantages, breed composition trends in U.S. beef calves indicate a substantial decline in Brahman influence nationwide, which is mainly due to the price discounts often applied to Brahman-influenced carcasses (McCabe et al., 2020). Because cattle typically change ownership multiple times throughout the beef supply chain, phenotypic information related to carcass and meat quality generated at packing plants often fails to return to the original seedstock operation (Van Eenennaam, 2014; Rowan, 2025). This lack of feedback limits breeders' ability to accurately assess the genetic merit of their animals for end-product traits. In contrast, in the hot and humid climate of the Southeastern U.S., the proportion of Brahman-influenced cattle has remained stable over time due to the breed's superior heat tolerance and parasite resistance (McCabe et al., 2020), highlighting the importance of continued genetic improvement of the Brahman breed, particularly in this region.

Seedstock operations must provide genetics that support functional maternal performance in replacement heifers while simultaneously improving growth and carcass quality in feeder calves. Economic selection indexes represent the most efficient approach for multiple-trait selection because they integrate trait-specific economic values, thereby optimizing both genetic progress and overall profitability (Hazel, 1943). However, their implementation is challenging because the economic importance of individual traits varies across production systems, breeds, and regions (Hazel, 1943). Economic values ensure that each trait receives appropriate emphasis within a breeding objective aligned with herd-specific goals (Konig & May, 2019). Moreover, they should be periodically updated to reflect the evolving needs of farmers across different environments and marketing systems, to incorporate new traits, and to account for changing economic conditions and genetic parameters both across and within traits (Cole & VanRaden, 2018). When properly derived, economic values provide a robust framework for aligning genetic improvement with both financial and production objectives, ultimately supporting a more sustainable beef cattle industry (Souza et al., 2021).

Currently, the American Brahman Breeders Association (ABBA) offers two primary selection indexes. The $Queen Index is a maternal index designed to rank animals based on their potential to produce high-quality replacement females by combining traits such as scrotal circumference, docility, and calving ease, helping breeders select females with superior reproductive and maternal potential. In contrast, the $Bull Index is a terminal index focused on identifying animals suited for market endpoints, with emphasis on growth, frame size, and carcass-related traits, and tends to favor cattle with larger frame size and enhanced growth potential that perform well under grid-based pricing systems. While these indexes provide valuable selection tools, they primarily emphasize either maternal or terminal performance, rather than offering a fully balanced approach that simultaneously accounts for both maternal and terminal traits. This highlights the need for broader economic selection indexes that integrate fertility, growth, and carcass traits within a single breeding objective.

Thus, this study aimed to estimate the economic values of fertility, growth, and carcass and meat quality traits for purebred Brahman seedstock herd operation in the Southeastern United State.

2 | MATERIAL AND METHODS

The purebred Brahman (BRA) herd at the University of Florida has been maintained since 1949, when its first animals were registered. The research herd is located near Gainesville, Florida, and is managed under a humid subtropical climate. Data on herd management, variable costs, and revenues collected from May 2024 to May 2025 were used to develop a deterministic bioeconomic model based on animal performance.

2.1. Management of the purebred Brahman herd (seedstock operation)

The UF BRA research herd consists of approximately 200 breeding females and is managed as a seedstock operation with the objective of improving fertility, reproductive efficiency, and carcass performance in Brahman cattle adapted to subtropical conditions. Breeding occurs over a 90-day period from May to August to ensure spring calving. Cows and heifers are enrolled in an estrus synchronization protocol followed by artificial insemination (AI), after which they are exposed to clean-up bulls. Animals are managed in contemporaneous groups under grazing conditions with *ad libitum* access to water and minerals.

Mineral supplementation was on average 0.11 kg per day for bulls, cows and heifers. Daily total dry matter intake (DMI) was assumed to be on average 2% of the body weight for bulls and cows, and 2.5% of the body weight for heifers (NRC, 2020). Mean body weight for each animal category as well as other biological input parameters is reported in Table 1. Supplementation strategies varied by season due to the availability and quality of perennial pastures, and by animal class, given differences in nutrient requirements across life stages and sex.

During the breeding season, bulls and cows were supplemented with 25% of DMI as corn gluten, and heifers received 30% of DMI as a grain blend (Creep Hazen). From August to November, bulls were supplemented with 25% of DMI as soybean hulls, and heifers continued to receive 30% of DMI as Creep Hazen. From December to April, animals received a winter supplementation of 20% of DMI as bahiagrass hay, plus corn gluten. Based on DMI, the winter supplementation proportions of corn gluten accounted for 25 % of intake for bulls and cows and 30% for heifers.

The calving season extended from February to May, and calves were weaned in September at an average age of 165 days. Prior to weaning, calves remained with their dams on pasture. Calves older than 60 days were assumed to graze at 1% of their body weight in DMI and receive 0.07 kg per day of mineral supplementation, achieving an average daily gain (ADG) of 0.93 kg. After weaning, calves followed one of four pathways: (1) sold at weaning, (2) retained as replacements, (3) harvested at 15 months of age for carcass and meat quality evaluation, or (4) sold at 27 months of age for breeding purposes.

From weaning to yearling age, heifers were fed an average of 0.10 kg per day of mineral and 2.5% of their body weight in DMI, consisting of 30% corn gluten and 70% bahiagrass pasture, resulting in an ADG of 0.83 kg. During the 90 days before the breeding season or sale as breeding stock, heifers received the same amount of mineral per day and 2.5% of their body weight in DMI composed of 50% corn gluten and 50% bahiagrass pasture, with an ADG of 0.72 kg.

From weaning to yearling age, bulls were fed at 2.5% of their body weight in DMI (30% corn gluten and 70% bahiagrass pasture) and received 0.10 kg per day of mineral, achieving an ADG of 1.09 kg over 180 days. Bulls designated for carcass and meat quality evaluation at 15 months of age were castrated at yearling and fed for 90 days on the same mineral amount per day and 2.5% of their body weight in DMI, consisting of 70% mixed feed, formulated as 50% citrus pulp, 45% whole cottonseed, and 5% molasses (hereafter referred to as mixed feed), and 30% bahiagrass hay. These steers achieved an ADG of 1.72 kg, and at harvest, 40% of carcasses were classified as USDA Yield Grade 3, while 54% graded USDA Select (Table 1).

Bulls intended for breeding purposes were provided 0.10 kg per day of mineral and 2.5% of their body weight in DMI (50% corn gluten and 50% bahiagrass pasture) for 90 days post-yearling, resulting in an ADG of 0.94 kg. From 15 months to 27 months of age, these bulls were fed 2% of their body weight in DMI consisting of 50% corn gluten and 50% bahiagrass pasture, along with 0.11 kg per day of mineral, achieving an ADG of 0.46 kg.

TABLE 1

Biological input parameters (mean) of the UF Purebred Brahman (BRA) herd.

Variable	Mean
Birth weight (kg)	31.00
Weaning weight 165d (kg)	185.23
Heifer weight at 15 mo (kg)	400.00
Steer weight 15 mo (kg)	536.17
Bull weight 27mo (kg)	648.00
Bull weight (kg)	775.43
Cow weight (kg)	511.00
Cow pregnancy rate (%)	85%
Heifer pregnancy rate (%)	50%
Dressing (%)	62%
Yield grade USDA (CWT)*	
(1) +$4.00	
(2) +$2.00	39%
(3) $0	40%
(4) - $10.00	17%

(5) - $15.00	4%
Quality grade USDA (CWT)*	
(Prime) + $14.22	
(Choice) + $14.74 (>70% premium on excess)	46%
(Select) - $14.74 (> 30% discount on excess)	54%

*cwt: hundredweight of carcass.

2.2. Southeastern U.S. seedstock simulated scenario

In addition to the empirical data from the UF purebred Brahman herd, a simulated scenario was developed to represent a broader range of seedstock operations in the Southeastern United States. Because seedstock operations typically do not market animals for slaughter, as UF does to evaluate carcass and meat quality, a hypothetical scenario was constructed. The simulated seedstock scenario was constructed assuming that 40% of the total calves were sold at weaning, 15% were sold at yearling, 30% were retained as replacement heifers, and the remaining 15% were sold for breeding purposes. The biological and economic inputs used were identical to those collected from the UF herd.

This approach allowed for the evaluation of economic outcomes across alternative production strategies commonly adopted by seedstock operations in the region.

2.3. Estimation of economic values

Economic values (EVs) were expressed as dollars of profit or loss per unit change in each trait (Ponzoni & Newman, 1989). The partial derivative of the gross margin with respect to trait performance was defined as EV and it represents the expected change in profitability resulting from a one-unit change in a specific trait, while holding all other variables constant (Eq. 1). Gross margin was calculated as total revenues minus total variable costs. All calculations were performed using Microsoft Excel (Microsoft Corporation, Redmond, WA).

$$EV = \frac{\Delta G}{\Delta P} \quad \text{(Eq. 1)}$$

where EV is the economic value, ΔG is the gross margin, and ΔP is the performance variation. Revenues were derived from the sale of weaned calves, yearling calves, slaughter steers, breeding bulls and heifers, and culled cows. Sale prices for each class of animals are shown in Table 2.

TABLE 2

Economic input parameters (means) of the Purebred Brahman (BRA) herd and the southeastern U.S. seedstock scenario.

Variable	CWT*	Total
Weaning sale	$ 196.20	$ 800.50
Yearling sale	$ 196.20	$ 1,646.12
Steers sale (slaughter)	$ 281.87	$ 2,063.91
Bulls and heifers sale (breeding)	-	$ 4,500.00
Cull cows sale	-	$ 1,100.00

*cwt: hundredweight of carcass.

Breeding costs included expenses associated with artificial insemination (AI) and the purchase and maintenance of breeding bulls for natural mating. The cost of AI averaged $47.95 per female and included two doses of prostaglandin, two doses of gonadotropin-releasing hormone (GnRH), half the price of a controlled internal drug release (CIDR) device (used twice), semen, supplies, labor, and inseminator fee. Bull-related costs totaled $114.62 per cow and included annual breeding soundness examination, herd health program, purchase price, and feeding. The annual breeding soundness examination cost was $55.00 per bull. Annual health care costs were estimated at $78.85 per bull. The purchase price was assumed to be $6,000.00 per bull and was assumed to have a lifespan of four years, with a bull-to-cow ratio of 1:20. Annual feeding costs were estimated at $713.52 per bull.

The herd health program costs included annual immunization protocols and systematic parasite control, resulting in an average of $36.84 per cow per year, $33.64 per heifer per year, and $16.13 per calf weaned per year. Feed costs were calculated considering pasture, mineral supplementation, and additional feed provided to the animals. Bahiagrass pasture maintenance costs, including fertilizer and herbicide, were estimated at $0.03/kg of dry matter. Mineral supplements averaged $0.77/kg. Additional feed resources included corn gluten, soybean hulls, and mixed feed, with costs of $0.32, $0.31, and $0.28 per kg, respectively. Dry matter contents were considered at 91.25%, 88.90%, and 90% for corn gluten, soybean hulls, and the feed mix, respectively. The bahiagrass pasture was harvested on-farm to produce hay, resulting in a final cost of $0.24/kg of dry matter. Other operational costs, such as permanent labor, maintenance, fees, and taxes, were excluded because they do not vary with one-unit genetic improvement of a trait (Ponzoni & Newman, 1989).

Economic values were estimated for the following traits: calving-to-sale success (CSS), age at first pregnancy (AFP), weight at weaning (WW), weight at yearling (WY), weight at 15 months of age (W15), dressing percentage (DP), USDA quality grade (QG), and USDA yield grade (YG). CSS represents a cow's ability to produce an offspring per production cycle, defined as a cow becoming pregnant and successfully weaning a calf that is either market or retained as replacement. AFP reflects sexual precocity in replacement heifers, defined as confirmed pregnancy at 15 months of age during their first breeding season, rather than 27 months of age during the second breeding season. WW, WY, and W15 correspond to the weights used to calculate income from steers sold at these ages. DP is the proportion of meat expressed as a percentage of live weight. USDA yield grade estimates the amount of usable meat (cutability) from the carcass, with YG1 representing the highest yield (leanest, most meat) and YG5 the lowest yield (fattest, least meat). USDA quality grade estimates expected meat palatability, including tenderness, juiciness, and flavor. Common QG categories are Prime (highest marbling and palatability), Choice (slightly less marbling but still high quality), Select (leaner, with less marbling and lower tenderness), and Standard (lower grades, often used for processed products). USDA YG and QG were assigned to each carcass, and price adjustments (discounts or premiums) were applied per hundred-carcass weight (CWT). QG and YG improvements were quantified as a one-level change in grade, expressed as the corresponding change in carcass value per CWT.

3 | RESULTS

Revenues, variable costs, and gross margin per cow per production cycle for both production systems are presented in Table 3. In the UF purebred Brahman herd, gross margin averaged \$528.44 per cow per production cycle, whereas the seedstock scenario generated \$508.95 gross margin per cow per production cycle.

Because biological and economic inputs were held constant across scenarios, the observed difference in gross margin between the UF BRA herd and the seedstock scenario was driven by differences in marketing strategies. The BRA herd achieved higher revenues by marketing a portion of animals for slaughter at 15 months of age, whereas the seedstock scenario marketed animals as yearlings. Although the BRA system incurred higher variable costs associated with the extended feeding and finishing, the increased carcass value more than offset these costs, resulting in greater gross margin per cow per production cycle.

TABLE 3

Revenues, variable costs, and gross margin per cow per production cycle for the Purebred Brahman (BRA) herd and the southeastern U.S. seedstock scenario.

Variable	BRA ($)	Seedstock ($)
Revenues (a)	**1,634.78**	**1,572.17**
Weaning	320.20	320.20
Meat/yearling	309.59	246.98
Breeding	675.00	675.00
Culled	330.00	330.00
Variable costs (b)	**1.106.34**	**1,063.22**
Weaning	315.69	315.69
Meat/yearling	181.40	138.28
Breeding	284.20	284.20
Culled	325.05	325.05
Gross margin (a–b)	**528.44**	**508.95**

These herd-specific economic parameters were subsequently used to estimate EVs for fertility, growth, and carcass traits.

Estimated EVs for calving-to-sale success, age at first pregnancy, weight at weaning, weight at yearling, weight at 15 months of age, dressing percentage, USDA quality grade, and USDA yield grade are presented in Table 4. All traits exhibit positive economic values, except YW in the BRA herd, which showed negative value due to the absence of direct yearling revenue in this production system. Across both systems, CSS was the most economically important trait, followed by AFP. Among growth traits, WY had the greatest economic importance in the seedstock scenario due to direct commercialization at yearling age, whereas W15 was more relevant in the BRA herd because of its slaughter-based marketing strategy. Weaning weight showed lower economic values relative to post-weaning growth traits. Among carcass traits, dressing percentage had the highest economic value in both scenarios,

TABLE 4

Economic values of fertility, growth, and carcass traits for the Purebred Brahman (BRA) herd and the southeastern U.S. seedstock scenario.

Objective	Traits	Unit	BRA	Seedstock

Reproduction	Calving success-to-sale	Cow	$ 991.04	$ 972.13
	Age at first pregnancy	Heifer/year	$ 804.35	$ 804.35
Growth	Weight at weaning	kg	$ 3.49	$ 3.49
	Weight at yearling	kg	$ (0.66)	$ 4.15
	Weight at 15 mo	kg	$ 3.67	
Carcass	Dressing	%	$ 33.29	$ 33.29
	USDA Quality	cwt	$ 16.33	$ 16.33
	USDA Yield	cwt	$ 3.72	$ 3.72

Differences in the economic value of CSS among the BRA herd and the seedstock scenario were primarily driven by differences in marketing strategies. In the BRA system, calves retained to slaughter at 15 months generated greater added value than calves sold at yearling age in the seedstock scenario, increasing the marginal economic importance of successful calving-to-sale.

The same EV was observed for AFP in both the BRA herd and the seedstock scenario. This value reflects the potential to increase profitability by reducing unproductive costs associated with delayed heifer conception, as postponing conception from 15 to 27 months results in an additional 12 months of reproductive, feeding, and health costs without generating economic returns.

The economic value of WY was lowest in the BRA herd due to the lack of direct revenue at yearling age. Conversely, the seedstock scenario yielded the highest economic value for WY among growth traits, due to the direct commercialization of yearling animals.

For carcass traits, the BRA herd placed 62% of total carcass importance on dressing, 31% on quality grade, and 7% on yield grade. DP is strongly influenced by live weight. Regarding QG, 59% of BRA carcasses were graded Select, resulting in higher price discounts, whereas YG was better classified, with 39% carcasses assigned to YG2 (Table 1). These results indicate that the BRA herd has greater potential for quality improvement than for yield improvement.

Although carcass traits were not directly marketable in the seedstock scenario, the same economic values were applied to reflect the importance of selecting end-product performance. Incorporating carcass traits into seedstock breeding objectives supports downstream value creation and long-term sustainability of the beef production system.

4 | DISCUSSION

Breeding objectives that integrate multiple traits into a single index are critical tools for modern beef cattle breeding programs. Because several traits influence economic outcomes, selection indexes optimize the distribution of emphasis across traits while accounting for correlated responses. Here, we estimated the economic values of fertility, growth, and carcass traits to support the development of an economic selection index for seedstock beef cattle operations, using the UF purebred Brahman herd as a reference population.

The results demonstrated that economic values vary across production systems and marketing strategies, underscoring the importance of tailoring selection indices to reflect herd-specific objectives. Traits that contribute most to profitability differ depending on whether animals are marketed at weaning, yearling age, or slaughter, highlighting the limitations of applying uniform selection criteria across diverse production systems.

Calving-to-sale success, a key indicator of fertility and maternal ability, had the highest estimated EV, reflecting its substantial contribution to herd profitability. Poor reproduction and fertility performances are primary drivers for culling, making them major contributors to inefficiency and profit loss in the beef industry (Moorey & Biase, 2020). The economic values estimated reinforce that retaining productive cows with consistent annual calving is more profitable than investing in the development of replacement heifers.

Although age at first pregnancy has a major economic impact by improving sexual precocity and resource-use efficiency, genetic progress for related traits may be slow. In a purebred Brahman herd, age at first calving did not show a significant genetic trend, likely due to its low heritability, however, favorable genetic correlations support the use of scrotal circumference as an indicator trait for indirect selection to improve age at first calving and stayability (Bessa et al., 2021).

Growth traits indicate faster-growing animals and provide economic benefits by reducing time to market when animals are sold at a fixed weight, or by increasing carcass weight when slaughter occurs at a fixed age. Additionally, genetic correlations indicate that body weight serves as a valuable selection criterion for inclusion in selection indexes in pure Brahman herds, as it is associated with both reproductive and carcass traits (Bessa et al., 2021). Moreover, studies have shown that WW, YW, and W15 are moderately to highly heritable and genetically correlated, reflecting shared biological mechanisms underlying growth across different life stages (Arango et al., 2002; Smith et al., 2022). Understanding these correlations is therefore critical for data-driven breeding decisions.

Among carcass traits, DP had the highest economic relevance. DP represents the proportion of the live animal converted into carcass and is a major determinant of trade value and profitability. Improvements in quality grade were economically 4.40 times more valuable than equivalent improvements in yield grade, demonstrating that profitability is influenced differently by these two carcass components. Consequently, their distinct economic weights must be properly reflected in selection decisions to achieve optimal economic response. Quality grade is determined by marbling and carcass maturity, and a higher quality grade is achieved with greater marbling and lower carcass maturity. The yield grade of a beef carcass is determined by considering the amount of backfat thickness, the ribeye muscle area, the amount of visceral internal fat, and the hot carcass weight (USDA, 2017).

It is worth noting that a reduction in numerical yield grade, which is desirable, occurs primarily when increases in ribeye area are achieved. A positive finding is that ribeye area can be used as a selection criterion because it exhibits a low genetic correlation with backfat thickness (0.10), indicating that selection for increased muscling is unlikely to substantially increase subcutaneous fat (Lopes et al., 2021). However, based on the economic values estimated in this study, quality grade had greater economic importance, and intramuscular fat should therefore be considered as a selection criterion when targeting marbling. Nevertheless, its genetic correlation with backfat thickness (0.19 – 0.25) suggests that selection for marbling may lead to undesirable increases in external fat (Londoño-Gil et al., 2022; Weik et al., 2022). These relationships highlight the importance of incorporating ribeye area, backfat thickness, and intramuscular fat into a multi-trait selection framework, with appropriate weighting based on their economic values, to achieve balanced genetic progress.

Genetic correlations between carcass and fertility traits reveal important biological relationships that must be considered and appropriately balanced within economic selection indices in breeding programs. A recent genomic study in Bos indicus cattle found that carcass traits measured by ultrasonography are moderately correlated with male reproductive traits, such as scrotal circumference and semen quality, suggesting that selecting for a single carcass trait may affect fertility (Mussi et al., 2025). Additionally, genetic analyses across sexes show that some reproductive traits, such as calving rate and heifer fertility, can exhibit genetic correlations with carcass fatness and muscle traits, suggesting that selection for improved carcass quality without regard to reproductive performance can lead to undesirable changes in fertility (Splan et al., 1998).

Overall, implementing an economic selection index requires understanding economic values with genetic correlations and additive genetic variances of traits for cattle producers to make 'balanced' selection decisions, considering each animal's relevant growth, carcass, birth, and fertility attributes to identify the animal that is most profitable for a particular production system. The EVs generated in this study provide a biologically and economically meaningful foundation for developing selection indexes tailored to purebred Brahman seedstock operations.

5 | CONCLUSION

Calving-to-sale success, age at first pregnancy, growth traits (weight at weaning, yearling, and 15 months of age), dressing percentage, USDA quality, and yield grades are economically relevant traits for improving productivity and sustainability in beef cattle systems. The implementation of an economic selection index requires an integrated understanding of economic values, genetic correlations, and additive genetic variances, enabling cattle producers to make balanced and informed selection decisions. The economic values estimated in this study provide a biologically and economically sound foundation for the development of selection indexes tailored to purebred Brahman seedstock operations. In addition, economic values provide an objective, data-driven basis for breeding programs and should be periodically updated to reflect changes in production costs, market conditions, and management practices.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

PERMISSION TO REPRODUCE MATERIAL FROM OTHER SOURCES

Does not apply.

REFERENCES

American Brahman Breeders Association (ABBA). (2025). Available from: ABBA: American Brahman Breeders Association - The World is Better with Brahman

Arango, J. A., Cundiff, L. V., & Van Vleck, L. D. (2002). Genetic parameters for weight, weight adjusted for body condition score, height, and body condition score in beef cows. *Journal of Animal Science*, *80*(12), 3112-3122. https://doi.org/10.2527/2002.80123112x

Bessa, A. F. de O., Duarte, I. N. H., Rola, L. D., Bernardes, P. A., Neto, S. G., Lôbo, R. B., Munari, D. P. & Buzanskas, M. E. (2021). Genetic evaluation for reproductive and productive traits in Brahman cattle. *Theriogenology*, *173*, 261-268. https://doi.org/10.1016/j.theriogenology.2021.08.008

Cole, J. B., & VanRaden, P. M. (2018). Symposium review: Possibilities in an age of genomics: The future of selection indices. *Journal of Dairy Science*, 101(4), 3686-3701. https://doi.org/10.3168/jds.2017-13335

Hazel, L. N., (1943). The genetic basis for constructing selection indexes. *Genetics*, 28(6), 476-490. https://doi.org/10.1093/genetics/28.6.476

Koch, R. M., Gibb, J. B., & Gosey, J. A. (1986). Evaluation of beef cattle industry breeding programs: breeders and breed associations. *3rd World Congress on Genetics Applied to Livestock Production.*

König, S., & May, K. (2019). Invited review: Phenotyping strategies and quantitative-genetic background of resistance, tolerance and resilience associated traits in dairy cattle. *Animal*, 13(5), 897-908. http://doi:10.1017/S1751731118003208

Londoño-Gil, M., Cardona-Cifuentes, D., Rodríguez, J. D., Brunes, L. C., Magnabosco, C. U., Pereira, A. S. C., Peripolli, E., Lôbo, R. B., & Baldi, F. (2022). Heritability and genetic correlations between marbling in longissimus dorsi muscle and conventional economic traits in Nellore beef cattle. *Tropical Animal Health and Production*, 54(5), 274. https://doi.org/10.1007/s11250-022-03293-6

Lopes, F. B., Baldi, F., Passafaro, T. L., Brunes, L. C., Costa, M. F. O., Eifert, E. C., Narciso, M. G., Rosa, G. J. M., Lobo, R. B., & Magnabosco, C. U., (2021). Genome-enabled prediction of meat and carcass traits using Bayesian regression, single-step genomic best linear unbiased prediction and blending methods in Nelore cattle. *Animal*, 15(1), 100006. https://doi.org/10.1016/j.animal.2020.100006

McCabe, E. D., King, M. E., Fike, K. E., Rogers, G. M., & Odde, K. G. (2020). Breed trends in beef calf lots marketed through video auctions from 1995 through 2018. *Applied Animal Science*, *36*(1), 78-90. https://doi.org/10.15232/aas.2019-01902

Moorey, S. E., & Biase, F. H. (2020). Beef heifer fertility: importance of management practices and technological advancements. *Journal of Animal Science and Biotechnology*, 11(1), 97. https://doi.org/10.1186/s40104-020-00503-9

Mussi, C. S., Medeiros, G. C., Espigolan, R., Baldi, F., Silva, M. R., Guimarães, J. D., Matos, E. C., Eler, J. P., Neto, T. M., Ferraz, J. B. S., Brito, L. F. (2025). Genetic correlations between carcass traits measured by ultrasonography and semen quality traits in Nellore cattle incorporating genomic information. *Livestock Science*, 105820. https://doi.org/10.1016/j.livsci.2025.105820

NRC. Natural Resources Conservation Service. (2020). *Feed and animal management for beef cattle. Nutrient Management Technical Note*, No. 190-NW-2.

Ponzoni, R. W., & Newman, S. (1989). Developing breeding objectives for Australian beef cattle production. *Animal Science*, 49(1), 35-47. https://doi.org/10.1017/S0003356100004232

Rowan, T. (2025). Exploring Next-Generation Phenotyping that Drives Commercial Profitability. *Angus Genetics Inc. Imagine Forum White Paper*, 1-12. https://cd.angus.org/-/media/project/american-angus-association/angus/pdf/agi/agi_phenotyping_white_paper_final.pdf

Souza, F. M., Lopes, F. B., Rosa, G. J., & Magnabosco, C. U. (2022). Economic values of reproductive, growth, feed efficiency and carcass traits in Nellore cattle. *Journal of Animal Breeding and Genetics*, 139(2), 170-180. http://doi/10.1111/jbg.12652

Smith, J. L., Wilson, M. L., Nilson, S. M., Rowan, T. N., Schnabel, R. D., Decker, J. E., & Seabury, C. M. (2022). Genome-wide association and genotype by environment interactions for growth traits in US Red Angus cattle. *BMC genomics*, *23*(1), 517. https://doi.org/10.1186/s12864-022-08667-6

Splan, R. K., Cundiff, L. V., & Van Vleck, L. D. (1998). Genetic parameters for sex-specific traits in beef cattle. *Journal of Animal Science*, *76*(9), 2272-2278. https://doi.org/10.2527/1998.7692272x

USDA. United States Department of Agriculture. (2017). *United States standards for grades of carcass beef.* < Carcass Beef Standard December 2017>

United States Department of Agriculture (USDA). (2025). Cattle & beef – sector at a glance. *Economic Research Service*. <Cattle & Beef - Sector at a Glance | Economic Research Service>.

Van Eenennaam, A. L., Weigel, K. A., Young, A. E., Cleveland, M. A., & Dekkers, J. C. (2014). Applied animal genomics: results from the field. *Annual Review Animal Bioscience*, 2(1), 105-139. https://doi.org/10.1146/annurev-animal-022513-114119

Weik, F., Hickson, R. E., Morris, S. T., Garrick, D. J., & Archer, J. A. (2022). Genetic parameters for growth, ultrasound and carcass traits in New Zealand beef cattle and their correlations with maternal performance. *Animals*, 12(1), 25. https://doi.org/10.3390/ani12010025

CAPÍTULO 3

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ECONOMIC VALUES OF FERTILITY, GROWTH, AND CARCASS TRAITS IN BEEF CATTLE COW-CALF OPERATION

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Abstract

Economic values (EVs) were derived for fertility, growth, meat, and carcass traits using the UF Multibreed Angus–Brahman (MAB) herd as a reference. Bioeconomic models were developed using herd variable costs, revenues, and management data collected from February 2024 to February 2025. In addition to the results from the MAB herd, three simulated scenarios were developed to represent a broader range of commercial cow–calf operations in the Southeastern United States. Offspring from the herd and from the simulated scenarios were either sold at weaning or yearling, retained as replacements, or slaughtered for carcass evaluation. Economic values were estimated as the expected change in profitability resulting from a one-unit change in the performance of a specific trait, while holding all other traits constant. Economic values were estimated for calving success-to-sale (CSS), age at first pregnancy (AFP), weaning weight (WW), yearling weight (WY), weight at 18 months of age (W18), dressing percentage (DP), USDA quality grade (QG), and USDA yield grade (YG). Calving success-to-sale was the most highly valued trait across the MAB herd and all simulated scenarios, followed by AFP, DP, QG, YG, and growth traits. Overall, the results support data-driven breeding decisions to optimize productivity, profitability, and genetic progress through multiple-trait selection.

Keywords: breeding decisions, multiple-trait selection, profitability, selection index

1. Introduction

Cow-calf operations must supply genetics that promote growth and carcass quality in feeder calves while also supporting strong, functional maternal performance in replacement heifers (Devani et al., 2021). Cow-calf operations represent the foundational segment of the U.S. beef cattle industry, providing the base supply for subsequent stages, in which mature beef cows and replacement heifers are maintained primarily on pasture to produce calves that are sold at weaning to backgrounding operations or retained for further growth and sold as yearlings to feedlot operations. Cow-calf operations are prevalent throughout the U.S., particularly in regions with extensive forage resources and land less suitable for cropping and are a key source of feeder calves for the broader beef cattle industry (USDA, 2020).

In the southeastern United States, cow-calf operations are especially important due to the warm, humid climate, and abundant grassland forage that favor extensive grazing systems. Under these subtropical conditions, characterized by high temperatures, many cow–calf producers exploit heterosis to improve performance and adaptability (Van Eenennaam et al., 2014). Although Angus genetics are present in over 80% of U.S. beef cattle, several other breeds play a critical role in regional adaptation and in supporting production systems across diverse environments. Consequently, a significant proportion of cattle in the southeastern United States contain Brahman genetics, as *Bos indicus* breeds are well adapted to tropical environments (Hansen, 2004; Scheffler, 2022). However, *Bos indicus* cattle generally produce carcasses with lower fat-to-lean ratios, reduced meat tenderness, and less intramuscular fat compared to *Bos taurus* breeds (Thrift & Thrift, 2003).

The long-term sustainability of cow-calf operations depends on cows consistently producing offspring capable of yielding sufficient and high-quality beef. When selection focuses on a single trait without accounting for its genetic correlations with other traits, unintended and potentially negative consequences may occur (Richardson, 2023). Multiple trait selection approaches optimize producer profitability while also supporting long-term industry sustainability (Cole & VanRaden, 2018).

The economic selection index is considered the most efficient methodology for multiple-trait selection because it incorporates trait-specific economic values, thereby optimizing both genetic progress and overall profitability (Hazel, 1943). Despite its advantages, implementation can be challenging because the economic importance of individual traits varies across production systems, breeds, and regions (Hazel, 1943). Economic values ensure that each trait receives the appropriate emphasis within the breeding objective aligned with herd-specific goals (Konig & May, 2019). Moreover, they should be periodically updated to reflect the evolving needs of farmers across different environments and payment systems, to incorporate new traits, and to account for changing economic conditions and genetic parameters both across and within traits (Cole & VanRaden, 2018). When properly derived, economic values provide a robust framework for aligning genetic improvement with financial and production objectives, ultimately supporting a more sustainable beef cattle industry (Souza et al., 2022).

Currently, the International Brangus Breeders Association (IBBA) only offers the Maternal Economic Index, which predicts maternal performance in systems that retain replacement heifers, and the Terminal Economic Index, which evaluates post-weaning growth and carcass traits in terminal production systems where calves are marketed on value-based grids. Recently, the IBBA launched the Brangus Built Index, which combines maternal and terminal traits, helping ranchers select animals that simultaneously contribute to herd productivity and end-product quality when those dual goals are desired. However, unlike some breed associations in the Brangus Built Index, maternal and terminal components are combined with equal emphasis rather than weighted by system-specific economic returns.

Thus, this study aimed to estimate the economic values of fertility, growth, and carcass traits for multibreed Angus x Brahman cow-calf herd operation in the Southeastern United State.

2. Materials and Methods

The Multibreed Angus-Brahman (MAB) herd of the University of Florida has been in operation since 1988 (Elzo & Wakeman, 1998). The research population is raised on properties located near Gainesville, Florida, under a humid subtropical climate. Data on costs, revenues, and herd management collected from February 2024 to February 2025 were used to develop a deterministic bioeconomic model based on animal performance.

2.1. Management of the Multibreed Angus-Brahman herd (cow-calf operation)

The UF MAB herd serves as a foundational research resource to study how varying proportions of Angus and Brahman genetics influence economically important traits under subtropical conditions. The herd consists of approximately 300 crossbred cows and is managed as cow-calf operation. The herd maintains a broad spectrum of breed compositions, from 100% Angus to 100% Brahman, representing the full gradient of crossbreeding between the two breeds.

For breeding purposes, cows and sires are assigned to one of five breed groups (BG) based on percentage of Brahman inheritance: 0–19.99% (BG1), 20–39.99% (BG2), 40–59.99% (BG3), 60%-79.99% (BG4), and 80%-100% (BG5). A diallel mating system is used, in which sires from each breed group (three to five sires per group) are mated to cows from each breed group (35–50 cows per breed group), generating progeny that represent all combinations of breed composition and parental breed group.

A 90-day breeding season from February to April is implemented in the MAB herd to also produce spring-born calves. All cows undergo estrus-synchronization for AI, followed by natural service, with single-sire mating practiced within sire breed groups. Angus, Brahman, and Brangus sires are sourced externally to ensure representation of their respective national populations. Sires from the BG2, BG3, and BG4 are selected primarily from within the multibreed herd due to availability, with external sires incorporated when suitable.

Animals were managed in contemporaneous groups with *ad libitum* access to water and minerals to meet or exceed maintenance requirements. Cattle were raised under grazing conditions and supplemented whenever the availability or quality of perennial pastures was insufficient to meet their nutritional needs. Mean body weight by animal category is presented in Table 1. Daily DMI was assumed to be 2% of body weight for bulls and cows and 2.5% for heifers. Bulls, cows, and heifers received an average of 0.11 kg of mineral per day. During December, January, and the breeding season, bulls were supplemented with citrus pulp at 20% of DMI, while cows and heifers received the feed mix of whole cottonseed (45%), citrus (50%), and molasses (5%), (hereafter referred to as feed mix) at 40% and 50% of DMI, respectively. From May through July, soybean hulls were provided at 20%, 20%, and 30% of DMI for bulls, cows, and heifers, respectively.

The calving season occurred from November through February, and calves were weaned in August at an average age of 216 days. Calves remained on pasture with their dams from birth to weaning. Beginning at 60 days of age, calves were assumed to graze perennial pasture at 1% of body weight in DMI and were provided 0.07 kg per day of mineral, achieving an average daily gain (ADG) of 1.00 kg. Following weaning, calves were managed through one of three pathways: marketed at weaning, retained as replacements, or transferred to a partner feedlot for finishing and subsequent evaluation of final product traits.

Approximately 20% of total calves were retained as replacements. From weaning until 14 months of age (210 days), these replacement heifers received 0.10 kg per day of mineral and were fed 2.5% of their body weight in DMI, consisting of 30% citrus pulp and 70% bahiagrass pasture, resulting in an ADG of 0.78 kg. Following weaning, roughly 30% of total calves were finished and evaluated for carcass and meat quality. Steers remained in the feedlot for an average of 312 days, achieving an ADG of 1.26 kg until approximately 18 months of age. At slaughter, 46% of carcasses were classified as Yield Grade 3, and 59% graded USDA Choice (Table 1).

Table 1

Biological input parameters (mean) of the Multibreed Angus-Brahman (MAB) herd.

Variable	MAB
Birth weight (kg)	36.00
Weaning weight 216d (kg)	252.00
Heifer weight at 14 mo (kg)	416.00
Yearling weight (kg)	390.00
Steer weight 18 mo (kg)	643.00
Bull weight (kg)	854.00
Cow weight (kg)	558.00
Cow pregnancy rate (%)	90%
Heifer pregnancy rate (%)	60%
Dressing (%)	65%
Yield grade USDA (cwt)*	
(1) +$4.00	2%
(2) +$2.00	15%
(3) $0	46%
(4) - $10.00	44%
(5) - $15.00	2%
Quality grade USDA (cwt)*	
(Prime) + $14.22	2%
(Choice) + $14.74 (>70% premium on excess)	59%
(Select) - $14.74 (> 30% discount on excess)	39%

*cwt: hundredweight of carcass

2.2. Southeastern U.S. cow-calf simulated scenarios

In addition to real data from the UF multibreed Angus-Brahman herd, a simulated scenarios were developed to encompass a broader range of commercial cow-calf operations in the Southeastern United States. Cow-calf operations are involved in the production of beef calves from birth to weaning. However, some operations opt to retain calves on-farm after weaning to place additional weight on them before sale or to finish them to slaughter weight (Gillespie et al., 2023).

Accordingly, three scenarios were developed: cow-calf, cow-calf/stocker, and cow-calf/finishing, assuming that 20% of the total calves at weaning were retained as replacement heifers and the remaining 80% were sold at weaning, yearling, or 18 months of age, respectively. The biological and economic inputs used were identical to those collected from the UF herd. From weaning to yearling, in the cow-calf/stocker and cow-calf/finishing scenarios, the remaining 80% of calves received 0.10 kg/day of mineral and were fed at 2.5% of their body weight in DMI, consisting of 30% citrus pulp and 70% bahiagrass pasture, resulting in an ADG of 1.15 kg. From yearling to 18 months of age, in the cow-calf/finishing scenario, the steers received 0.10 kg pr day of mineral and were fed 2.5% of their body weight in DMI, consisting of 70% citrus pulp and 30% bahiagrass pasture, resulting in an ADG of 1.40 kg.

This approach allows evaluation of economic outcomes across alternative production strategies commonly adopted by commercial cow-calf operations in the region.

2.3. Estimation of economic values

Economic values (EVs) were expressed as dollars of profit or loss per unit change for each trait (Ponzoni & Newman, 1989). The partial derivative of the gross margin with respect to trait performance was defined as EV and it represents the expected change in profitability resulting from a one-unit change in a specific trait, while holding all other variables constant (Eq. 1). Accordingly, it is necessary to identify sources of revenues and variable costs in the evaluated herd to construct a gross margin function, calculated as total revenues minus total variable costs. The gross margin function and the EVs were calculated using Excel (Microsoft Corporation, Redmond, WA).

$$EV = \frac{\Delta G}{\Delta P} \quad \text{(Eq. 1)}$$

Where EV is the economic value; ΔG is the gross margin variation, and ΔP is the performance variation.

Revenues were derived from the sale of weaned calves, yearling calves, slaughtered steers, and culled cows. Sale prices for each class of animals are shown in Table 2.

Table 2

Economic input parameters (means) for the Multibreed Angus-Brahman (MAB) cow-calf herd and southeastern U.S. scenarios.

Variable	**cwt***	**Total**
Weaning sale	$ 198.63	$ 1,102.40
Yearling sale	$ 198.63	$ 1,708.22
Steers sale (slaughter)	$ 287.91	$ 2,651.80
Cull cows sale	-	$ 1,300.00

*cwt: hundredweight of carcass.

Breeding costs included those associated with artificial insemination (AI) and the purchase and maintenance of breeding bulls for natural mating. The cost of AI was $47.95 per female for both herds, covering two doses of prostaglandin, two doses of gonadotropin-releasing hormone (GnRH), half the price of a controlled internal drug release (CIDR) device (used twice), semen, supplies, labor, and an artificial inseminator technician. Bull-related costs included the annual breeding soundness examination, health care, purchase price, and annual feeding, totaling $45.47 per cow. The annual breeding soundness examination costs $55.00 per bull. Annual health care costs were estimated at $77.46 per bull. The purchase price per bull was $3,500.00, assuming a useful life of four years, with a bull-to-cow ratio of 1:30. Annual feeding costs for bulls were estimated at $411.55 per bull.

The health care costs included annual immunization protocols and systematic parasite control, resulting in an average of $38.82 per cow per year, $34.20 per heifer per year, and $19.70 per calf weaned per year.

Feed costs included pasture, mineral supplementation, and provided additional feed. The available pasture consisted of bahiagrass, with maintenance costs, including fertilizer and herbicide, estimated at $0.03/kg of dry matter for both herds. Mineral supplements cost an average of $0.77/kg. Additional feed resources included soybean hulls, citrus pulp, and mixed feed, with costs of $0.31, $0.24, and $0.28 per kg, respectively. Dry matter contents were considered at 88.90%, 90.30%, 90.00% for soybean hulls, citrus pulp, and mixed feed, respectively. Other operational costs, such as permanent labor, maintenance, fees, and taxes, were excluded because they do not vary with one-unit genetic improvement of a trait (Ponzoni & Newman, 1989).

Economic values were estimated for the following traits: calving success-to-sale (CSS), age at first pregnancy (AFP), weight at weaning (WW), weight at yearling (WY), weight at 18 months of age (W18), dressing percentage (DP), quality grade (QG), and yield grade (YG). CS represents a cow's ability to produce an offspring per production cycle, defined as becoming pregnant, successfully weaning, and selling or retaining a calf. AFP reflects sexual precocity in replacement heifers, defined as confirmed pregnancy at 15 months of age during their first breeding season, rather than 27 months of age during the second breeding season. WW, WY, and W18 correspond to the weights used to calculate income from steers sold at those ages. DP is the proportion of meat expressed as a percentage of live weight. USDA yield grade (YG) estimates the amount of usable meat (cutability) from the carcass, with YG1 representing the highest yield (leanest, most meat) and YG5 the lowest yield (fattest, least meat). USDA quality grade (QG) estimates expected meat palatability, including tenderness, juiciness, and flavor. Common QG categories are Prime (highest marbling and palatability), Choice (slightly less marbling but still high quality), Select (leaner, with less marbling and lower tenderness), and Standard (lower grades, often used for processed products). USDA YG and QG were assigned to each carcass, and price adjustments (discounts or premiums) were applied per hundredweight of carcass (cwt). QG and YG improvements were quantified as a one-level change in grade, expressed as the corresponding change in carcass value per CWT.

3. Results

Revenues, variable costs, and operational gross margin per cow per production cycle are presented in Table 3. These herd-specific economic parameters were used to estimate the economic values for fertility, growth, and carcass traits.

Table 3

Revenues, variable costs, and gross margin per cow per production cycle for Multibreed Angus-Brahman (MAB) herd and the southeastern U.S. cow-calf scenarios.

Variable	MAB ($)	Cow-calf ($)	Cow-calf/ stocker ($)	Cow-calf/ finishing ($)
Revenues (a)	**1,606.74**	**1,141.92**	**1,626.56**	**2,381.44**

Weaning	551.20	881.92		
Yearling			1,366.57	
Meat	795.54			2,121.44
Culled	260.00	260.00	260.00	260.00
Variable costs (b)	**1,021.49**	**668.22**	**751.62**	**1,085.43**
Weaning	323.50	517.59		
Yearling			600.99	
Meat	547.37			2,121.44
Culled	150.62	150.62	150.62	150.62
Gross Margin (a - b)	**585.25**	**473.70**	**874.96**	**1,275.45**

Estimated EVs for calving success-to-sale, age at first pregnancy, weight at 18 months of age, dressing percentage, USDA yield grade, and USDA quality grade were positive. Weight at weaning and weight at yearling were negative in the cow-calf/stocker and cow-calf/finishing scenarios, indicating that increasing weight when there is no directly associated income will increase costs without improving profitability (Table 4). Calving success-to-sale per cow was the most economically important trait in the herd and across all scenarios, followed by age at first pregnancy, dressing percentage, USDA quality grade, USDA yield grade, and growth.

Table 4

Economic values of fertility, growth, and carcass traits for the Multibreed Angus-Brahman (MAB) herd and the southeastern U.S. cow-calf scenarios.

Traits	**Unit**	**MAB**	**Cow-calf**	**Cow-calf/ stocker**	**Cow-calf/ finishing**
Fertility					
Calving success-to-sale	Cow	$1,003.47	$ 896.16	$ 1,289.39	$ 1,681.87
Age at first pregnancy	Heifer	$ 712.99	$ 712.99	$ 712.99	$ 712.99
Growth					
Weight at weaning	kg	$ 4.23	$ 4.28	- $ 0.28	- $ 0.15
Weight at yearling	kg			$ 4.27	- $ 0.28
Weight at 18 mo	kg	$ 4.12			$ 3.82
Carcass					
Dressing	%	$ 40.80	$ 40.80	$ 40.80	$ 40.80
USDA Yield	cwt	$ 5.64	$ 5.64	$ 5.64	$ 5.64
USDA Quality	cwt	$ 10.84	$ 10.84	$ 10.84	$ 10.84

Differences in the economic value of calving success-to-sale among the MAB herd and the cow-calf scenarios were driven by system-specific calf utilization strategies. In systems retaining calves beyond weaning or marketing animals at later ages, calving success-to-sale encompassed a broader revenue stream, including post-weaning growth and carcass value, whereas in systems selling calves at weaning its economic impact was primarily associated with weaning output.

Age at first pregnancy remains constant across MAB herd and production systems scenarios. Its economic value reflects the potential to increase profitability by avoiding the additional reproductive, feeding, and health costs incurred when heifers delay conception from 15 to 27 months of age.

In the cow-calf and cow-calf/stocker scenarios, economic values for carcass traits could not be directly calculated. However, the same values were applied because selecting end-product traits is important for supporting the sustainability of the beef cattle industry.

In the MAB herd and in the cow-calf/finishing scenario 71%, 10%, and 19% of the total economic importance for carcass traits were assigned to DP, YG, and QG, respectively. The estimated EVs indicates that improvements in QG are 1.91 times more economically valuable than equivalent improvements in YG, highlighting the need to balance selection between both components of end-product merit.

4. Discussion

Breeding objectives that combine multiple traits into a single index are a critical tool for cattle breeders. Because several traits influence economic outcomes, a selection index optimizes the distribution of emphasis across traits while accounting for genetic correlations. Here, we estimated the economic values of fertility, growth, carcass, and meat traits to support the development of an economic selection index for cow-calf beef cattle operations, using the UF Multibreed Angus-Brahman herd as a reference population.

Calving success-to-sale, a fertility indicator, had the highest estimated EV, reflecting its substantial contribution to herd profitability. The sale of offspring more than offsets cow maintenance costs, whereas poor reproduction and fertility are primary reasons for culling, making them major contributors to inefficiency and profit loss in the beef industry. Low fertility shortens cow longevity and increases the replacement rates (Richardson, 2023), ultimately raising production costs and decreasing overall herd efficiency and sustainability.

Notably, 10% of cows in MAB herd were culled per production cycle due to reproductive failure. Given that improving CS remains an essential strategy to enhance long-term productivity and economic viability in beef cattle operations.

Age at first pregnancy, a measure of sexual precocity, also had a major economic impact by reducing the number of unproductive animals maintained in the herd and improving resource-use efficiency. Heifers in this study were exposed to mating at 15 months of age, and their ability to conceive during the first breeding season was recorded. AFP typically exhibits moderate to high heritability, ranging from 0.37 to 0.54 across different populations, and shows high favorable correlation with rebreeding (0.83) and longevity (0.73-0.97) (Schmidt et al., 2019; Eler et al., 2014; Mwansa et al., 2000). It is noteworthy that direct selection for lifetime productivity is more challenging because it is measured later in life, underscoring the value of AFP as an early indicator trait. Additionally, studies demonstrate that females with earlier age at first calving (22–24 months) have survival rates comparable to those calving at 33–36 months, while exhibiting favorable performance in shorter calving intervals, and lighter mature weights from parity 1 to 4, thereby reducing maintenance costs and increasing their economic value within cow–calf systems (Twomey & Cromie, 2023). Heifers born within the first 21 days of the calving period are more likely to be cycling at the start of the breeding season and tend to exhibit superior lifetime reproductive performance (Richardson, 2023). Thus, selecting replacement heifers born early in the calving season is an essential strategy for optimizing herd-wide reproductive success (Moorey & Biase, 2020).

Growth traits indicate faster-growing animals and provide economic benefits by reducing time to market when animals are sold at a fixed weight, or by increasing carcass weight when slaughter occurs at a fixed age. Estimating EV of trait readily available for inclusion in a selection index, such as growth and mature live weight, may therefore provide a more practical, short-term, promising approach to improve efficiency than relying on residual feed intake, which is more expensive and demanding to measure (Hietala & Juga, 2017). Additionally, the results of this study highlight the importance of aligning selection for growth traits with marketing endpoints that generate direct revenue.

Among carcass traits, dressing percentage had the highest economic relevance. DP represents the proportion of the live animal converted into carcass and is a major determinant of trade value and profitability. Quality grade and yield grade were evaluated according to USDA standards. QG predicts lean palatability and is primarily influenced by marbling level, muscle firmness, and maturity-related physical characteristics (USDA, 2017). Besides age, marbling score is an indicator of QG and a key determinant of eating quality in beef. YG reflects the expected yield of closely trimmed (≤ 1/2 inch fat), boneless retail cuts from major wholesale cuts of the carcass, such as round, sirloin, short loin, rib, and square-cut chuck (USDA, 2017). Ribeye area and subcutaneous fat thickness are primary predictors of YG.

Trends in the U.S. beef industry show increasing QG and a rising prevalence of YG 4 and 5 carcasses, along with heavier carcass weights that often exceed optimal thresholds (Mayer et al., 2024). These trends highlight the need to balance marbling, ribeye area, and backfat thickness in selection programs. The low genetic correlation between ribeye area and backfat thickness (0.10) suggests that selection for increased muscling does not substantially increase subcutaneous fat deposition (Lopes et al., 2021). However, the moderate genetic correlation between backfat thickness and intramuscular fat (0.19–0.25) indicates that selection aimed at improving palatability may unintentionally increase undesirable fatness (Londoño-Gil et al., 2022; Weik et al., 2022), underscoring the importance of balanced multiple-trait selection. In this study, the EVs estimated for QG and YG reflect this necessary balance among carcass traits.

Moreover, the moderate negative genetic correlation between the fertility traits and ribeye area (-0.46) suggests that selection for increased muscling may negatively affect pregnancy outcomes (Weik et al., 2022). Because both fertility and muscling strongly influence profitability, they must be carefully balanced when constructing a selection index.

Overall, implementing an economic selection index requires integrating economic values with genetic correlations and additive genetic variances to enable data-driven decisions about trait emphasis. The EVs generated in this study provide a biologically and economically meaningful foundation for developing selection indexes tailored to multibreed Angus-Brahman cow-calf operations.

5. Conclusion

Calving success-to-sale, age at first pregnancy, weight at sale age, dressing percentage, and USDA quality and yield grades were identified as key economic drivers of productivity and sustainability in beef cattle systems. The application of trait-specific economic values enables selection strategies to be explicitly aligned with the objectives of distinct production segments, thereby improving the efficiency of genetic progress. Moreover, economic values provide a robust, quantitative basis for breeding decisions and should be periodically updated to account for changes in production costs, market conditions, and management practices, ensuring their continued relevance across diverse production environments.

Author contributions: CRediT

PPB performed formal analyses and wrote the initial version of the manuscript. PPB and FMR conceptualized and designed the study. JDS provided the data and management explanation from both herds. CR provides the economics knowledge. FMR and RMS supervised this study. All co-authors reviewed, edited and approved the manuscript.

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Declaration of competing interests

The authors declare that there is no conflict of interest.

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References

Boscollo, P. P., Dauria, B. D., Portes, J. V., Petrini, J., da Silva Lopes, J. E., Ladeira, G. C., Santos Junior, L. F., & Mourao, G. B., 2022. Bioeconomic selection indexes for terminal lamb systems in tropical conditions. Small Ruminant Research, 211, 106701. https://doi.org/10.1016/j.smallrumres.2022.106701

Cole, J. B., & VanRaden, P. M., 2018. Symposium review: Possibilities in an age of genomics: The future of selection indices. Journal of Dairy Science, 101(4), 3686-3701. https://doi.org/10.3168/jds.2017-13335

Devani, K., Quinton, C. D., Archer, J. A., Santos, B. F., Martin-Collado, D., Amer, P., Pajor, E. A., Orsel, K., & Crowley, J. J., 2021. Estimation of economic value for efficiency and animal health and welfare traits, teat and udder structure, in Canadian Angus cattle. Journal of Animal Breeding and Genetics, 138(3), 314-325. http://doi/10.1111/jbg.12540

Eler, J. P., Bignardi, A. B., Ferraz, J. B. S., & Santana Jr, M. L., 2014. Genetic relationships among traits related to reproduction and growth of Nelore females. Theriogenology, 82(5), 708-714. rights reserved. http://dx.doi.org/10.1016/j.theriogenology.2014.06.00

Elzo, M. A., & Wakeman, D. L., 1998. Covariance components and prediction for additive and nonadditive preweaning growth genetic effects in an Angus-Brahman multibreed herd. Journal of Animal Science, 76(5), 1290-1302. https://doi.org/10.2527/1998.7651290x

Gillespie, J., Whitt, C., & Davis, C., 2023. Structure, management practices, and production costs of U.S. beef cow-calf farms. United States Department of Agriculture, Economic Research Service, Report Number 321.

Hansen, P.J., 2004. Physiological and cellular adaptations of zebu cattle to thermal stress. Animal Reproduction Science. 82-83(2-83):349–360. http://doi:10.1016/j.anireprosci.2004.04.011

Hazel, L. N., 1943. The genetic basis for constructing selection indexes. Genetics, 28(6), 476-490. https://doi.org/10.1093/genetics/28.6.476

Hietala, P., & Juga, J., 2017. Impact of including growth, carcass and feed efficiency traits in the breeding goal for combined milk and beef production systems. Animal, 11(4), 564-573. http://doi/10.1017/S175173111600187

International Brangus Breeders Association (IBBA), 2025. Available from: IBBA Brangus | The International Brangus Breeders Association>

König, S., & May, K., 2019. Invited review: Phenotyping strategies and quantitative-genetic background of resistance, tolerance and resilience associated traits in dairy cattle. Animal, 13(5), 897-908. http://doi:10.1017/S1751731118003208

Londoño-Gil, M., Cardona-Cifuentes, D., Rodríguez, J. D., Brunes, L. C., Magnabosco, C. U., Pereira, A. S. C., Peripolli, E., Lôbo, R. B., & Baldi, F., 2022. Heritability and genetic correlations between marbling in longissimus dorsi muscle and conventional economic traits in Nellore beef cattle. Tropical Animal Health and Production, 54(5), 274. https://doi.org/10.1007/s11250-022-03293-6

Lopes, F. B., Baldi, F., Passafaro, T. L., Brunes, L. C., Costa, M. F. O., Eifert, E. C., Narciso, M. G., Rosa, G. J. M., Lobo, R. B., & Magnabosco, C. U., 2021. Genome-enabled prediction of meat and carcass traits using Bayesian regression, single-step genomic best linear unbiased prediction and blending methods in Nelore cattle. Animal, 15(1), 100006. https://doi.org/10.1016/j.animal.2020.100006

Mayer, T. R., Borders, S. E., Schwartz, T. E., Gehring, K. B., Griffin, D. B., Kerth, C. R., Belk, K. E., Scanga, J. A., Nair, M. N., ... & Savell, J. W., 2024. National Beef Quality Audit—2022: in-plant assessments of quality and yield determining carcass characteristics of fed steers and heifers. Translational Animal Science, 8, txae098. https://doi.org/10.1093/tas/txae098

Moorey, S. E., & Biase, F. H., 2020. Beef heifer fertility: importance of management practices and technological advancements. Journal of Animal Science and Biotechnology, 11(1), 97. https://doi.org/10.1186/s40104-020-00503-9

Mwansa, P. B., Kemp, R. A., Crews Jr, D. H., Kastelic, J. P., Bailey, D. R. C., & Coulter, G. H., 2000. Selection for cow lifetime pregnancy rate using bull and heifer growth and reproductive traits in composite cattle. Canadian Journal of Animal Science, 80(3), 507-510. https://doi.org/10.4141/A99-135

NRC. Natural Resources Conservation Service., 2020. Feed and animal management for beef cattle. Nutrient Management Technical Note, No. 190-NW-2.

Ponzoni, R. W., & Newman, S., 1989. Developing breeding objectives for Australian beef cattle production. Animal Science, 49(1), 35-47. https://doi.org/10.1017/S0003356100004232

Richardson, C. M., Crowley, J. J., & Amer, P. R., 2023. Defining breeding objectives for sustainability in cattle: challenges and opportunities. Animal Production Science, 63(11), 931-946. https://doi.org/10.1071/AN23021

Scheffler, T.L. 2022. Connecting heat tolerance and tenderness in Bos indicus influenced cattle. Animals (Basel) 12(3):220. http://doi/10.3390/ani12030220

Schmidt, P. I., Ferreira, I. A., Silveira, D. D., Campos, G. S., Souza, F. R. P., Carvalheiro, R., & Boligon, A. A., 2019. Reproductive performance of cows and genetic correlation with weight gains and principal components of traits used in selection of Nelore cattle. Livestock Science, 229, 77-84. https://doi.org/10.1016/j.theriogenology.2019.01.032

Souza, F. M., Lopes, F. B., Rosa, G. J., & Magnabosco, C. U., 2022. Economic values of reproductive, growth, feed efficiency and carcass traits in Nellore cattle. Journal of Animal Breeding and Genetics, 139(2), 170-180. http://doi/10.1111/jbg.12652

Thrift, F. A., & Thrift, T. A., 2003. Longevity attributes of Bos indicus× Bos taurus crossbred cows. The Professional Animal Scientist, 19(5), 329-341. https://doi.org/10.15232/S1080-7446(15)31438-8

Twomey, A. J., & Cromie, A. R., 2023. Impact of age at first calving on performance traits in Irish beef herds. Journal of Animal Science, 101, skad008. https://doi.org/10.1093/jas/skad008

USDA. United States Department of Agriculture., 2017. United States Standards for grades of carcass beef. < Carcass Beef Standard December 2017>

United States Department of Agriculture (USDA), 2020. Beef Cow-calf management practices in the United States, 2017, report 1. USDA–APHIS–VS–CEAH–NAHMS. Fort Collins, CO.

Van Eenennaam, A. L., Weigel, K. A., Young, A. E., Cleveland, M. A., & Dekkers, J. C., 2014. Applied animal genomics: results from the field. Annual Review Animal Bioscience, 2(1), 105-139. https://doi.org/10.1146/annurev-animal-022513-114119

Weik, F., Hickson, R. E., Morris, S. T., Garrick, D. J., & Archer, J. A., 2022. Genetic parameters for growth, ultrasound and carcass traits in New Zealand beef cattle and their correlations with maternal performance. Animals, 12(1), 25. https://doi.org/10.3390/ani12010025