RANGE

BEEF COW SYMPOSIUM XXVIII

December 13-14, 2023

The Ranch Events Complex, Loveland, Colorado

PROCEEDINGS

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28TH BIENNIAL
RANGE BEEF COW SYMPOSIUM

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Proceedings, The Range Beef Cow Symposium XXVIII
December 13 & 14, 2023, Longmont, Colorado

MARKETING FEEDER CALVES FOR INCREASED VALUE

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INTRODUCTION

Feeder cattle, collectively and at any one point in time, represent a diverse set of animals that vary widely in size, age, gender, quality, genetics, condition, and management. Moreover, regional variation in cattle production systems, cattle types and cattle industry culture add to the national diversity across feeder cattle markets. This paper summarizes a project to collect feeder cattle auction data in a broad set of markets in multiple states with the objective of completing a comprehensive analysis to analyze factors that impact feeder cattle value (Peel, et.al, 2023). The project had two primary objectives:

1) To collect feeder cattle auction data in multiple states/sales including as many cattle characteristics as possible to permit analysis that would identify factors affecting the value of different lots of cattle.
2) To quantify the individual impact of various factors that affect the value of feeder cattle using multi-variate econometric analysis.

DATA COLLECTION

The basic data collection protocol consisted of capturing the details of the sale for a particular lot of animals. Information on lot characteristics, physical cattle characteristics, and calf management practices were recorded for each lot. Lot characteristics include number of head in the lot, average weight, gender, and uniformity. Calf management characteristics include weaning status, days weaned, vaccination status, health status and program certifications. Physical cattle characteristics include hide color/breed, muscling, frame, fill, flesh, Brahman influence, and horns. Additional data collected include sale time, date, age and source verification, seller-announced, and any announced or written management comments. In general, the project attempted to capture the full range of information that buyers have available to them during the sale. This includes visual characteristics of the sale lot, announcements and verbal descriptions provided and, sometimes, written sale information. This set of information, combined with the details of the sale transaction, represents the data that can be analyzed to assess the impact of various factors on the value of a given lot of cattle.

Data was collected from October 2021-April 2022 across seven states in a total of 92 individual sales at 21 locations (Table 1). States included Kansas, Kentucky, Nebraska, Missouri, Oklahoma, South Dakota, and Wyoming. Specific sale locations are identified in Table 6. In total, the data includes 275,335 head of feeder cattle in 18,038 sale lots. The value of cattle included in the data was over $291 million. Data was collected by extension personnel and contractors in each of the states. Locations in Oklahoma and South Dakota account for 60% of the lots, but 75% of the cattle.

DATA SUMMARY

Lot Size Differences Across States

Average lot size is one indicator of regional differences, both across states and within states. The average lot size was highest in South Dakota at 25.6 head, followed by Nebraska (20.6), Wyoming (15.5) and Oklahoma (13.1). Kansas (8.8), Missouri (6.2) and Kentucky (4.3) all have average lots sizes under 10 head, with Kentucky reporting the smallest lot sizes, overall and across individual sales within the state. Lots sizes were relatively consistent across in-state sales for Kentucky, Nebraska, and South Dakota. The Joplin sale in Missouri had the largest lot size (15.4 head) by far for the state while, in Oklahoma, the average lot size for McAlester (2.5) was substantially lower than for the other three sale sites.

Physical Characteristics

Nearly 48% of steer lots and 47% of heifer lots were sold at average weights between 500 and 700 pounds. Mixed #1-2 muscled lots represented approximately 63% of total lots as did medium/large-framed lots. Lot sizes were significantly higher for lots scored as #1 muscling than for those with lower muscling scores. This holds true to a lesser extent for large-framed lots relative to lots with other frame scores.

Black hided cattle dominate the data, with 60% of cattle recorded as black hided and another 15% recorded as predominantly black. This is followed by nearly 9% designated as mixed high-quality lots. These are typically lots with no predominant hide color, but cattle of good quality. Red or predominantly red lots make up 7.8% of lots, followed by white/gray-hided lots of cattle at 6.3%. Herefords were represented in less than 1% of lots. Approximately 9% of lots showed Brahman influence with another 1% of lots showing minimal Brahman influence.

Management Characteristics

Management characteristics are those attributes of the cattle directly influenced by producers through how cattle are managed between birth and sale. Nearly 64% of cattle were marketed as weaned cattle, implying they had been separated from the dams for a minimum of 30 days before marketing. Vaccination information was collected in two forms: (1) vaccinated cattle were reported as having more than one dose of respiratory complex vaccinations and (2) limited vaccination cattle were reported as having had one dose of respiratory complex vaccinations. Cattle considered fully vaccinated comprise 54.1% of the lots collected and limited vaccination cattle comprise another 8.4%, for a total of 62.5% of lots having received at least one round of respiratory vaccinations prior to sale. Approximately 46% of lots were both weaned and vaccinated prior to marketing. Nearly 6% of lots were marketed as Natural (5.4%) or Non-Hormone Treated Cattle (NHTC) (0.5%).

The lot size for NHTC cattle was nearly double that of other characteristics. Two certification programs with sizable data were the Oklahoma Quality Beef Network (OQBN) with 1.1 percent of the lots and the Integrity Beef program with 0.5 percent of total lots. A very small number of sale specific certification programs were noted in the data as well. Finally, horns or minimal horns were documented in 3.3% of lots.

VALUE CHARACTERISTICS OF FEEDER CATTLE AUCTION DATA

Modeling

The economic concept of the "law of one price" holds that price differences for a particular product are explained by adjusting for time, place, and form. In the case of feeder cattle, observed price differences for a particular lot of cattle are therefore due to time differences impacting the supply and demand conditions that determine overall market values (time), location differences (place), and individual characteristics of the animals (form). A hedonic pricing model that accounts for overall market conditions at each point in time as well as location differences was used to analyze the contribution of lot attributes, physical attributes, and management attributes to overall lot price. The basic assumption of hedonic models is that buyers choose among goods with varying attributes and place values on the individual characteristics of a good based on the perceived utility or benefit that they gain from each. The overall price of a good then is the sum of values that the buyer places on each of the good's individual characteristics.

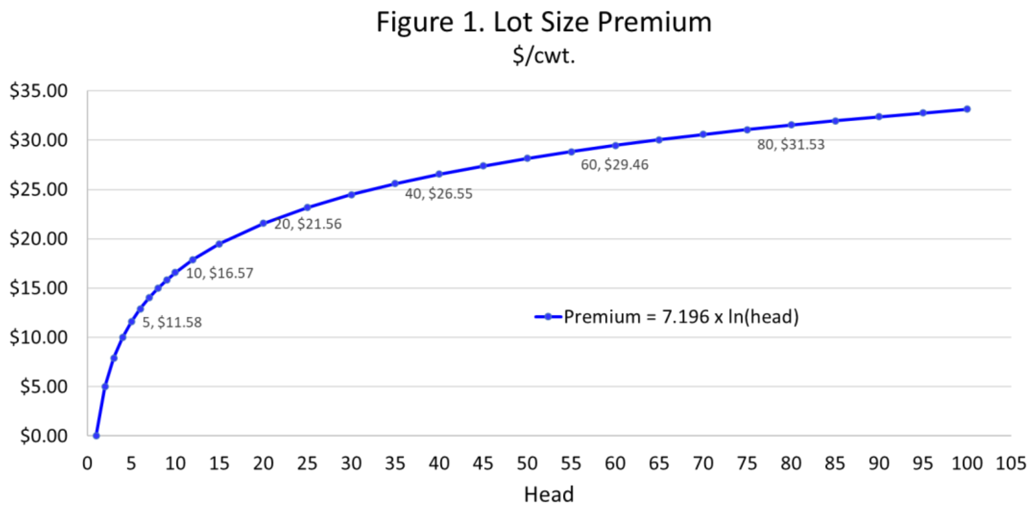
Hedonic models are commonly used to model pricing differences in markets where the product can be viewed as differentiated in that buyers have choices related to specific characteristics. Examples include real estate, rental housing, and cars. Hedonic modeling has been used often to analyze the marginal price impact of varying lot characteristics, physical characteristics, and calf management practices on lot prices for feeder cattle. Selected examples include Coatney, Menkhaus, and Schmitz (1996), Schroeder et al. (1988), Williams et al. (2014), Williams et al. (2012), and Zimmerman et al. (2012).

RESULTS

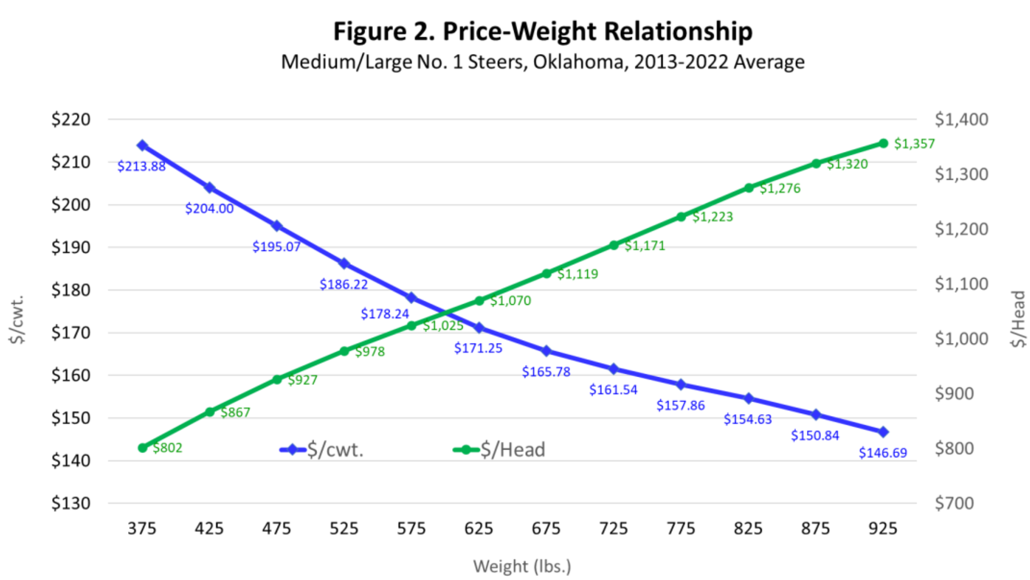
Results from the hedonic model analysis are presented in Tables 2, 3, 4, 5, and 6[1]. Table 2 reports estimates for general sale characteristics, including lot size and average weight. Figure 1 illustrates market premiums for lot size as depicted in the data set, based on a logarithmic function. Lot size premiums for feeder cattle are routinely observed to be nonlinear with larger marginal premiums as lots move from 1 up to 10 head and decreasing marginal premiums thereafter.

Price premiums are quite pronounced for lots less than 10 head. For example, a lot of 5 head has a premium of $11.58/cwt compared to a single animal lot. For larger lots the marginal increase in price for larger lots decreases significantly. For example, a 40 head lot receives an average premium of $4.99/cwt. compared to a 20 head lot and a lot of 60 animals receives a premium of $2.91/cwt. over a 40 head lot.

[1] Statistical significance of parameter estimates in Tables 2-6 are indicated by *** , ** , and * representing the 0.001, 0.05, and 0.1 levels of significance.



Feeder cattle price per hundredweight ($/cwt.) decreases as animal weight increases. Figure 2 shows the average relationship between steer weight and value per head in Oklahoma auctions. The price decrease is not linear but decreases at a decreasing rate as weight increases. This price decrease, frequently referred to as the price slide or price rollback, varies seasonally and with different market conditions, including feed costs (Peel and Riley, 2018). The model estimates show that, on average, price decreases in a nearly linear fashion by $14.62/cwt for each one hundred pounds of weight. The quadratic term is small but will slow the decrease in price by weight by 0.416 times weight squared. This quadratic term would offset the linear decrease at a weight well above the feeder cattle weight range.



Value of Animal Characteristics

Table 3 includes model estimates for the value of various animal characteristics. Compared to steers, heifer price is lower by an average of 18.70/cwt. Bulls/mixed lots are lower in price by 7.39/cwt. Although producers cannot generally control the production of steers versus heifers (sexed semen being an exception), marketing bulls rather than steers is a management choice. At the average weight of 596 pounds, this analysis indicates that bulls bring an average of $44.06/head less than steers.

Some heifers are specifically identified as replacement heifers in sales. The price of replacement heifers is $20.09/cwt. less than steers and is a bigger discount than the heifer average. This surprising result is likely an artifact of the data since these identified replacement heifers made up just 0.3 percent of the lots and included, for example, unusual lots with weights in excess of 1100 pounds. In general, few heifers identified as replacement heifers are sold in regular auctions. All of the gender variables are highly significant statistically.

All lots were identified by hide color or breed characteristics if possible. The majority of lots were black-hided (60%) with another 15 percent predominantly black-hided. All of the estimated differences due to hide-color/breed were statistically significant. Compared to black-hided lots, the predominantly black-hided lots had the smallest discount of $1.93/cwt. (Table 3). Red-hided, white/gray hided, and mixed high-quality lots all had discounts between $5-$6/cwt relative to black-hided lots. Animals with distinctive Hereford breeding received a discount of $9.93/cwt. compared to black-hided animals. Lots identified as dairy or longhorn breeding, mixed low quality or beef-dairy crossbred animals received discounts ranging from $28.62 - $32.52/cwt. Regardless of hide color, animals exhibiting brahman breeding were identified and received an additional discount of $8.94/cwt. While lots with a few animals showing Brahman breeding (Minimal Brahman) received an additional discount of $6.17/cwt. compared to cattle exhibiting no Brahman influence. These discounts are in addition to any discount related to the lot's specific hide color or breed notation.

Using lots with mixed #1-#2 muscling as a base, lots that were all #1 muscling received a premium of $2.91/cwt. In comparison. Lots of #2 muscling received a slight discount of $0.63/cwt. While lots of #2-#3 muscling were discounted $6.06/cwt. However, the estimates for #2 and #2-#3 muscling were not statistically different from #1-#2 muscled lots. Lots with #3 muscling received a statistically significant discount of $24.31/cwt.

Compared to medium-framed animals, lots of large-framed animals received a statistically significant discount of $2.67/cwt. Mixed medium/large frame and small framed animals received similar discounts of $1.41-$1.51/cwt. However, these discounts were not statistically different from the medium-framed animals.

Value of Management Characteristics

Management decisions have a significant impact on the value of feeder cattle. The decision to market feeder cattle as bulls rather than steers was discussed in the previous section (see Table 3). Table 4 presents the value of a variety of other management decisions affecting feeder cattle. Weaned calves (30 days or more) bring a premium of $4.48/cwt compared to unweaned calves. Vaccinated calves receive a premium of $1.97/cwt. over unvaccinated calves. Removing horns or using polled genetics increases feeder cattle value over horned cattle. Cattle with horns receive a discount of $8.47/cwt. compared to no horns.

Lots that included only a few horned animals (less than 20 %) received a slightly smaller discount of $6.20/cwt.

Animals marketed with excessive flesh were discounted $4.02/cwt. compared to animals of average flesh. Animals described as thin flesh received a slight but statistically insignificant premium compared to average fleshed animals. Animals described as full (tanked) received a discount of $15.15/cwt. compared to animals with average fill. Likewise, animals described as gaunt received a similar discount of $16.30/cwt. Animal fill is sometimes under control of the producer but may also be the result of auction facility management.

Producers may participate in a wide variety of certification programs. In this analysis, enough data for three programs permitted evaluation of program certification value, including the Oklahoma Quality Beef Network (OQBN), the Integrity Beef program, and Non-Hormone Treated Cattle (NHTC). A small number of other program cattle were included in the data, but numbers were insufficient to analyze individually. The value of OQBN certification was $4.52/cwt. while the Integrity Beef certification had a premium of $10.39/cwt. NHTC had a positive value of $1.20/cwt., but the estimated parameter is not statistically significant. Note that numbers of NHTC cattle were minimal in the data (0.5 percent of lots), but the estimated parameter is included here because of the national scope of the program. Most NHTC cattle are not marketed through auctions.

Programs such as OQBN and Integrity Beef encompass preconditioning protocols such as weaning and vaccination, along with castration and dehorning. Integrity Beef includes additional requirements for genetics, likely influencing the magnitude of the premium. The total value of these programs is the sum of these management practices and the certification. For example, the value of OQBN would be a total of certification, weaning and vaccination implying that the total value-added for a 550-pound steer would be $10.97/cwt. ($4.52+$1.97+$4.48). This is consistent with observed premiums for OQBN cattle in Oklahoma, where the 5-year average OQBN premium over nonpreconditioned cattle for 5 weight steers was $12.59/cwt for 2018-2022 (Raper and Peel, 2023). A significant number of cattle were marketed as natural (977 lots with 24,233 head). Natural definitions vary widely and are not consistent. The estimated parameter on natural cattle is slightly negative at -$0.88/cwt. but is not statistically different from zero.

Cattle identified visually as obviously unhealthy received discount of $38.25/cwt. (Table 5). Cattle specifically identified as crippled received a discount of $49.90/cwt. while cattle with bad eyes were discounted $20.46/cwt.

Location

Feeder cattle prices at any point time vary considerably in different regions of the country (Highfill and Peel, 2015). The hedonic model used in this analysis included binary variables to account for different sale locations. Table 6 presents the estimated parameters for each sale location compared to the base market at OKC National. The signs and significance of the location variables generally confirm previously identified regional differences in feeder cattle prices. Variables that are statistically insignificant cannot be said to have prices different from OKC National.

Consistent with previous research, the highest average prices and largest premiums to the base market are noted in Nebraska/Wyoming with statistically significant premiums of $11.07/cwt. for Valentine, a premium of $9.47/cwt. for Ogallala and $10.24/cwt. in Torrington. By contrast, Kentucky auctions showed statistically significant discounts to the base market of OKC National. Estimates for the four Kentucky markets are -$19.09/cwt. for Springfield; -$12.75/cwt. in Campbellsville; -$9.22/cwt. in Stanford; and -$7.56/cwt. for Richmond.

South Dakota auctions showed a mixed set of discounts and premiums, generally not significantly different from the base market. This includes premiums of $4.01/cwt. in Faith; $3.62/cwt. in Philip and discounts of -$1.80 for Mitchell and -$0.57 for Pierre. The discount of $5.16/cwt for Hub City was statistically different from the base market at OKC National.

Within Oklahoma, OKC West (El Reno) has a premium of $2.05/cwt while Woodward posts a slight premium of $0.58/cwt. However, neither of these estimates are statistically significant. Prices at McAlester, OK are significantly less than OKC National by $5.58/cwt. The auction at Salina, KS posted a $4.02/cwt. premium to the base market that was marginally significant.

Regional Observations and Comments

Significant regional differences became apparent in this project that impacts both market reporting and data collection. In some cases, these differences reflect regional culture relative to how cattle are marketed as well as regionally unique terminology and practices including the amount of information provided and the manner in which information is provided to buyers. Individual sale barns vary widely in sale management and information availability/communication, which affect the feasibility and amount of market information that can be reported/collected.

SUMMARY

This project analyzes factors affecting the value of feeder cattle with what is likely the most comprehensive feeder cattle auction data set available. The data includes information on numerous additional factors beyond current market reporting. The analysis provides estimates of the contributions of a variety of sale, animal and management characteristics that contribute to the value of a lot of feeder cattle. Additionally, the analysis confirms regional differences in feeder cattle value based on geographic location.

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Table 1. General Data Summary

	Total	**Average**	**Range (Min-Max)**
Sales	92		
Head	275,335		
Sale Lots	18,038	15.3 head	1 – 453 head
Weight (lbs.)		596	149 – 1422
Price ($/cwt.)		$156.82	$5.00 - $308.18
Value of Sales	$291,710,731.01	Lot: $16,172; Head: $919	

Table 2. Model Estimates: General Sale Characteristics

Variable	**Estimate**	**Std. Error**	**t-value**
Log lot size (head)	7.196***	.312	23.03
Avg. weight (cwt.)	-14.62***	1.086	-13.46
Avg. weight^2 (cwt.)	.416***	.086	4.86

Table 3. Model Estimates: Animal Characteristics

Comparison Base	**Variable**	**Estimate**	**Std. Error**	**t-value**
Steers				
	Heifers	-18.698***	.487	-38.43
	Bulls	-7.392***	.862	-8.58
	Rep. Heifers	-20.094***	2.096	-9.59
Black-hided				
	Black mixed	-1.93***	.502	-3.84
	Red	-5.252***	.817	-6.43
	Red mixed	-2.945***	.678	-4.34
	Hereford	-9.932***	1.304	-7.62
	White/Gray	-5.152***	.789	-6.53
	Dairy/Longhorn	-32.521***	4.628	-7.03
	Mixed Low Quality	-28.057***	4.468	-6.28
	Mixed High Quality	-5.597***	.722	-7.75
	Beef-Dairy Cross	-29.618***	6.688	-4.43
	Brahman Influence	-8.935***	2.315	-3.86
	Minimal Brahman	-6.165***	.966	-6.38
#1-2 Muscling				
	# 1	2.91**	1.48	1.97
	#2	-.631	1.039	-0.61
	#2-3	-6.061	3.719	0.103
	#3	-24.31***	2.555	-9.51
Medium Frame				
	Large	-2.669***	1.033	-2.58
	Medium/Large	-1.406	.946	-1.49
	Small	-1.514	6.006	-0.25

Table 4. Model Results: Management Characteristics

Comparison Base	Variable	Estimate	Std. Error	t-value
Unweaned				
	Weaned	4.475***	.649	6.89
Unvaccinated				
	Vaccinated	1.966***	.578	3.40
No Horns				
	Horns	-8.465***	1.563	-5.42
	Minimal Horns	-6.198***	1.324	-4.68
Average Flesh				
	Thin	.466	1.566	0.30
	Fleshy	-4.024***	1.37	-2.94
Average Fill				
	Full	-15.153***	3.035	-4.99
	Gaunt	-16.295**	7.173	-2.27
Not Certified				
	OQBN	4.524***	1.539	2.94
	Integrity Beef	10.39***	1.61	6.45
	NHTC	1.204	1.418	0.85
Conventional				
	Natural	-.884	.97	-0.91

Table 5. Model Results: Animal Health

Comparison Base	Variable	Estimate	Std. Error	t-value
Healthy				
	Unhealthy	-38.248***	6.182	-6.19
	Crippled	-43.903***	7.381	-5.95
	Bad Eye	-20.458***	3.228	-6.34

Table 6. Model Results: Location Impacts

Comparison Base	**State**	**Sale**	**Estimate**	**Std. Error**	**t-value**
OKC National					
	Oklahoma	OKC West	2.045	2.495	0.82
		McAlester	-5.581**	2.23	-2.47
		Woodward	.581	1.884	0.31
	Kansas	Salina	4.016*	2.355	1.71
	Kentucky	Springfield	-19.088***	.973	-19.62
		Campbellsville	-12.745***	2.263	-5.63
		Stanford	-9.218***	3.253	-2.83
		Richmond	-7.562**	3.282	-2.30
	Missouri	F&T Livestock	-1.583	2.845	-0.56
		Joplin	0.66	2.824	0.23
		EMCC	1.371	2.169	0.63
		Kingsville	4.546**	2.234	2.03
	Nebraska	Ogallala	9.474***	2.285	4.15
		Valentine	11.071***	2.378	4.66
	South Dakota	Faith	4.012	2.639	1.52
		Ft. Pierre	-0.569	2.362	-0.24
		Hub City	-5.157**	2.149	-2.40
		Mitchell	-1.799	1.922	-0.94
		Philip	3.616	3.039	1.19
	Wyoming	Torrington	10.236***	2.024	5.06

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PRINCIPLES FOR SUCCESSFUL LIVESTOCK GRAZING MANAGEMENT ON WESTERN RANGLANDS

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INTRODUCTION

Livestock grazing management in the diverse rangelands of the Western U.S. is enormously complex. Across a wide range of climates and ecosystems that are characterized by a lack of predictability, human managers aim to sustainably produce livestock products while maintaining ecologically healthy rangelands. For more than a century, range scientists have aimed to provide usable information to producers to increase their likelihood of success. However, no concise statement of what we have learned exists. While this is largely due to the diversity and complexity of grazing management, it creates problems for producers, industry, extension, and range scientists themselves as compelling but evidence-challenged narratives fill the void.

OBJECTIVES

Our objective for this project was to work with the range science community to identify a set of concise, evidence-based, and adaptable principles for successful livestock grazing management on western semi-arid and arid rangelands.

METHODS

We created the principles using an iterative survey and feedback process between an eight-member advisory committee and a group of >80 grazing management experts from across the west. After initial work by the advisory team, a widely distributed survey elicited lengthy responses totaling >25,000 words of wisdom about successful grazing management. We then distilled these into a set of draft principles, which were debated and revised among the advisory team. These draft principles were then returned to the initial survey respondents for further feedback. We also received feedback from >100 range professionals in a "campfire conversation" session at the 2023 Society for Range Management Annual Meeting. The advisory team further debated and revised to arrive at seven principles, structured as short memorable statements followed by paragraph-length descriptions that highlight key ideas and practices.

RESULTS

The seven identified principles are intended to evolve with conversation, debate, and more research. Already, we are adapting them for use in a guidebook for Colorado ranchers and have heard from extension and NRCS staff across the west that they intend to use them in outreach work. With the development of an associated checklist, these principles are ideal for use by industry organizations seeking to support successful livestock grazing management in their supply chains.

Figure 1: Short versions of the seven principles for successful livestock grazing management.

Acknowledgements: Thank you to participating survey participants. EJ Raynor and Anna Shadbolt provided additional edits and insights.

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Proceedings, The Range Beef Cow Symposium XXVIII
December 12-14, 2023, Loveland, Colorado

IONOPHORES AND REPRODUCTION: WHAT IS THE BENEFIT FOR RANGE COWS AND HEIFERS?

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INTRODUCTION

The most important factors affecting financial viability of a cow-calf enterprise are reproduction and nutrition (Hess et al., 2005). Financial cost associated with feed is the greatest factor influencing profit of commercial beef cow operations, accounting for over 63% of the variation in total annual cow costs (Miller et al., 2001). Management options focused on reducing forage/harvested feedstuff costs and (or) supplementation costs while potentially improving reproductive performance could ultimately improve cow/calf enterprise profitability (Gadberry et al., 2022). Reproductive performance can be compromised in grazing beef production systems due to a mismatch of physiological nutrient demands and suboptimal forage conditions (Mulliniks et al., 2019). Thus, supplementation strategies focused on eliciting a metabolic response with minimal inputs, which can positively alter important economic production traits such as conception date and overall pregnancy rates should be evaluated.

Although ionophores have been utilized extensively in feedlot and backgrounding diets, inclusion of ionophores into beef cattle supplements for cows and heifers can elicit a positive increase in feed efficiency and increased gain. Monensin, in particular, has been shown to hasten the days to puberty in heifers and decreases the postpartum interval in beef cows (Gadberry et al., 2022). Although indirectly, supplementation of monensin increases propionate supply for post-ruminal glucose availability as propionate is the primary gluconeogenic volatile fatty acid (VFA). Supplementation to increase post-ruminal supply of glucogenic precursors with propionate salts has been shown to decrease days to resumption of estrus and increase pregnancy rates in young range cows (Mulliniks et al., 2011). Overall, inclusion of ionophores in grazing livestock diets may have the potential to improve feed efficiency, decrease harvested feed intake, and improve reproductive performance in heifers and lactating range cows.

Although other ionophores can be utilized, this article will focus on monensin, simply because more information is available due to its longstanding and widespread use in the cattle industry since the mid-1970s.

Mode of action of ionophores

Ionophores have been safely utilized in the beef industry for a long time although mostly in feedlot and backgrounding diets. When fed according to the recommended rates, ionophores are considered safe and effective. Ionophores can be fed to cattle in several different supplemental packages from liquid feeds, cakes, pellets, and loose minerals. The classification of the animal (i.e., lactating cow vs stocker) can dictate how ionophores are delivered according to the label. Ionophores approved for use in cattle include monensin (Rumensin®), lasalocid (Bovatec®) and laidlomycin propionate (Cattlyst®).

Ionophores are feed additives used in cattle diets to increase feed efficiency and body weight gain. In addition, ionophore can decrease the incidence of bloat and coccidiosis. Ionophores are compounds that alter rumen fermentation and fermentation end products. Monensin, for instance, is a carboxylic polyether ionophore that selectively inhibits gram positive bacteria, which in return increases ruminal production of the volatile fatty acid propionate and decreases methane production (Appuhamy et al., 2013). In forage-based diets, ionophores have been found to improve body weight gain without depressing intake, while still resulting in improved feed conversion (Bergen and Bates, 1984). This results in enhanced animal performance due to improved retention of carbon and energy during rumen fermentation (Bergen and Bates, 1984). Monensin can shift the acetate:propionate ratio by increasing propionate supply without increasing acetate (Linneen et al., 2015). In addition, inclusion of monensin in diets has shown to increase ruminal propionate by 10.4% and reduced ruminal acetate by 1.7% in steers consuming a forage-based diet (Bell et al., 2017).

Impact of Ionophores on Yearling Beef Heifers

Replacement heifers play an integral part in sustaining herd size, which are necessary to replace culled cows and to improve the genetics of the herd. The most expensive and, arguably, the most critical time in a beef female's life is the heifer development period. Heifer development is one of the largest expenses for beef cattle operations due to inherent opportunity and development costs for retaining heifers. Conception rates have been reported to be greater in heifers that are bred on their third estrus rather than at pubertal estrus (Byerley et al., 1987). Therefore, heifer development methods have been focused on the physiological processes that influence puberty (Patterson et al., 2000). Nutritional management influences the differences in age and/or weight at puberty onset in heifers (Patterson et al., 1992). Yearling beef heifers fed monensin have been shown to have increased average daily gain. Reviews of numerous grazing trials using steers and heifers indicate that supplementation with 155 mg/day of monensin results in an improvement in average daily gain of 0.18 lb/day or a 13.5% increase compared to non-supplemented control cattle (Kunkle et al. 2000). When the amount of monensin increased to 200 mg/day, cattle gained an additional 0.20 lb/day or a 16% improvement compared to cattle not offered an ionophore. In an analysis of 18 different studies, Gadberry et al. (2022) reported an improved average daily gain of 0.07 lb/d in heifers fed monensin over heifers without monensin. In addition, this study did show an overall decrease in feed intake by 4.3%, which increased feed efficiency of monensin-fed heifers by 14%.

One of the key factors that may indirectly influence reproduction is improved nutrient utilization. Monensin is one of the most used ionophores and has been shown to improve feed efficiency in growing cattle (Duffield et al., 2012). The increased efficiency in converting feed into energy can support the energy requirements for reproductive processes, including estrous cycling and embryonic development. In a meta-analysis, age at puberty was reduced in yearling beef heifers with the inclusion of monensin in the diet by approximately 9 days; however, within the same analysis, weight at puberty and overall pregnancy rates were not affected by monensin supplementation compared to heifers not receiving monensin (Gadberry et al., 2022). McCartor et al. (1979) suggested that increasing ruminal propionate production was responsible for reduced age at puberty in heifers fed monensin. One of the benefits of the inclusion of ionophores in grazing livestock diets is increased ruminal propionate production. Increasing ruminal propionate production has been shown to decrease days to resumption of estrus and overall pregnancy rates in young range cows (Mulliniks et al. 2011). Similarly, in range heifers, Lalman et al. (1993) compared monesin to a direct supplemental propionate source, which monensin-fed yearling heifers achieved puberty at an earlier age than heifers fed propionate directly. Similarly, Hubbard (2017) reported that monensin-fed beef heifers had greater percentage of pubertal heifers at the start of breeding than propionate salt-fed heifers. Therefore, these data suggest that the potential to positively influence puberty with monensin may not be exclusively due to an increase in propionate supply. Previous research has shown that heifers-fed monensin had greater responsiveness to gonadotropin stimulation (Bushmich et al., 1980) or estradiol and gonadotropin releasing hormone (Randel et al., 1980; Randel and Rhodes, 1980a, 1980b). Although the mode of action behind the positive influence on puberty attainment in heifers is unknown, monensin does seem to have an overall positive impact the reproductive physiology.

Impact of Ionophores on Range Beef Cows

During early lactation, the animal's energy requirement for lactation and maintenance can exceed energy intake, resulting in mobilization of stored resources from adipose tissue to meet energy demands. This period in beef cows provokes a negative energy balance (NEB), characterized by elevated concentrations of beta-hydroxybutyrate (BHB), which is associated with a metabolic dysfunction resulting from inadequate adaptation to NEB and incomplete oxidation of energy substrates (Herdt, 2000). The adaptive responses to high metabolic demands, such as lactation, vary among animals even with the same nutrient requirement. For example, postpartum cows prioritize metabolizable energy first towards milk production, then growth, and finally the regaining of adipose tissue (Lucy, 2003). Under the same metabolic load of lactation, cows will partition nutrients and adapt to metabolic demands differently. Decreased nutrient intake can further exacerbate energetic challenges associated with pregnancy and nutrient demands of lactation, thus creating the most difficult periods in managing beef cows. During early lactation, cows experience NEB and will mobilize both protein and fat storage to offset the energy deficiency. A NEB during early lactation can lead to an inadequate glucose supply during the physiological stage of the highest glucose demand. The requirement for glucose is maximum in pregnant or lactating females. Glucose is the only precursor for lactose synthesized in milk. Approximately 1.5 units of glucose are needed to synthesize 1 unit of milk lactose, and the net daily requirement may be as much as 2.8-3 kg of glucose in the case of high milk production. Thus, the ability to synthesize glucose through gluconeogenesis, from non-glucose precursors such as propionate and glucogenic amino acids becomes mandatory. Range forage diets generally promote high ruminal production of acetate relative to propionate (Cronje et al., 1991). Ruminal fermentation products of dormant native range yields small amounts and potentially inadequate quantities of glucogenic precursors, particularly propionate. Propionate is the primary precursor for gluconeogenesis for ruminants. Therefore, propionate needs to be in sufficient quantities to satisfy glucose energy demand for metabolism (Leng et al., 1967). Increasing glucogenic potential of the diet through increased ruminal propionate supply has been shown to partition nutrients away from milk production while increasing reproductive performance (Mulliniks et al., 2011). Therefore, increasing ruminal propionate supply to young cows consuming low-quality forage-based diets may increase energy metabolism and reproductive performance.

Similar to yearling heifers, feeding beef cows ionophores has shown to potentially decrease feed intake, increased feed efficiency and increase reproductive performance. Ionophores have been shown to increase body weight (BW) gains and feed efficiency in beef cattle without any detrimental effect on other measures of performance such as fertility and milk production (Sprott et al., 1988). However, cow BW, body condition score (BCS), and forage intake responses to ionophore supplementation are dependent on forage quality and physiological stage of the cow (Sprott et al., 1988). Moseley et al. (1977) supplemented a 20% natural protein range cube that carried either 0 mg or 200 mg of monensin per head daily. These authors proposed that monensin supplementation may be beneficial as a means of increasing BW gains on forage-based diets when feed intake is restricted by forage availability and cattle are maintained on a low plane of nutrition. In a review, Goodrich et al. (1984) indicate on average a 13% improvement in BW gains and the ability for beef cows to maintain on approximately 10% less feed in response to monensin. During late gestation, Musgrave et al. (2024) comparing protein supplements with either monensin or a direct propionate source, reported that supplementation strategy did not influence cow BW change during late gestation; however, subsequent pregnancy rates were greater in cows fed the direct propionate source.

Use of ionophores in diets have also shown positive effects on reproduction. In a meta-analysis, Gadberry et al. (2022) reported resumption of estrus after calving was decreased by 18 d with the inclusion of monensin in the diet of lactating mature beef cows. Hixon et al. (1982) determined the effects of monensin supplementation on nutritional and reproductive measurements on energy-stressed primiparous range cows. These authors reported that supplementation of monensin decreased postpartum interval, milk yield, and BCS at 120 d postpartum. In a review, Sprott et al. (1988) suggests that the impact of ionophores on postpartum interval may be due to the impact of ionophores on BCS and BW gain during the supplemental feeding period.

The greatest benefit in feeding ionophores to lactating beef cows are in young, 2- and 3-year-old cows. Reproductive performance in young 2- and 3-yr-old cows are often the lowest in the cow herd, which is due to their inability to consume enough energy and protein to meet their requirements for growth and lactation. King et al., (2023) compared efficacy of differing feed additives that increase ruminal propionate supply providing insight to develop supplementation strategies to optimize reproductive performance in young March-calving cows in the Nebraska

Sandhills. The objective of this study was to determine the impact of the addition of either monensin (Rumensin 90, Elanco Animal Health) or propionate salt (NutroCal 100, Kemin Industries) in protein supplements on BW change, BCS, energy metabolism, reproduction, milk production, and calf weaning BW in young postpartum range cows. In this study, postpartum supplementation strategies did not influence cow BW or BCS after calving; however, supplementing young range cows with 40 g of calcium propionate increased the number of cows cycling prior to the initiation of breeding and increased pregnancy rate compared to cows receiving monensin.

Young May-calving cows grazing primarily dormant native upland range in the Nebraska Sandhills can experience NEB postpartum and throughout the breeding season, which can lead to a decrease in reproductive performance. As summer months progress, maturing native upland range forages lead to deficiencies in energy and metabolizable protein. Woita (2022) compared postpartum supplementation strategy on reproduction, cow BW, and calf performance in lactating young May-calving range cows in the Nebraska Sandhills. Supplementation was initiated 30 d prior to the start of the breeding season (45-d postpartum) and continued throughout the 45-d breeding season (125-d postpartum). Supplementation was provided daily with treatments being: 1) 4 oz/d mineral supplement alone, 2) 4 oz/d mineral with monensin (200 mg per cow), 3) 4 oz/d of a mineral with an additional 8 oz/d of a high rumen undegradable protein source, or 4) 2 lb/d of dried distiller grains. Supplementation strategy did not influence any changes in cow BW or BCS. However, reproductive performance in cows receiving either the mineral with the rumen undegradable protein source and the dried distiller grains were increased over the mineral alone and mineral with rumensin. The addition of rumensin to the mineral had similar reproductive performance compared to mineral alone.

Ionophores are a widely used feed additive in beef cattle production, primarily known for its effects on feed efficiency and growth performance in the feedlot phase. While the impact of ionophores on reproduction has not been as extensively studied as growth studies, there is evidence to suggest potential benefits in the cowherd. The mechanisms by which ionophores may improve reproduction include enhanced nutrient utilization and increased BW gain. However, the results have been highly variable, and additional research is required to elucidate the precise interactions and factors that influence the effects of ionophores on reproduction in beef cows. Understanding these relationships could offer valuable insights for beef cattle producers aiming to optimize their reproductive efficiency.

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Proceedings, The Range Beef Cow Symposium XXVIII
December 13 & 14, 2023, Loveland, Colorado

SHOULD WE BE SUPPLEMENTING MORE VITAMIN A TO PREGNANT BEEF COWS?

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INTRODUCTION

Vitamin A has several important roles in the body. It is well-known for its role in vision, but it is also important for proper immune function and epithelial integrity, specifically in the gastrointestinal and respiratory tracts. Research has shown that the young calf is the most at risk for vitamin A deficiency in cow/calf systems. Calves are born with very low vitamin A stores, and their primary source at birth is colostrum. Calves that do not get enough vitamin A from colostrum can be at increased risk for diarrhea and respiratory disease.

Fresh green forage contains high amounts of beta (β) carotene, a precursor that can be used by the cow to synthesize vitamin A. Diets consisting primarily of stored or brown forages and concentrates contain low amounts of β-carotene. Thus, diets consisting of these feeds during late gestation will impact vitamin A concentrations in colostrum, which may lead to a calf being deficient and subsequently impact calf health. The focus of this paper will be on the vitamin A intake of gestating cows and its potential impact on vitamin A status of the young calf.

ROLE OF VITAMIN A

Vitamin A is important for reproductive health and is essential for proper embryonic development and organ formation. The vitamin A status of the cow during gestation is important because of its role in embryonic and fetal development and placental growth (Clagett-Dame and Knutson, 2011). Deficiencies could result in complete failure to breed, fetal resorption, abortion, or congenital malformations; thus, the time point at which a vitamin A deficiency is present will affect reproductive outcome (Clagett-Dame and Knutson, 2011).

However, in cow/calf systems the potential impacts on young calf health are arguably the most significant. Supplementation of the cow in gestation is important to enhance young calf survival. The amount of vitamin A needed for the cow herself (including successful reproduction) is much lower than what is needed to fortify the calf though colostrum to ensure it is healthy (Guilbert and Hart, 1935; Church et al., 1956; Meacham et al., 1970). The most commonly reported symptoms associated with vitamin A deficiency in calves are diarrhea and/or respiratory infections in the first week or two of life (Guilbert and Hart, 1934; Stewart and McCallum, 1938; Church et al., 1956; Jones et al., 1962).

VITAMIN A IN FEEDSTUFFS

In the majority of cow/calf systems, winter is the time dietary vitamin A may fall short. Grazing of green pasture in the spring and summer will build up liver vitamin A stores that can be used during the fall and winter, as the amount of β-carotene, a vitamin A precursor, is sizable in fresh green forages (Weiss, 1998). Less mature forages have more β-carotene than more mature forages (Calderon et al., 2012). Because β-carotene content of forages is directly related to their green color, forages that do not appear very green (ex. dormant range, corn residue, straw, and sun-bleached hay) will be very low in vitamin A (Table 1). Sun drying of hay will greatly reduce the amount β-carotene, with additional losses occurring during storage of hay (Ballet et al., 2000).

Table 1. Amount of vitamin A potentially available from carotenoids in various feedstuffs (DM basis)

Feedstuff	**Vitamin A, IU/lb DM[1]**	**Intake for 1300 lb cow, IU/d[2]**
Fresh Pasture	8,571 to 23,455	222,846 to 609,830
Silage, corn	2,423 to 13,333	81,536 to 113,464
Green hay, alfalfa	8,081 to 11,111	210,106 to 288,886
Average alfalfa hay, some green color	4,040 to 6,262	105,040 to 162,812
Green grass hay, grass	4,040 to 6,262	105,040 to 162,812
Average grass hay, some green color	1,818 to 3,937	47,268 to 102,362
Brown hay	127	3,302
Straw, wheat	27	624
Corn, cracked	68	
Corn, high moisture	163	
Distillers grains, dry	219	
Distillers grains, wet	363	

[1]Calculated as 1 mg of β-carotene = 400 IU vitamin A, 1 mg β-cryptoxanthin= 200 IU vitamin A, 1 mg of α-carotene = 200 IU vitamin A. Data from Maynard et al., 1979, Calderon et al., 2012, Pickworth et al., 2012.
[2] Assumes a cow is consuming 2.0% of BW/d (DM basis)

WHAT ARE CURRENT RECOMMENDATIONS?

The NASEM (2016) does a nice job of summing up our current understanding of vitamin A needs in cow/calf systems when they say "Limited recent data are available investigating vitamin A requirements in pregnant beef heifers and cows…... Definitive studies with modern breeds and beef production practices have not been conducted". The current requirements for vitamin A of pregnant and lactating beef cows are 1,273 IU/lb and 1,773 IU/lb, respectively (NASEM, 2016), and have not been changed from the time they were established in 1976. This recommendation is for supplemental vitamin A, meaning that this is the recommended feeding level above what vitamin A is already being contributed by the diet. It is not entirely clear what type of diet was assumed when developing these recommendations. Given the variability of vitamin A available from various feedstuffs (Table 1), the type of diet would have significant effects on vitamin A intake and supplemental vitamin A needs.

It appears these recommendations are based on very few studies in which beef cows were used (Guilbert and Hart, 1935; Church et al., 1956; Meacham et al., 1970). All of these studies involved a single supplementation amount compared to a non-supplemented control. It can also be argued that genetics of the cows used in the aforementioned studies on which vitamin A requirements were based are likely different from modern beef cows; therefore, current requirements may not be applicable to cows in today's herds. Genetic selection for growth and performance over time has resulted in the modern beef cow being significantly larger and calf growth being significantly greater. Greater growth rates may result in increased vitamin A needs.

HOW DO OUR CURRENT RECOMMENDATIONS COMPARE TO OTHERS?

There are more studies that have been conducted with small ruminants. If we scale the small ruminant vitamin A recommendation (NRC, 2007) for an ewe in late gestation to the 1300-lb cow, it would be almost 90,000 IU/d (Table 2). This recommendation accounts for increased growth of conceptus during late gestation as well as the increased maintenance requirements of animals during late gestation (NRC, 2007). The Australian Nutrient Requirements of Domestic Ruminants (CRISO, 2007) recommends that a pregnant cows has similar to requirement to what the NRC suggests for the late gestation ewe. (Table 2). The basis for their recommendations is the maintenance of liver stores and the understanding that vitamin A has roles in gene and hormone regulation, although they indicate that there is not enough data for definitive requirements to be set. Across these publications there is no discussion on the amount needed to ensure sufficient colostrum transfer of vitamin A to the offspring. The British Nutrient Requrment of Ruminant Livestock (ARC, 1980) does suggest a significant increase in the requirement to provide for the suckling calf, although they indicate this as a lactation requirement (Table 2). To fortify the colostrum this diet would need to be fed in late gestation, thus for our purposes it seems relevant.

It could be concluded that the Beef NASEM recommendation is lower than others. Part of this discrepancy is because the recommendation is for supplemental and not total vitamin A needs. With a diet of average green grass hay, the supplemental suggestion will result in a total vitamin A intake that is probably similar to other recommendations. The difference is for diets consisting of brown forages, such as dormant range, corn residue, or brown hay, supplementation at the NASEM recommendation would result in these diets containing 30 to 60% of the other recommendations.

Table 2. Comparison of vitamin A recommendations for pregnant cows and ewes			
		IU/lb DM	**Intake scaled to a 1300-lb cow, IU/d[1]**
Pregnant cow (Beef NASEM, 2016)	Supplemental	1,272	33,090
Late pregnant ewe (Small ruminant NRC, 2007)	Total	3,450	89,394
Pregnant Cow (CSIRO, 2007)	Total	3,400	88,660
Pregnant Cow (ARC, 1980)	Total	2,250	58,500
Provide for suckled calf (ARC, 1980)	Total	4,924	128,018
[1]Assumes DM intake at 2.0% of BW			

NEW VITAMIN A DATA IN BEEF COWS

We recently conducted two studies to evaluate the impacts of vitamin A supplementation of cows during gestation on the status of their calves (Speer et al., 2024). In the first study, we used multiparous beef cows that had previously been grazing on pasture (6.4 ± 1.2 years of age; n = 120) and were in mid-gestation. They were either assigned to receive 9,638 IU/d vitamin A (n = 30) or 24,973 IU/d vitamin A (n = 90). These levels were approximately one-third and two-thirds of the current NASEM recommendation (33,000 IU/d) for gestating beef cows weighing 1,300 lbs consuming 2.0% of body weight in DM per day. Cows were individually supplemented in Calan gates from 111 days pre-calving to 32 days post-calving. Their diet consisted of alfalfa hay, corn silage, and a supplemental pellet that contained vitamin A, which was provided as retinyl acetate. Basal diet vitamin A concentration was calculated to be 223 IU/lb DM based on its β-carotene content, so mean vitamin A intake from the basal diet was 4,583 ± 649 IU/d.

Because cows had recently spent time on green grass, initial liver retinol (storage form of vitamin A) concentrations (mean 830 µg/g DM) of cows were well above adequate. By 32 days post-calving, mean cow liver retinol concentration (482 ± 182 SD µg/g DM; Puls, 1994) had decreased but was still considered adequate based on the current reference range of 300–700 µg/g DM (Puls, 1994).

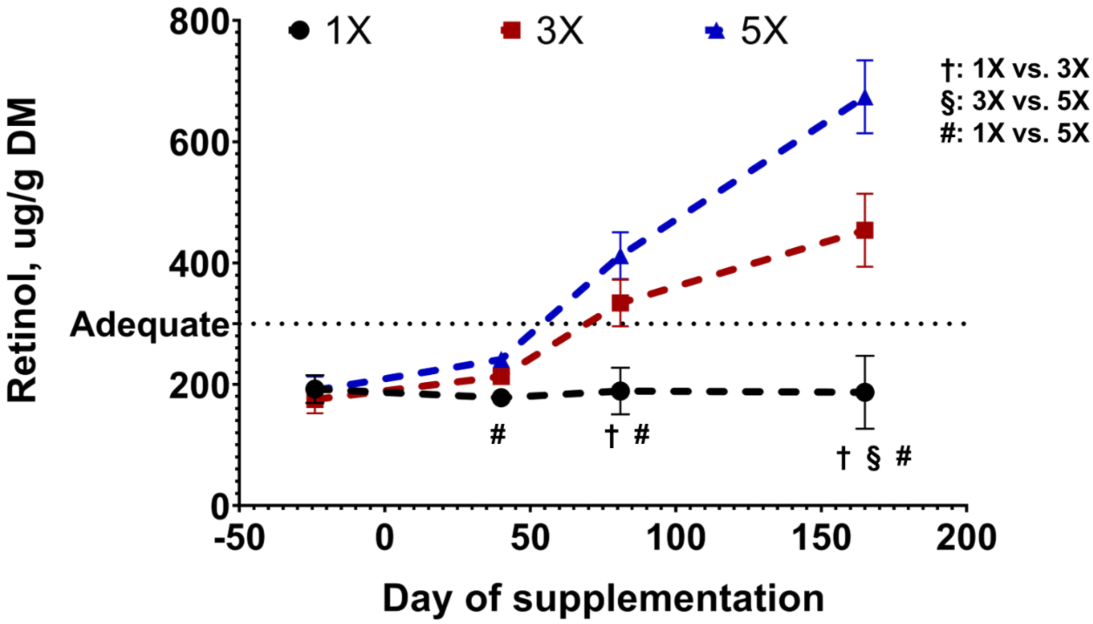
There was a positive correlation ($P < 0.01$; r = 0.31) between cow and calf liver retinol, suggesting that as cow retinol liver concentrations increased, calf liver retinol concentrations increased. However, it appears that despite cows having adequate liver retinol concentrations when low vitamin A was fed, it did not result in calf liver retinol stores (51 ± 27 SD µg/g DM) that would be considered adequate for calves at 32 d of age given current reference ranges (100–350 μg/g DM; Puls, 1994). Indeed, Swanson et al. (2000) observed increased incidence of diarrhea and hyperthermic rectal temperatures in dairy calves in their first month of life when liver vitamin A was below 75 μg/g DM. In our study, however, there were no observed illnesses or clinical signs of vitamin A deficiency amongst the calves.

Adequate liver stores in the dam did not result in enough transfer to the calf because cow liver retinol stores are not the only contributor to vitamin A in colostrum. Research in beef cattle indicates cow liver stores only contribute about ~40% of the vitamin A found in colostrum, while the other 60% comes from the cow's diet (Branstetter et al., 1973; Tomlinson et al., 1974). Therefore, dietary vitamin A levels the cow receives during late gestation, as well as her liver vitamin A stores, affect the amount of vitamin A her calf receives in the colostrum to build its own liver vitamin A stores.

In the second study, multiparous beef cows (n = 54) that had been fed in the drylot for a year or more were stratified by body condition score and time spent in drylot and assigned to a pen. Pens (n = 3 per treatment) were then randomly assigned to receive 1 of 3 supplemental vitamin A levels: the current NASEM recommendation for gestating beef cows (31,000 IU/d; 1X), 3 times (93,000 IU/d; 3X), or 5 times the current NASEM recommendation (155,000 IU/d; 5X). The 1X level was selected in this study assuming a cow weight of 1,200 lbs that consumed 2.0% of body weight in DM per day. Prior to treatment initiation, all cows were receiving the 1X supplemental level. Treatments were initiated in mid-gestation and concluded 32 days post-calving. Cows were limit-fed a diet consisting of wheat straw, corn silage, and wet distillers grains. Vitamin A, as retinyl acetate, was added to the diet via a micronutrient machine. Liver biopsies were collected for retinol analysis on cows 24 days before treatment initiation, d 40 and d 81 of supplementation, and both cows and calves were sampled 32 d post-calving (165 ± 22 d SD of supplementation).

No differences (P = 0.86) in initial cow liver retinol concentration (mean 186 μg/g DM) were observed between treatments. Cows were receiving the 1X supplemental vitamin A level before the study, suggesting that the current supplemental vitamin A recommendation of 31,000 IU/d was not enough to get cows to adequate liver retinol concentrations (300–700 μg/g DM; Puls, 1994). Liver retinol concentrations of 1X cows remained below adequate reference ranges (300–700 μg/g of DM; Puls, 1994) throughout the study, whereas 3X and 5X were elevated into the adequate range by d 81 of supplementation (Figure 1).

Figure 1. Effect of supplemental vitamin A level [1X = 31,000 IU/d (current NASEM recommendation), 3X = 93,000 IU/d, and 5X = 155,000 IU/d] on cow liver retinol concentrations. Dashed line indicates the liver retinol concentration considered adequate for cows (300 μg/g DM; Puls, 1994). † § # Significant difference of $P \leq 0.05$.



Liver retinol concentrations considered adequate for calves at 32 days of age (100–350 µg/g of DM; Puls, 1994) were not observed in 1X calves (51 µg/g DM) but were observed in calves from 3X and 5X cows (119 and 165 µg/g DM, respectively). Despite cows on the 3X and 5X treatment reaching adequate liver retinol status by d 81, only 60% of the 3X calves and 80% of the 5X calves reached liver retinol concentrations greater than 100 µg/g DM. These results suggest that for cows fed stored feeds long term, supplementing cows with the current NASEM recommendation for vitamin A will not result in their calf's liver vitamin A concentrations being within the adequate reference range. Our data also suggests that cows with initially low liver retinol stores needed to be fed 93,000 IU/d (3 times the NASEM recommendation) of vitamin A to achieve adequate liver retinol concentrations. However, this amount did appear to result in continuously increasing liver stores. More research is needed to understand the exact amount of supplemental vitamin A required to maintain cow liver retinol concentrations in the adequate range and ensure adequate concentrations in the colostrum for the calf.

BOTTOMLINE

Current NASEM recommendations for vitamin A supplementation of beef cows are based on minimal data and likely do not reflect needs of modern beef cows. They also do not specify diet type, which can change supplemental vitamin A needs. Stored and dormant forages are low in vitamin A, while fresh green forage is high in vitamin A.

The young calf is at greatest risk of vitamin A deficiency in cow/calf systems. A cow that has adequate liver vitamin A stores at the time of calving does not ensure that the calf will receive enough vitamin A in the colostrum. Both cow liver stores and cow vitamin A intake in late gestation influence vitamin A levels in colostrum. It benefits the calf if the cow has both adequate liver vitamin A stores and receives adequate supplemental vitamin A in late gestation. In our second study, supplementing the current NASEM recommendation of

31,000 IU/d to gestating cows on a stored forage diet did not result in the cow or the calf achieving adequate liver stores of vitamin A. Increasing supplementation to 93,000 IU/d of vitamin A in this same diet resulted in both cow and calf liver retinol levels that would be considered adequate. This amount is in line with the recommendations for vitamin A needs suggested for late gestation in other countries.

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Proceedings, The Range Beef Cow Symposium, XXVIII
December 12-14, 2023, Loveland, Colorado

CARRYING CAPACITY ENHANCEMENT WITH INTENSIFIED GRAZING

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INTRODUCTION

Range cow beef producers rely on grazing lands for forage resources. These grazing lands can be diverse from simple monocultures to highly complex plant communities, and span the spatial scale from small paddocks of a few acres to extensive landscapes with tens to hundreds of thousands of acres. A key question for producers is the ability to enhance carrying capacity on their operations. Answering this takes on more economic importance given the substantial increases in land values, both for purchase and rent. Understanding the ecological underpinnings of how soils, plant communities, climate, and topography influence the production potential of sites, the biological realities of plant physiology and what options are available to influence plant photosynthesis and subsequent plant production, and the management acumen needed for enhancing carrying capacity through intensifying grazing will be the focal components discussed below.

SITE POTENTIAL

Distinct types of land on the landscape with different soils, plant communities, climate/weather, and topography are classified into ecological sites. These ecological sites have corresponding aboveground biomass production potentials and associated livestock production (Reynolds et al. 2019). Site production potential is influenced by the plant community state or phase of the ecological site which responds to management actions and natural disturbances. The sensitivity of forage production to both precipitation amount and pattern varies by topographic position in a landscape as well (Hoover et al. 2021). In addition, the spatial and temporal variability in precipitation can be high at the ranch-scale (Augustine 2010). The production potential of an ecological site is greatest with the reference plant community state as decreased production in other states or phases are due to changes in species composition resulting in less productive plants (Porensky et al. 2016, 2017). Management actions can be implemented to reverse this decline in site potential through restoration pathways. The success of management actions is not ubiquitous across all ecological sites as diverse management strategies can produce similar ecological outcomes across grazing lands of the western US (Wilmer et al. 2018, Copeland et al. 2023).

Sites can become invaded with plant species that compromise the production potential for range beef cow producers. For example, weedy species like leafy spurge (*Euphorbia esula*) can invade plant communities and result in reducing forage production.

Likewise, invasive annual grasses like cheatgrass (*Bromus tectorum*) can alter plant species composition on ecological sites and result in changing nitrogen and water dynamics resulting in lowered forage production for the native species. Eastern red cedar (*Juniperus virginia*) is a tree that has markedly expanded across the Great Plains and reduces forage production as well as livestock access to the remaining forage due to its physical presence. Mechanical treatments and prescribed fire can be used to reduce the number of eastern red cedar trees and increase the forage production potential and access to the forage produced. Patch-burn grazing in lower productivity environments (e.g., western Great Plains) can be used to negatively impact plains prickly pear cactus (*Opuntia polyacantha*) and improve livestock access to forage that was previously inaccessible (Augustine and Derner 2015), as well as to improve forage quality and resultant livestock weight gains through the reduction of low-quality standing dead biomass in both dry (Augustine and Derner 2014) and wet (Winter et al. 2014, Spiess et al. 2020) grazing land environments.

For sites that have been previously cultivated or highly degraded due to poor management, changing the site potential can be accomplished through seeding and establishment of species with higher forage production. This can be done by seeding of an entire plant community (monoculture or mixture) or interseeding of species into an existing plant community. These seeded or interseeded efforts require energy inputs, and the species are often non-native, such as grasses including crested wheatgrass (*Agropyron cristatum*), intermediate wheatgrass (*Thinopyrum intermedium*), and smooth brome (*Bromus inermis*), shrubs like forage kochia (*Bassia prostrata*), and legumes such as yellow-flowered alfalfa (*Medicago sativa* ssp. *falcata*). These "improved plant communities" are often managed with agronomic rather than ecological principles; as such additions of nitrogen or other nutrients can be applied to further stimulate forage production but producers need to be aware that nutrient additions can promote invasion by other plants (Blumenthal et al. 2017).

BACK TO BASICS – PLANT PHYSIOLOGY

The basic fundamentals of plant physiology provide the foundation for enhancing carrying capacity through greater forage production. First, the photosynthesis equation is the process of transferring sunlight energy into chemical energy for growing plants. Water (H_2O) plus atmospheric carbon dioxide (CO_2) in the presence of sunlight will yield plant growth. For range beef cow producers, increasing either water or atmospheric carbon dioxide or both, provides a mechanism for enhancing carrying capacity. Since the Industrial Revolution, increases in atmospheric carbon dioxide have been occurring; the 2022 global average was 417 parts per million (ppm), which is over 30% greater over values first measured at Mauna Loa Observatory in Hawaii in 1958. Increasing concentration of this greenhouse gas is beneficial to plant growth, with C_3 (cool-season) plants benefiting more than C_4 (warm-season) due to the different photosynthetic pathways in these plant function groups (Morgan et al. 2011). Enhanced forage production has been quantified with increased atmospheric carbon dioxide concentrations in experimental field research for grazing lands. The magnitude of this increase is 26-47% in shortgrass steppe (Morgan et al. 2001), and >25% in northern mixed-grass prairie (Mueller et al. 2016). Observations from a semiarid shortgrass rangeland showcase about 60% increase in forage production from the 1940-1960s to current, along with a 72% increase in livestock carrying capacity due to increased atmospheric carbon dioxide concentrations and recovery from the 1930s Dust Bowl (Raynor et al. 2021). Associated with this increase in forage quantity, however, is a reduction in forage quality (Augustine et al. 2018). This lowered forage quality has implications for range cow beef producers regarding meeting dietary protein requirements for livestock growth and the likely need for increase supplementation of protein. Increasing advancement of plant phenology with higher atmospheric carbon dioxide will alter nutritive quality of plants during the growing season with plant maturing earlier (i.e., becoming reproductive more quickly), likely resulting in a "summer slump" of forage quality where producers may need to feed supplemental protein to support livestock gain (Augustine et al. 2018). Advances in remote sensing technology to assess in near-real time spatial and temporal variation in standing herbaceous biomass (Kearney et al. 2022) and forage crude protein on offer (Irisarri et al. 2022) can provide range beef cow producers with emergent tools to assist in adaptive decision-making to more effectively match animal demand to forage quantity and quality at the ranch scale (Derner et al. 2021).

Increases in atmospheric carbon dioxide concentrations are occurring without range beef cow producers needing to provide inputs or associated costs. Conversely, the alteration of water to enhance photosynthesis and associated forage production is more difficult and often incurs economic investments. For example, numerous management actions in the past have been used to increase available water at the site level. These actions include: pitting, water harvesting, deep ripping, contouring, snowfences, strategic location of shelterbelts, and many others (Vallentine 1989). These actions all require the input of energy and mechanized equipment, along with disruption of the site through disturbance to the existing plant community, in order to increase site availability of water for enhancing forage production.

Emergent interest in soil health for grazing lands (Derner et al. 2018) provides an ecological approach in contrast to the prior disturbance approach to benefit increased water at the site level. Through actions to increase cover of soils, presence of living roots, and biodiversity, while minimizing disturbance, improving soil health can increase organic matter levels which results in better water infiltration and soil water holding capacity. Thus, improving soil health provides a pathway for range beef cow producers to more effectively capture precipitation that falls on the site and prevent runoff of water as well as reducing associated soil erosion. Moreover, if neighboring lands have lower soil health, there is capacity for your lands with higher soil health to capture run off from those lands and result in more soil water for your sites and thus greater forage production.

Basic plant physiology considerations for range cow beef producers also include an ecological understanding of types and locations of growing points, the influence of apical meristems on regrowth potential, bud banks, and the contrasting management applications for pasture-based (i.e., forages and simple plant communities) versus native rangeland (i.e., complex plant communities with many different plant functional groups) (Bedunah and Sosebee 1995). For example, Briske (1991) summarizes the developmental morphology of grasses with comparisons of buds versus rhizomes, elevated versus low growing points (e.g., apical meristems), prostrate versus erect growth forms, and the comparative aspects of C_3 (cool-season) versus C_4 (warm-season) plants as well as CAM plants. Physiological responses of individual plants to grazing was synthesized by Briske and Richards (1994) where the influence of carbohydrate reserves, apical dominance, and compensatory processes were addressed. Carbohydrate reserves are valid from the physiological perspective, but has been overextended as a management criterion. Apical dominance was the primary mechanism influencing tiller development, but this traditional interpretation is simplistic within the context of environmental and physiological processes that regulate tillering. Compensatory processes of photosynthesis, resource allocation, nutrient absorption, and shoot growth have been documented but the occurrence, magnitude, and significance of these processes to induvial plants, and more importantly, entire plant communities remains unclear.

Regrowth of plants following grazing (i.e., defoliation) provides the potential for enhancing carrying capacity through intensified grazing management. For this to be a magnitude sufficient for use by range beef cow producers, contextual application is warranted. First, when could regrowth be expected? Under conditions of favorable growing conditions with adequate water, conducive temperatures, sunlight, available growing points, and sufficient leaf area, regrowth of the grazed plant can occur from that plant if it is in the vegetative state. If the growing point is removed with grazing, then subsequent regrowth will need to occur from buds or tillers, both of which happen more slowly. If the myriad of favorable conditions are not present, then regrowth becomes much less predictable and more variable. Managers will need to be cognizant of the time of year, the photosynthetic pathways of the grazed species, and environmental conditions regarding the potential for regrowth.

What type of plant community is being grazed? If the plant community is simple (one to a few species), then range beef cow producers can more intensely manage those pastures to encourage regrowth. For example, with a simple plant community consisting of all cool-season forage grasses with high growth potential, a manager could intensively graze sub-areas (e.g., paddocks) using agronomic principles with a key priority of ensuring the plants remain in a vegetative growth phase. Removal of sufficient plant material with high stock densities (numbers of grazing animals per unit land area) while ensuring that growing points are not damaged and enough leaf area remains to provide photosynthetic capacity can work well with rotational grazing. Higher stocking density can result in improved utilization and harvest efficiencies of the forage (Smart et al. 2010), but will negatively influence individual animal gains (Olson et al. 2002, Augustine et al. 2020) by reducing foraging behavior of grazing animals (Augustine et al. 2023). The rate of return back to the same paddock would be predicated on keeping the plants in a vegetative stage. Having plants transition to a reproductive state where growing points are elevated and at risk for removal, as well as rapidly decreasing forage quality, are negative outcomes for range cow beef producers. Intensive grazing management can be accomplished provided there is a sufficient amount of precipitation to provide soil water for growth, and that temperatures remain in the optimum range (64-75 degrees Fahrenheit) for C_3 plant growth. Conversely, if these C_3 forage grasses enter the reproductive stage, or soil water is limited, or higher air temperatures occur, then regrowth potential markedly declines. Therefore, range beef cow producers will need to effectively match intensive grazing to the desirable plant community under suitable environmental conditions.

If the plant community being grazed is one with high complexity of different plant functional groups (e.g., perennial C_3 grasses, perennial C_4 grasses, annual and perennial forbs, subshrubs, and/or shrubs) like those found on many rangelands, then using intensive grazing for providing opportunities to encourage regrowth for enhancing carrying capacity is substantially more challenging. Rather than implementing agronomic principles in management, range beef cow producers should use ecological principles within a systems context to maintain ecological integrity and resilience of the ecosystem. Here it will be desirable to have a more complete inventory of plant species and their respective functional groups, and plant phenology stage(s) of the plant functional group being targeted for potential regrowth. Even with a comprehensive plan to when to target seasonality of grazing for possible regrowth of a plant functional group, the highly variable within-year precipitation, especially in arid and semiarid environments (Knapp and Smith 2001) can preclude managers from expecting regrowth of desired plants in these complex plant communities. Range cow beef producers will need greater understanding of the complexity, more adaptive capacity with the increased weather variability to effectively match animal demand with forage availability including quantity and quality aspects, and additional drought contingencies for both within a year and across years.

EXAMPLES OF ENHANCED CARRYING CAPACITY

One example in rangelands where enhanced carrying capacity from intensive grazing management would be expected is the matching of targeted grazing of key species in the early spring when precipitation amounts and reliability are greater. Range beef cow producers could enhance carrying capacity in complex rangeland plant communities by target grazing in high growth C_3 (cool-season) grasses in early spring. For example, grazing of the invasive annual grass cheatgrass, or introduced forge grasses like smooth brome, crested wheatgrass and/or Kentucky bluegrass (*Poa pratensis*) in rangelands provides extra forage for livestock consumption at a time when C_4 (warm-season) plants are inactive. Failure to capitalize on this "extra" forage can be a two-fold loss. First, these early growing season plants quickly lose nutritional value when they move to a reproductive stage. Second, left ungrazed, these plants can markedly reduce the forage production potential of other species in the complex plant community through their uptake of soil nitrogen and water. This reduces the competitive ability of the remaining species for these scarce resources.

A second example of increasing carrying capacity from intensive grazing management is the use of multiple species (syn. mixed-species grazing) to increase efficiency of forage harvest (Olson et al. 1999). Mixed-species grazing benefits ranch economics (Hintze et al 2021) as well reducing invasive plant species populations (DiTomaso et al. 2000, Henderson et al. 2012) for the range beef cow producer. Limited use of mixed-species grazing can be attributed to sufficient infrastructure, labor, or equipment as barriers to adoption (Adhikari et al. 2023), as well as predation losses especially with small ruminants. Mixing flocks of small ruminants with a herd of cattle into a flerd can protect the small ruminants from predation and provide more efficient use and conversion of the forage into animal protein (Anderson et al. 2012).

A third example of increasing carrying capacity from intensive grazing management is the use of plant communities both in the growing and dormant season. For example, the use of intensive early stocking (IES) provides range beef cow producers with the opportunity to increase livestock gains per unit land area by maximizing forage utilization during peak precipitation periods during the year when forage growth and nutritive quality is high (Grings et al. 2002, Olson et al. 2002). A benefit to range beef cow producers is that following the period of use with intensive early stocking, a non-grazing period can regrowth to accumulate with this forage being used during the dormant season when grazing animals have lower nutritional needs (e.g., dry cows)(Owensby and Auen 2013). Additionally, intensive early season grazing can incorporate late season grazing for increased forage utilization and economic returns, as long as stocking rates are not substantially increased during the period of intensive early season grazing (Owensby and Auen 2018).

MANAGEMENT ACUMEN NEEDED WITH INTENSIFIED GRAZING

Building upon knowledge and understanding of site potential and the basic fundamentals of plant physiology in simple plant communities managed with agronomic principles or complex plant communities using ecological principles to guide intensified grazing, a key for range beef cow producers regarding implementation is the management acumen needed. Here, we will proceed from modest acumen needed for increasing carry capacity due to addressing access and use of available forage, to highly skilled acumen to accomplish system-level approaches with adaptive capacity amidst high variability and risk.

First, in many extensive rangeland landscapes, there is often unused and under-utilized forage that could be accessed to enhance carrying capacity. This is often not the case with pastures due to their agronomic management and smaller spatial scale. Managers have attempted to improved grazing distribution in extensive rangelands through development of additional water, strategic placement of supplements to attract grazing animals, individual animal selection, herding, and fencing (Bailey 2004). In addition to these approaches providing accessing to and use of more available forage, intensified grazing can be used to create more even distribution of grazing animals resulting in re-distributing fecal nitrogen away from water sources and pasture corners (Augustine et al. 2013). Modest management acumen is needed here when intensifying grazing, often incorporating higher stocking densities and rotational movements of grazing animals among areas, because of the need to balance provision of multiple ecosystem services at the ranch scale (Raynor et al. 2022), as well as maintaining sufficient vegetation residue (e.g., residual dry matter or RDM) to reduce soil erosion risks, enhance soil health, and ecosystem resilience (Bement 1969, Bartolome et al. 2002). Since different grazing management strategies can produce similar ecological outcomes and ecosystem services for ranches (Wilmer et al. 2018), there is not one "best" grazing management strategy", nor is there a template or directions to follow in a prescriptive manner.

Second, the influence of topography can substantially influence grazing distribution at an individual ranch (Gersie et al. 2019) and across regional landscapes (Raynor et al. 2021). Here, range beef cow producers can enhance carrying capacity through intensified grazing with modest acumen by matching timing of grazing with plant phenological development specific to the topography (e.g., elevational gradient) that will more effectively match the grazing animal to the environment. Emergent technological tools like virtual fence provide promise to assist in this intensive grazing through reducing labor and costs of physical/temporary fence as well as using text alerts for abnormal livestock movement that may indicate animal health issues or animals beyond the virtual fence boundaries. Virtual fence is being used to create strategically-located fire breaks in fire prone landscapes (Boyd et al. 2023). Substantial potential exists for expanded use on extensive landscapes regarding grazing management applications of environmentally sensitive areas like riparian areas, critical wildlife habitat and migration corridors, targeted grazing, and more effectively matching spatial and temporal patterns of forage quantity and quality across ranches and landscapes.

SUMMARY

Site production potential is influenced by the plant community state or phase of the ecological site which responds to management actions and natural disturbances. Sites can become invaded with plant species that compromise the production potential for range beef cow producers. Management actions such as targeted grazing, patch-burn grazing, and seeding/interseeding can be implemented to reverse the changes in plant community composition and restore site potential. Enhancing carrying capacity through greater forage production is based on the basic fundamentals of plant physiology. Increasing atmospheric carbon dioxide has resulted in forage production enhancements of >25% but forage quality is reduced. Increasing available soil water through improving soil health provides a pathway for range beef cow producers to more effectively capture precipitation that falls on the site and prevent runoff of water as well as reducing associated soil erosion. Plant regrowth following grazing is context-dependent, with influences of existing soil moisture, precipitation patterns and amounts, temperature, leaf area and growing points, and type of principles employed in simple forage pastures (agronomic) or complex systems including rangelands (ecological). Examples of enhanced carrying capacity include 1) targeted grazing of key species in the early spring when precipitation amounts and reliability are greater, 2) use of multiple species (syn. mixed-species grazing) to increase efficiency of forage harvest, and 3) the use of plant communities both in the growing and dormant season. Management acumen needed to use intensified grazing to enhance carrying capacity can be modest with incorporating higher stocking densities and rotational movements of grazing animals among areas. High management acumen may be needed to incorporate emergent technology like virtual fence to assist intensive grazing through grazing management applications of environmentally sensitive areas like riparian areas, critical wildlife habitat and migration corridors, targeted grazing, and more effectively matching spatial and temporal patterns of forage quantity and quality across ranches and landscapes.

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Proceedings, The Range Beef Cow Symposium XXVIII
December 13 &14, Loveland, Colorado

CATTLE MARKET IMPORT/EXPORT BALANCE

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INTRODUCTION

The U.S. cattle and beef trade is a complex and diverse market that operates through a lens of finding the best value for products but can be complicated by factors outside the highest bidder for a given cut of beef. Proximity, trade agreements, exchange rates, and quotas are just a few examples of some of the externalities that also affect how cattle and beef move around the world, which partners the U.S. has formed stronger trade ties with and those trade partners that may be more opportunistic.

The U.S. exports about 15-20% of its total beef production in any one year and imports the equivalent of about 10-13% of U.S. beef production from trade partners. The top export markets have changed in recent years with China entering the top 5. In rank order: Japan, South Korea, China/Hong Kong, Mexico, and Canada are the top 5 export markets for the U.S. for the last few years. The top 5 import markets in rank order are: Canada, Australia, New Zealand, Mexico, and Nicaragua.

The live animal portion of trade should not be overlooked as the U.S. is a large importer of cattle for grow-out phases and slaughtering. Total cattle imports make up roughly 5-8% of commercially slaughtered cattle in a year. However, most of the cattle imported are feeder cattle and are not slaughter-ready. The U.S. exports the equivalent of less than half a percent of its total cattle inventory every year, mostly in the form of breeding-type animals. Mexico and Canada are primary markets for both exported and imported cattle.

TRADE AGREEMENTS, PARTNERSHIPS, AND PROXIMITY

It is not surprising that some of our closest beef exporters and importers are those that are physically close. The ties between the U.S., Canada, and Mexico are long-standing and extend well beyond the cattle and beef markets. In fact, according to the USDA Foreign Agricultural Service (FAS), beef and cattle ranked 8th in terms of export value by commodity to Mexico in 2022 while corn and soybeans were 1st and 2nd, respectively, and dairy was the highest animal-based product[1]. For Canada, baked goods, forest products, and

[1] United States Department of Agriculture Foreign Agricultural Service. “Mexico.” Accessed November 28, 2023. https://fas.usda.gov/regions/mexico

fresh vegetables and fruits locked up top spots based on value, but U.S. beef did not fall within the top 10 despite Canada being a top 5 beef export market[2].

The U.S. has free trade agreements with 20 countries but only four of these are included as key beef and cattle trading partners: South Korea, Mexico, Canada, and Australia[3]. While not all countries may have a free trade agreement, there are other forms of trade agreements, partnerships, and quota structures associated with U.S. trade partners that can be beneficial for beef trade.

A great example of a partnership that does not have a free-trade agreement is Japan. Japan was the U.S.' largest beef market, but the U.S. was not necessarily its largest supplier and fell second to Australia. Japan has historically had a safeguard quota system for beef. This mechanism is designed to protect domestic (Japanese) beef production and slow the movement of beef into the country after a certain amount has been imported. Once the quota limit is reached or triggered, this results in a tariff rate shift from 38.5% to 50%. Australia, however, began to receive more preferential treatment years before with the ratification of the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP) in 2018. This tipped the scales so that Japan was importing 49.7% from CPTPP countries, while the U.S. represented 47%. The U.S. ratified a bilateral trade agreement with Japan that entered into force on January 1, 2020, called the U.S.-Japan Trade Agreement (USJTA). The USJTA moved the U.S. safeguard triggers to higher levels and tariff rate quotas more in-line with countries that were part of CPTPP. Although the USJTA improves market access for U.S. beef into the Japanese market, U.S. safeguard triggers are still lower than countries under CPTPP making it more likely that safeguards could trigger. Initially, upon ratification of USJTA, the U.S. gained market share but quickly saw safeguard quotas triggered resulting in increased tariff rates on beef in 2021. In March of 2022, the U.S. renegotiated the trigger conditions to include further stipulations including that imports from the U.S. must be exceeding levels from the previous year and imports from the U.S. plus CPTPP countries must exceed the CPTPP trigger level for the fiscal year.[4]

While many of our trade agreements may have country specific nuances for the U.S. to send beef, most of the countries exporting beef to the U.S. face a similar structure. Only 17 countries are eligible to ship beef to the U.S., and each must go through an approval process while meeting certain sanitary requirements. Only four countries have single country allotments at which they can receive a more favorable tariff rate, while all others fill the "Other" bucket. Currently, Australia, New Zealand, Argentina and Uruguay have their own quota limits. Australia, with its free trade agreement to the U.S., is currently the only country that can export beef to the U.S. tariff-free up to their quota limit. Once over the quota limit,

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[2] United States Department of Agriculture Foreign Agricultural Service. "Canada." Accessed November 28, 2023. https://fas.usda.gov/regions/canada

[3] United States Trade Representative. "Free Trade Agreements." Accessed November 28, 2023 https://ustr.gov/trade-agreements/free-trade-agreements

[4] Sabala, Ethan and Davis, Eric. (2023). "The Impact of Japan's Trade Agreements and Safeguard Renegotiation on U.S. Access to Japan's Beef Market." *Economic Research Report Number 318*. Accessed November 29, 2023: https://www.ers.usda.gov/webdocs/publications/106719/err-318.pdf?v=7042

the tariff rate is reduced for Australia from what other countries are subject to who do not have free trade agreements[5].

Brazil is often discussed regarding import trade because at times they have been the largest single supplier to the U.S. Brazil gained access to the U.S. market in 2017 but disease hardship resulted in limited access. Brazil does not have its own tariff rate bucket at this time and utilizes the "Other" country bucket, filling most of it early in the calendar year. Brazil's primary export to the U.S. is manufactured beef and competes directly with Australia and New Zealand for U.S. market share.

Shipping rates and exchange rates also play a role as they relate to the cost structure of trade. These impacts usually occur under a much shorter time-frame and deal with economic headwinds. While the distance to a country may not change, the shipping rates, supply chain issues, labor strikes, etc. may make trade more or less cost-effective. The U.S. benefits a great deal from being the "world currency", but that, too, seems to be changing as other countries are shifting to doing business using other currencies. Still, the U.S. dollar remains a key foundation for trade and one that many countries rely on. As it relates to beef, though, short-term influences can make U.S. goods and services more or less expensive, but for the most part, exchange rates play a larger role in the U.S.'s ability to export beef rather than import it.

TRADE: LIVE ANIMALS

Live animal trade predominately takes place between the U.S. and North American trade partners Canada and Mexico. The U.S. has a larger herd size than both countries and has developed a greater capacity to feed and slaughter those animals. The economic efficiency at which cattle are traded is impressive, and this is partly due to free trade. Drought, slaughter plant closures, and worker strikes have also been known to shift these trade dynamics in the short term.

Mexico is the largest supplier of feeder cattle to the U.S., and this year has seen impressive year-over-year gains. This year, the volume is up 50% from last year comparing January through October data. This number is strong given the expansion of feeding and slaughter capacity in Mexico in recent years. However, a lot of the increase is due to how high U.S. feeder cattle prices are and the ability to arbitrage that market. Cattle genetics and emphasis on delivering cattle that are more similar to their U.S. counterparts has been a focus and has helped further strengthen the U.S.-Mexico reliance on each other for cattle trade. The U.S. does export some cattle to Mexico but most are slaughter-ready cows.

Canada has had a shrinking cattle sector for more than a decade. The combination of fewer feedlots, lack of herd rebuilding, and increasing slaughter plant closures has further shifted feeder cattle to move to the U.S., but over the long term is expected to decline in total numbers as a function of a smaller herd size. This year feeder cattle imports from Canada are

[5] Brower, Jack. (2022). "Reviewing the Tariff-Rate Quotas for U.S. Beef Imports." Accessed November 29, 2023. https://fas.usda.gov/data/reviewing-tariff-rate-quotas-us-beef-imports

down 15% from last year when analyzing January through October data. Slaughter steers, heifers, and cows are another segment that is more unique to Canada than Mexico. These numbers have increased as Canada has closed plants across the country. They include dairy cull cows in these numbers but represent a little less than half a million head annually for the last five years.

TRADE: MEAT CUTS, VARIETY MEATS, & BY-PRODUCTS

The U.S. exports a wide variety of meat cuts to its customers based on their tastes and preferences. The U.S. Meat Export Federation (USMEF) estimates, as shown in their infographics (publicly available on their website), that exports generate about $400 per head in meat alone (excludes variety meat, and by-products). USMEF estimates about 56% of the short plate primal, 21% of the rib, over 14% of the chuck, and over 7% of the round go to the export market. Loin, flank, and brisket are less than 5% each.[6]

The U.S., on the other hand, imports predominately lean beef trimmings of greater than 90% lean. These trimmings are than mixed with domestic fed cattle trimmings that are typically 50% lean to produce ground beef products.

Total meat cut exports in 2023, using January through September data, are down 15%. Many major markets are finding U.S. beef exceedingly expensive. Pull backs across major markets this year have included China, Japan, and South Korea -- all down more than 15% compared to last year. Mexico and Canada have been the exception to the downward trajectory with Mexico up 15% and Canada up 1%.

Imports into the U.S. have worked in the opposite manner, capitalizing on high U.S. prices. Total meat cut imports are up 7% from last year through the first three quarters of the year. Key markets of Argentina, Australia, New Zealand, and Uruguay are all up more than 20% from last year during this time frame. Interestingly, Brazil is down 10%, which would rank them only 5th in terms of total volume shipped to the U.S. this year.

Variety meats are sometimes an overlooked aspect of trade but a critical value to the carcass value of an animal. Organ meat is not widely consumed in the U.S. and exporting that product allows the U.S. cattle supply chain to extract maximum value. According to the USMEF, variety meat exports equate to about 25 pounds per head of fed slaughter and are valued at $48 per head in 2022.[7] Destinations by organ type are quite varied. Japan and Mexico are two of the larger U.S. trading partners for variety meats, taking most of the tongue and lip exports as well as the stomach and intestine. China and Egypt also import a large mix of organ and edible offal products. Variety meat imports have increased in recent years and have roughly doubled in value in the last five.

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[6] USMEF (2022). "Guide to Major Destinations for U.S. Pork and Beef Cuts, Variety Meat. Accessed November 24, 2023: "https://www.usmef.org/news/guide-to-major-destinations-for-u-s-pork-and-beef-cuts-variety-meat/

[7] USMEF (2022). "Guide to Major Destinations for U.S. Pork and Beef Cuts, Variety Meat. Accessed November 24, 2023: "https://www.usmef.org/news/guide-to-major-destinations-for-u-s-pork-and-beef-cuts-variety-meat/

Tallow and grease imports doubled in value between 2021 and 2022, which is likely due to the smaller slaughter of fed supplies lowering the overall availability of tallow and grease supplies on the market. Mexico and Canada are the top buyers of U.S. edible tallow, with Mexico dominating the market, buying more than 95% of tallow shipped. The U.S. exported about 50% less tallow in 2022 compared to 2021, but prior to 2022, was shipping 100-120 thousand metric tons. Last year, tallow exports did not surpass 70 thousand metric tons, and this year, shipments are even lower, down 41% through the first three quarters.

Another piece to consider is inedible items such as hides or inedible tallow, which also find themselves into the export market and add value. The U.S. is a net exporter of hides, shipped in pieces or whole, usually netting about $1 billion from those sales with the larger volume taking place in whole hides. However, last year sales of hides were substantially lower due to a 12% drop in export volumes. China has historically been the dominant buyer of U.S. whole hides, buying more than 50% of total exports, and in some years, more than 60% of total U.S. exports. The second largest buyer of whole hides is Mexico, which usually takes about 15% of the U.S. market share. The U.S. whole hides shipments are 10% behind last year looking at January through September data. Hide pieces are up 3%, the majority of these go to Japan or China. Before 2020, Mexico was also buying a large share of these pieces but has backed way off in recent years.

Inedible tallow is predominately going to Canada and Mexico which take more than half that market share combined, ranking 1st and 3rd, respectively. Singapore has been the second largest buyer of inedible tallow in the last five years but has varied year-to-year in terms of how much market share they bought. Biofuels is starting to enter into the tallow and grease space in a large way and will likely boost the value of this product for years to come as developed countries strive for zero emissions. Although this sector still has a way to go in terms of scalability there is anecdotal evidence that some slaughterhouses are already making changes to sell directly into energy pipelines by-products that meet those needs. At the end of November 2023 a transatlantic flight made news by being propelled solely by tallow and other waste fats, making it one of the first of its kind.[8]

CONCLUSION

Trade is complex and deals with a wide range of products that are more complicated than the standard meat case. Each country has its preferred cuts, styles, and preferences, and further complicating things is that the U.S. has unique relationships with its trade partners as well. The bottom line is that the U.S. needs trading partners both in terms of places to export to achieve maximum value per carcass but also on the import side to achieve the mix of products that U.S. consumers prefer as well. The live cattle business is very much intertwined with Canada and Mexico in a way is unlikely to fall to zero in the long term. Politics, disease interruptions and other short term effects could play a role but the efficiencies gained by all three countries are strong enough that the relationships will change

[8] Melley, Brian. (2023). "High-fat flight is first jetliner to make fossil fuel-free trans-Atlantic crossing from London to NY." AP News. Accessed 11/29/2023: A commercial jet powered solely by waste fats, not fossil-fuels, is first to fly from London to NY | AP News

over time but stay connected. We are already seeing evidence of Mexico's focus on their domestic production and may see a greater shift for them becoming a larger exporter of beef in the future. However, that transition will be slow especially while U.S. prices for feeder cattle remain so high. It's also important to note that this type of transition takes decades to invest in the infrastructure around the industry and build a genetics and trade partnerships to support the overall vision. Another important note is that Mexico will need to import the majority of their feed to expand their feedlot sector and the U.S. would be a likely benefactor to those feed supply needs.

Proceedings, The Range Beef Cow Symposium XXVIII
December 13 & 14, 2023, Loveland, Colorado

HERD HEALTH PLANNING: PROTECTING YOUR COW HERD

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INTRODUCTION

As it pertains to livestock operations, the term "herd health" has been defined in a variety of ways, with goals as varied as:

- …maximizing health and production while decreasing the incidence of…diseases (Bowen, 2016).
- …[controlling] or [eliminating] diseases and management inefficiencies that impact animal welfare or limit productivity (Whyte et al., 2011).
- …a key to food safety (Newman and Magolski, 2014).
- …[preventing] introduction and transmission of diseases within the herd and [keeping] all [animals] in optimal health (Tank and Monke, 2022).

While these objectives are important to producers, traditional herd health "programs" have focused on a "calendar of events" for processing and applying products such as vaccines and dewormers.

Unfortunately, even the strictest adherence to such lists does not always prevent the occurrence of disease problems in cow-calf operations, whether they are insidious, chronic, slowly spreading drains on health and productivity or acute devastating outbreaks. Disease prevention requires much more than following a vaccine schedule.

This paper will offer yet another viewpoint regarding herd health planning for the cow-calf operation, illustrating how a herd health "plan" will differ from farm to farm and even from timepoint to timepoint within an individual farm. Each operation should develop their own guidelines and practices with input from the herd veterinarian, Extension and university resources, and other trusted sources.

These general concepts can be used as a framework for procedures specific to each operation, based on its unique circumstances and goals:

A. Know and control the disease risk from incoming animals.
B. Detect and diagnose problems promptly.
C. Use vaccines as a safety net.

D. Pay attention to everyday chores that affect animal health.

A. KNOW AND CONTROL DISEASE RISK FROM INCOMING ANIMALS

The largest risk of novel infectious disease agents entering a cow-calf herd comes from the introduction of subclinically infected animals. Most cow-calf herds are not "closed," meaning that they bring at least some animals into the herd from outside sources, which poses risk of new disease incursion. This risk increases with the number of animals, the different types of animals, and the number of different sources of animals. For instance, herds that only bring in a handful of bulls from a single source once a year take on less risk than a similar operation buying bulls, replacement heifers, bred cows, and feedlot calves from many different sources multiple times a year.

Understanding and controlling these risks can be divided into two categories: 1) Risk management prior to purchase, and 2) Risk management after arrival of new animals.

1. **Risk management prior to purchase** requires an understanding of the health status of the herd of origin, and in some cases, of individual animals. In certain situations, such as when cattle are purchased through livestock auctions, this knowledge might be impossible to obtain. However, for producers purchasing seedstock from an individual operation, it is often possible to obtain answers to pertinent questions:
    a. What is the provider's current awareness about pertinent disease problems such as Johne's Disease or Bovine Viral Diarrhea Virus (BVDV) persistent infection?
    b. What if any, herd disease testing programs are in place for those diseases?
    c. What vaccination programs are in place?

   A previous, ongoing relationship with the seedstock producer can be invaluable in this regard.

   Disease testing programs in the herd of origin are not a guarantee of the absence of disease in individual animals purchased from these operations, but they demonstrate an awareness and level of disease management not present in herds that are not addressing these problems. For example, Johne's Disease testing, while valuable for detecting animals in advanced stages of the disease, is imperfect at finding recently infected animals. Even so, a herd regularly testing for the disease is less likely to sell an infected animal compared to a non-tested herd of similar status.

   Some disease issues lend themselves better to individual animal tests prior to purchase. Negative tests for BVDV persistent infection, anaplasmosis, and Neosporosis in individuals are useful. For bulls, most state regulations require non-virgin bulls to be tested negative for trichomoniasis prior to sale.

2. The most important aspect of **risk management of new animals after arrival** is that of isolation prior to their entry into groups of existing herd members. An isolation period allows for:

a. Any in-progress disease incubation period to elapse, allowing identification and diagnosis of clinical illness such as pneumonia, diarrhea, foot rot, etc., prior to the affected animal being able to infect existing herd members;
b. Shedding of respiratory or digestive germs from healthy-appearing animals to subside. Such germs may pose little problem for the previously exposed animals, yet cause illness in animals whose immune system has not yet encountered them;
c. Time for the results of diagnostic testing to be obtained; and
d. Time to vaccinate, deworm, or otherwise treat the new animals to prepare them for contact with the existing herd.

<u>Planning steps for managing the risk of disease from incoming animals:</u>

- Learn about the herd of origin: its health issues as well as regular disease testing strategies
- Ask about pre-sale tests of individual animals: BVDV persistent infection, anaplasmosis, Neospora, trichomoniasis, etc.
- Identify a site for 30-60 days of isolation: feed and water sources, nose-to-nose separation from existing herd animals, weather protection, etc.
- Arrange care for isolated animals: personnel responsibilities, scheduling and managing people and equipment between isolated animals and the existing herd.
- Choose and schedule appropriate vaccines, dewormers, and other treatments for isolated animals as necessary. Examples include reproductive vaccines, pre-calving vaccines, internal and external parasiticides and antibiotic treatments for diseases such as anaplasmosis and leptospirosis.
- Determine what, if any, diagnostic tests should be performed on new animals: sampling, timing of results, and (importantly) what will be done if unexpected (positive) results come back. Diagnostic testing should not be performed if unexpected test results will not be acted upon. Examples may include BVDV persistent infection, anaplasmosis, and neosporosis.

B. DETECT AND DIAGNOSE DISEASE PROBLEMS PROMPTLY

Early detection of disease problems is of great importance in limiting that disease's impact on the herd. Once an issue is identified, steps can be taken to protect unaffected animals from the same fate. Veterinarians may need to be involved with individual or group examinations, or post-mortem examinations. In some cases, the services of veterinary diagnostic laboratories may be necessary or useful. Some examples that highlight the utility of early diagnosis include:

- Cow illness or death loss. A wide variety of herd problems are first identified with sick or dead cows, particularly on pastures. Individual cases of anthrax, anaplasmosis, and toxic exposures such as blue-green algae and nitrates can mount into high mortality events. Rapid recognition and diagnosis of these issues can mean the difference between life and death for other cows and bulls, when proper treatments can be quickly instituted, or animals moved off problematic pastures. Veterinarian and diagnostic lab input are necessary to accurately ascertain the cause of these problems, but cannot be successful unless animals are found shortly after death, or the onset of illness.

- Calf scours. Prompt realization that calves are affected with neonatal diarrhea can lead to changes in managing calving areas or movement of pregnant cows so new calves are not affected.
- Calf respiratory disease. Quick recognition of summer (pasture) pneumonia not only leads to better treatment success, it can also aid in the detection of more serious issues such as BVDV persistent infection in the herd.
- Reproductive failure. Timely pregnancy examination is the hallmark of detecting infectious as well as non-infectious causes of reproductive problems in cows. Routine reproductive observations should also include detecting cows returning to heat and evidence of early pregnancy loss or abortion.

<u>Planning steps for disease detection and surveillance:</u>

- Chart out and schedule routine health surveillance for different groups of animals at the various times of year. For example, how and when will summer pastures be scouted for sick or dead animals? Some surveillance plans lend themselves well to existing management practices (e.g., scouting for scouring calves while checking for calving problems) but surceying large, far-flung, pastures during summer months will require more planning.
- Plan contingencies for moving animals off pasture if necessary. Where will the cattle go? What feed and water resources will be necessary?
- Discuss intervention steps with your veterinarian ahead of time. For example, at what level of illness (percent of herd affected) is intervention necessary? What situations would require samples for diagnostic testing and which animals are best to sample? At what point is a dead animal "too dead" to be of use diagnostically?
- Schedule routine pregnancy and reproductive examinations well ahead of time and prepare the necessary facilities. Plan time for a review of findings with your veterinarian.

C. USE VACCINES AS A SAFETY NET

"Herd health" programs traditionally have featured vaccine schedules as their prominent (or only) component. However, veterinarians and many cattle producers can cite examples of times when vaccines were insufficient to prevent disease. Since effective vaccines do not exist for every possible cattle ailment, reliance on managing replacement animal disease risk and early disease detection and intervention is essential. Even for vaccine-preventable diseases, overwhelming exposures to infectious disease germs or ineffective immunization due to animal stress or other factors can commonly overtake expected protection from even the most complete vaccine program.

Therefore for many cattle disease issues, it's best to primarily rely upon good biosecurity, cleanliness, nutrition, and breeding management as the primary components of disease prevention. Vaccines can, however, play an important role in preventing severe disease effects should those basic husbandry processes prove insufficient. This is especially true for endemic disease agents that are constantly present in animals or their environments, making biosecurity or avoidance impossible. Examples include:

- Animal-adapted germs such as respiratory viruses and bacteria in calves.
- The reproductive effects of Infectious Bovine Rhinotracheitis Virus or some strains of leptospirosis in cows.
- Viral and bacterial diarrhea germs, addressed by vaccinating pregnant cows and heifers for the benefit of the baby calf.
- Clostridial bacteria and the causative agent of anthrax, which have adapted themselves to lengthy survival in pasture environments.

Implementing biosecurity measures and working toward a closed herd will prevent many problems. However, exposures, both recognized and unrecognized, can occur, necessitating the "safety net" of cattle vaccines. Examples include BVDV exposure via fenceline contact, or unwanted fence-jumpers from other herds.

<u>Planning steps for vaccine use:</u>

- Annually schedule a day to review your vaccine programs, including products, timing, and animal groups to be vaccinated.
- Annually schedule time with your veterinarian to review your program. Ask the following questions:
    - Does my program accurately address the risks specific to my animals and management? Am I vaccinating for a disease I no longer need to be vaccinating against? Am I neglecting to vaccinate for something I should be?
    - What additional vaccine-preventable problems are you seeing in your practice area that could apply to my herd?
    - While considering my labor and facility resources, am I giving these vaccines to the right animals at the right time?
    - Have any new products come on the market that may be useful to my program? What are their costs and benefits?
- Critically examine the temperature-maintaining ability of refrigerators used to store vaccines.
- Replace or repair any broken syringes or related equipment.

D. PAY ATTENTION TO EVERYDAY CHORES THAT AFFECT ANIMAL HEALTH

The discussion above leaves out components that are included in some other discussions of herd health. This is not to minimize their importance. On the contrary, these practices may do more for the overall health of the herd than some of the items mentioned previously. These items are more "everyday" in nature, as opposed to the more episodic approaches to incoming animal management, disease detection, and vaccine use:

- Keeping environments clean and dry – particularly where calves and their mothers spend time.
- Internal and external parasite control.
- Nutrition (including pasture management) to optimize cow and calf vigor and health.

- Genetics and breeding programs to match genetic potential to the environment and ensure calf vigor at birth.
- Recordkeeping to document individual animal performance and trends in population performance.
- Documented and thoughtful protocols for when antibiotics or other treatments are necessary, including documentation of a valid veterinary client patient relationship.

As cow-calf producers who have experienced disease outbreaks can attest, ensuring herd health is a multifaceted task that requires work and prior planning. Cow-calf operations vary greatly regarding their disease risks, environments, size, type of cattle, and availability of labor and other resources. A plan to optimize herd health is not one-size-fits-all for every operation. Cow-calf producers should regularly invest planning time into their busy schedules to critically evaluate ways to reduce their animals' risk of health problems.

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Proceedings, The Range Beef Cow Symposium XXVIII
December 13 & 14, 2023, Loveland, Colorado

Reproductive Vaccine Effects on Reproductive Performance in Beef Cattle.

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Introduction

Even with the importance of heard health on profitability, the question is often asked; can time and labor be reduced by vaccinating animals at the start of the synchronization protocol or breeding season?
Modified-live virus (MLV) vaccines stimulate the immune system by actively infecting host cells. In general, these types of vaccines are considered to be more cross-reactive and broader in their immune system stimulation (antibody production and cell-mediated immunity), exhibit longer duration of effect; however, MLV vaccines also carry with them the potential to revert to virulence and inflict the damage they are designed to prevent. Inactivated virus vaccines (IVV) are safe to use in a wide variety of circumstances yet carry the general considerations that their effects are less broad and of shorter duration compared to MLV vaccines (Kelling, 2007). It is commonly thought that IVV provide some protection against these viruses, but the same level of protection as a MLV is not achieved (Zimmerman et al., 2007; Rodning et al., 2010). However, a study that vaccinated heifers with a MLV prior to their first breeding season and then vaccinated with a Chemically Altered/Inactivated vaccine CA/IV before their second breeding season had similar levels of abortions following both a BVD and IBR challenge as animals vaccinated with a MLV before their second breeding season (Walz et al., 2017).

Infectious diseases affecting reproduction can create losses all throughout the reproductive process by decreasing ovulation rates, fertilization rates, embryonic survival rates, and fetal survival rates. Thus, the cow-calf industry spends millions of dollars a year to vaccinate cows against diseases that can impact reproductive efficiency. This is important as reproductive performance is of critical importance to the profitability in a cow-calf operation, but *the caveat to reproductive management is the things you do well do not compensate for the mistakes you make*. Instead, the mistakes you make cancel out all the things you do well. Thus, to have optimal reproductive efficiency we need to evaluate the details and how they can impact efficiency.

Infectious Diseases Affecting Reproduction:

Several diseases can have an impact on reproductive performance. They include Brucellosis, Leptospirosis, Vibriosis, Trichomoniasis, Bovine Viral Diarrhea and Infectious Bovine

Rhinotracheitis. All of these diseases can impact reproductive performance through decreased conception rates and embryonic/fetal losses. This review will focus on viral diseases that are usually vaccinated for annually.

<u>Bovine Viral Diarrhea</u>

Evidence of exposure to BVD virus is widespread in cattle throughout the world (estimated prevalence 15.74% of cattle; (Su et al., 2022)) worldwide, and thus it is considered endemic in the majority of the countries of the world. In the United States prevalence is much lower (usually estimated at <1%). For example, one study reported only 25 out of 4530 were persistently infected (PI; 0.55% of cattle), but there was at least 1 PI animal in 5 of the 30 herds tested in the south-central US (16.7%; (Fulton et al., 2009)), and another study reported that 24 out of 7,544 stocker calves were PIs (0.32%; (Stephenson et al., 2017)). The reproductive effects of BVD; however, surpass its other effects in economic importance, when the occurrence of persistently infected animals is factored in.

The impact of BVD on reproduction depends on the stage of gestation in which the cow or heifer is infected. Early gestation infection results in low conception rates due to early embryonic death. Infection in mid-gestation may result in the formation of persistently infected calves, which occurs as a result of infection during a period of fetal development (roughly between 40 and 120 days of gestation) in which the fetus is differentiating its own cells from foreign materials. *The result is a calf that has incorporated the virus into its own body and sheds high levels of virus persistently throughout its lifetime*. Later infections may result in congenital defects, late-term abortions, or the birth of congenitally infected calves, which are weaker and more prone to illness than normal calves.

A recent study reported the impact of BVD exposure during the breeding season on reproductive success (Epperson et al., 2021). The presence of a transient infection during the breeding season reduced AI conception rates by 22% and breeding season pregnancy rates by 20%. The BVD virus is spread through many body fluids including saliva, respiratory secretions, and feces. The virus does not persist in the environment but can survive long enough to be transmitted via infected equipment, needles, and palpation sleeves.

<u>Infectious Bovine Rhinotracheitis (IBR, "Red-nose")</u>

IBR virus is also termed BHV-1, or "bovine herpesvirus 1." Being a herpes virus (in the same family as viruses causing cold sores in people), it has a propensity to become "latent" or dormant in nerve clusters in the throat area or lower spine and can be re-activated during times of stress. Because of this, any animal exposed to IBR in the past could potentially shed the virus to susceptible animals. IBR is shed and transmitted in nasal secretions and aerosols from infected animals. In addition to its effects on the respiratory tract, IBR virus affects reproduction by its effects on the ovaries, uterus, and developing embryo or fetus. The result can be infertility or early embryonic death, but in addition, IBR is one of the most frequently diagnosed viral causes of late-term (5th to 9th month of gestation) abortions.

Impact of Vaccination against IBR and BVD on Reproductive Performance

The effects of vaccination on estrus synchronization and conception are variable. A study in which the vaccination history was not reported and titer concentrations were not determined indicated that vaccination with a MLV at time of the start of a synchronization protocol (day -9, with AI on day 1 to 5) did not impact estrous response or pregnancy success (Stormshak et al., 1997). In another study, animals were vaccinated with a MLV vaccine at least two times prior to synchronization protocol (the second dose being administered at day -90 prior to peak breeding day). The heifers were then revaccinated either at -40 d or -3 d prior to peak breeding (three doses total) and no differences in conception rates were observed (Bolton et al., 2007). However, several studies have reported negative impacts on pregnancy success by vaccinating naïve heifers with a MLV around time of breeding (Miller et al., 1989; Chiang et al., 1990; Miller, 1991; Perry et al., 2013).

Vaccination at the start of the breeding season: Most recently developed estrous synchronization or fixed-time AI protocols in heifers and cows try to control follicular development by inducing ovulation at the start of the synchronization protocol; therefore, insemination should occur on the second ovulation after the start of the protocol (Lamb et al., 2010; Grant et al., 2011). To investigate if vaccination only impacted the follicular wave present at the time of vaccination, naïve heifers were vaccinated with either a MLV or IVV at the time of the first induced ovulation of a fixed-time AI synchronization protocol (Perry et al., 2013). In this study, no control heifers (nonvaccinated) experienced an abnormal estrous cycle following AI. An abnormal estrous cycle was defined as an estrous cycle less than 15 d (concentrations of P4 decreased to < 1 ng/mL prior to day 15 after AI) or concentrations of P4 never increased above 1 ng/mL. Heifers vaccinated 36 and 8 days before AI with an IVV experienced 10% (2/21) abnormal cycles and heifers vaccinated 8 days before AI with an IVV experienced 14% (1/7) abnormal cycles. There was no difference between these groups ($P = 0.72$), and both were similar to controls ($P = 0.31$ and 0.22, respectively). A greater percentage of heifers vaccinated with a MLV 8 days before AI had abnormal estrous cycles [38% (8/21)] compared to control heifers ($P = 0.02$). Of the heifers that experienced an abnormal estrous cycle, 100% of heifers in both IVV groups (2/2 and 1/1) conceived during the return cycle. However, only 38% of heifers vaccinated with a MLV (3/8) conceived during the return cycle.

Table 1. Impact of vaccine on luteal function and pregnancy success in naïve animals.

Vaccine	Abnormal luteal function	AI Pregnancy Success (%)	Pregnancy Success (%) to second service
1 dose Modified Live	8/21 (38%)^{b}	7/21 (33%)^{b}	3/8 (38%)
1 dose Inactivated	1/7 (14%)^{a}	5/7 (71)^{ab}	1/1(100%)
2 doses Inactivated	2/21 (10%)^{a}	17/21 (81%)^{a}	2/2 (100%)
Saline	0/10 (0%)^{a}	9/10 (90%)^{a}	-----

Means within a column having different superscripts are different $^{ab}P < 0.05$
Adapted from Perry et al., 2013

In previously vaccinated cattle, a study was conducted to examine the differences in pregnancy success between beef females vaccinated with either a MLV vaccine or an IVV vaccine 30 days before the breeding season, with sufficient power to detect a difference of less than 10 % in pregnancy success between groups (9 herds with 1436 animals) (Perry et al., 2016). Conception rates to the fixed-time AI tended to differ between MLV treated animals and IVV treated animals (P = 0.055), but control animals were intermediate with no difference in conception rates between MLV and Control (P = 0.21) or between IVV and Control (P = 0.49). When pregnancy was determined on day 56 of the breeding season (AI conceptions plus 1 return estrus) conception rates in the IVV group were greater (P = 0.01) compared to the MLV group. Animals treated with MLV also had decreased pregnancy success compared to the Control ($P \leq$ 0.01), but there was no difference between IVV and Control. Following the breeding season, pregnancy success was similar between MLV and Control (P = 0.34) as well as between the Inactivated and Control (P = 0.14), but there was still a difference between MLV and IVV (P = 0.01). a second field study was conducted to examine the differences in pregnancy success between beef females vaccinated with either a MLV vaccine or a CA/IV vaccine between 27 and 89 days before the breeding season, with sufficient power to detect a difference of less than 10 % in pregnancy success between groups (10 herds with 1565 animals) (Perry et al., 2017). Conception rates to AI were greater in the CA/IV vaccine group compared to the MLV vaccine group (P = 0.05; 60% vs 52%; Table 2).

Table 2. Impact of vaccine on pregnancy success among previously vaccinated animals.

	Vaccine	AI Conception (%)	Day 56 Pregnancy Success (%)	Breeding Season Pregnancy Success (%)	Early Embryo Loss (%)
Study 1	Modified Live	40.0 ± 4^{a}	88.9 ± 2^{c}	95.2 ± 2^{c}	2 ± 1
	Inactivated	46.5 ± 4^{b}	93.2 ± 2^{d}	98.0 ± 1^{d}	2 ± 1
	Saline	43.3 ± 4^{ab}	92.5 ± 2^{d}	96.4 ± 1^{cd}	2 ± 1
Study 2	Modified Live	52.0^{y}		95.2 ± 2	
	Chemically Altered/Inactivated	60.0^{z}		96.4 ±1	

Means within a column having different superscripts are different ^{ab}P = 0.055, ^{cd}P ≤ 0.01, ^{yz}P < 0.05
Adapted from Perry et al., 2016 and Perry et al., 2017

A recent publication (Stewart et al., 2023), reported that when cows that had previously been vaccinated were vaccinated at the start of the synchronization protocol that animals vaccinated with a MLV had increased AI conception rates compared to cows vaccinated with an IVV in a spring breeding season (54% vs 46%; P< 0.01), but in a fall breeding season AI conception rates did not differ (P = 0.62; 48% vs 49%, respectively). It is unknown why there were differences between spring and fall, but some differences between this study and the previously mentioned study include, a different MLV vaccine was used, and all cows were vaccinated only 10 days before AI. In addition, there was not a nonvaccinated control group or blood samples collected to determine possible exposure to wildtype viruses. Thus, it cannot be determined if differences between treatments and season could be due to protection or timing. A recent study reported that when naïve heifers were vaccinated at the start of a synchronization protocol with a MLV control animals housed in the same pen seroconverted before the end of the study (Chase unpublished data). This indicates that when animals are vaccinated with a MLV animals can shed the virus impact animals that they are around.

Timing of vaccination

Negative impacts of vaccinating with a MLV on pregnancy success has been reported on not only on first service conception rates, but also on a low percentage of animals conceiving during the second service following vaccination (Chiang et al., 1990; Perry et al., 2013), and in some heifers infected with BHV-1 at or near estrus, normal estrous cycles were delayed for up two months (Miller and Van der Maaten, 1985). Furthermore, BVDV antigen has been detected in the ovary up to 30 d post-vaccination (Grooms et al., 1998). In the second field trial mentioned above, interval from vaccination with either MLV or IVV until AI also influenced conception rates ($P = 0.02$; Figure 1). Animals vaccinated 27 to 30 d prebreeding and animals vaccinated 30 to 37 days prebreeding had similar ($P = 0.98$; 52% and 52%) conception rates; however, both were decreased compared to animals vaccinated 38 to 89 d prebreeding ($P < 0.03$; 64%). There was no treatment by interval interaction ($P = 0.79$), indicating at all three intervals conception rates to the CA/IV vaccine were increased compared to the MLV. Furthermore, there was no effect of treatment ($P = 0.18$) or treatment by interval interaction ($P = 0.17$) on breeding season pregnancy rates.

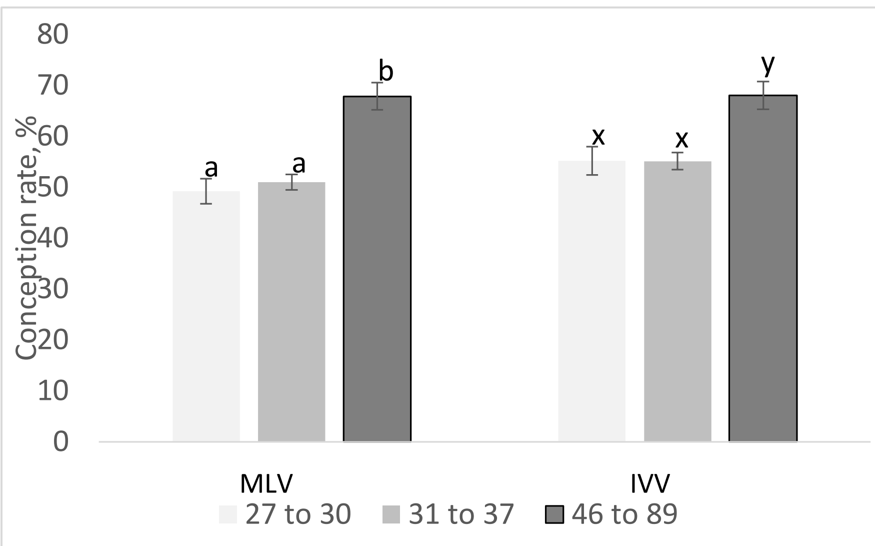

Figure 1. Influence of vaccination interval on pregnancy success in beef cattle. Adapted from Perry et al., 2017.

Possible causes of decreases in reproductive performance

Decreases in fertility by vaccination of naïve heifers around the onset of standing estrus are likely mediated through negative effects on corpus luteum (CL) function (Van der Maaten and Miller, 1985; Smith et al., 1990), with the hypothesis that the virus can get inside antral follicles and disrupt the formation and development of the corpus luteum. This has further been established as vaccination of naïve heifers with a MLV around time of breeding has negative impacts on corpus luteum development and on pregnancy success (Miller et al., 1989; Chiang et al., 1990; Miller, 1991) even when utilizing a synchronization protocol that induces ovulation of the dominant follicle at the start of the protocol (Perry et al., 2013).

The same effect of abnormal appearing corpora luteal (no signs of necrosis or mineralized luteal tissue) did not occur when heifers had been vaccinated twice with a IVV and then vaccinated with a MLV, but 37.5% (3/8) of animals that exhibited estrus had a large CL with progesterone concentrations less than 1 ng/mL on day 6 to 7 after estrus (Spire et al., 1995). The mechanism that inflicts CL damage following MLV vaccination is still unknown. Our laboratory has recently investigated the effect of a commercially available MLV or IVV vaccine administered around the time of estrus on CL development and function through evaluation of luteal cell populations, degree of apoptosis, and circulating progesterone and cytokine concentrations (Epperson, 2023). There were reduced numbers of large luteal cells (LLC) in MLV compared to IVV and controls (*P*<0.0001), but IVV were similar to controls (*P*=0.11; Table 3). MLV had a decreased percentage of LLC compared to controls, and IVV were intermediate (*P*<0.0001, MLV: 1.57±0.33%, IVV: 2.99±0.30%, Control: 6.45±0.33%). Based on P4 concentrations, 24% of MLV and 0% of IVV had an abnormal cycle following vaccination. Overall, MLV had reduced P4 concentrations (*P*=0.02; MLV: 3.61±0.22; IVV: 4.81±0.46ng/mL). The new CL that formed following an abnormal cycle in MLV had the greatest percentage (35.56 ± 5.5%) apoptotic cells. Treatment by cycle status interaction, and time significantly affected IFN-γ, IP-10, MIP-1β, and MCP-1 (*P* < 0.03), with several time points having elevated concentrations in abnormally cycling MLV animals. Collectively, this demonstrates MLV vaccination around estrus negatively influenced luteal cell populations, P4, and increased luteal apoptosis and pro-inflammatory cytokines.

Table 3. Histological and Apoptotic Evaluation of the Corpus Luteum.

	MLV[a]-new CL[b]	MLV-old CL	IVV[c]	Control	*P*-value
Large luteal cell number	5.11 ± 0.86^{x}	3.74 ± 0.73^{x}	12.33 ± 0.79^{y}	14.22 ± 0.86^{y}	< 0.0001
Total cell number	342.69 ± 15.72^{x}	339.51 ± 13.28^{x}	451.73 ± 14.35^{y}	233.34 ± 15.72^{z}	< 0.0001
Large luteal cell, %	1.57 ± 0.33^{x}	1.24 ± 0.28^{x}	2.99 ± 0.3^{y}	6.45 ± 0.33^{z}	< 0.0001
Luteal apoptosis, %	35.56 ± 0.06^{x}	7.055 ± 0.05^{y}	4.248 ± 0.05^{y}	--	< 0.0001

[a]modified-live virus vaccine (MLV)
[b]Corpus Luteum (CL)
[c]Inactivated virus vaccine (IVV)
Different [xyc]superscripts within rows depict statistical differences ($P \leq 0.05$) between treatments.

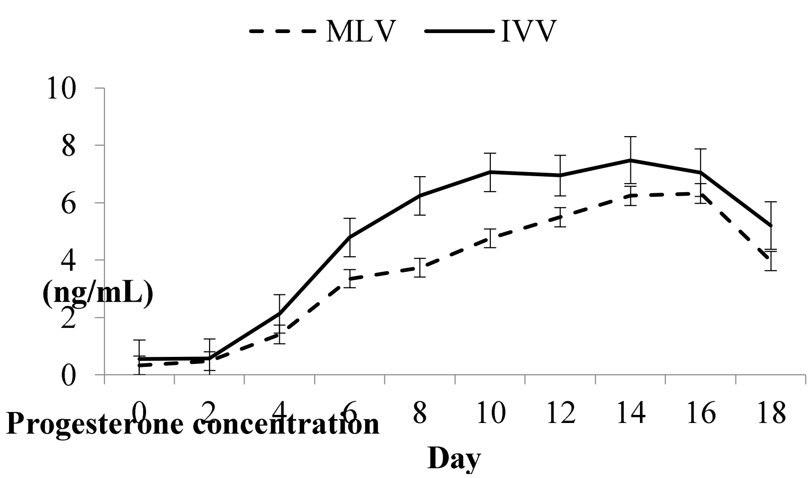

Figure 2. The influence of the interaction of treatment and time on circulating concentrations of progesterone (ng/mL) among all bovine females administered either a modified-live virus vaccine (MLV) or inactivated virus vaccine (IVV) on d 0 (P = 0.05). Data points marked with a *superscript denote statistical differences ($P \leq 0.05$) between treatments within day, while those marked with a #superscript tend to be different ($0.05 < P \leq 0.10$).

Conclusions

So where do these studies leave us on the impact of virus vaccines on reproductive success? Vaccines against infectious reproductive diseases are valuable tools in the prevention of these diseases, as outbreaks of these diseases can be potentially devastating to a beef herd. *This emphasizes the importance of proper vaccination of females before they enter the breeding herd.*

However, evidence is growing that MLV versions of these vaccines can have negative effects on reproductive management in well managed herds. Studies utilizing different pre-breeding vaccination protocols and intervals indicate that MLV vaccines, when given at labeled pre-breeding intervals, may negatively affect reproductive parameters compared to cattle vaccinated with inactivated vaccines. In light of this research, it appears the choice of pre-breeding vaccine product type and timing is one to carefully consider. Important to this consideration is the level of exposure that a given herd may have, as none of these large prebreeding studies were carried out in the face of disease challenge and do not address the question of protection in the face of an infectious reproductive disease exposure. Future research will help determine how to strike the best balance between appropriate disease protection and minimizing harmful effects from the vaccines themselves. It is reasonable to expect that striking this balance will be different for each individual cattle operation, making it imperative that cattle producers consult their veterinarian and weigh all available information when making decisions about pre-breeding vaccinations in their herds.

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Proceedings, The Range Beef Cow Symposium XXVIII
December 13 & 14, 2023, Loveland, Colorado

MANAGING REPRODUCTIVE EFFICIENCY: TAKING A SYSTEMS APPROACH

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INTRODUCTION

Reproductive performance is one of the core drivers of profitability and success in cow-calf operations. Costs associated with managing heifers prior to weaning their first calf must be recovered through subsequent calf crops. Reproductive failure and infertility result in significant economic loss. Cows or heifers that fail to become pregnant during the breeding season are often culled, resulting in increased development or maintenance costs for herd mates, negatively impacting the overall profitability of the operation. Previous reports have suggested a loss of $6.25 per exposed cow for every 1% decrease in pregnancy rates and projected a gross loss of $2.8 billion annually in the United States due to infertility (Lamb et al., 2014). Therefore, reproductive efficiency, fertility, and longevity are critical to the sustainability and economic viability of cow-calf operations.

Reproductive performance, however, is impacted by management decisions made throughout the year. Numerous factors including nutritional management, body condition, herd health, environmental stressors, genetics, etc. can impact reproduction. Due to the significant relationship between reproduction and management throughout the production cycle, it is important to evaluate reproduction from a whole systems approach. Taking a whole systems approach and evaluating all of the factors that influence reproduction from a multiyear perspective can allow producers to manage both proactively and reactively to improve the sustainability and profitability of beef cow-calf operations. So how can we evaluate reproductive efficiency and take a systems approach to managing reproduction in the cowherd?

EVALUATING REPRODUCTIVE EFFICIENCY

Understanding current reproductive performance within the herd is an important first step before making any changes to the current management program. Assessing reproductive performance each year will allow for identification of problems that may have occurred during the breeding season, gestation, and between calving and weaning as well as provide an opportunity to plan for the upcoming year and continue to build on the current success of the program.

Maintaining records of the number of females exposed to artificial insemination (AI) and(or) bulls, dates when bulls were turned in and removed, calving percentage, calving distribution, and the number of calves weaned can allow for assessment of reproductive efficiency. Pregnancy detection (palpation, ultrasound, or blood test) is an extremely useful tool in assessing reproductive rates, allowing for determination of pregnancy status, as well as potentially identifying any late bred cows or heifers. Pregnancy rate can be calculated by taking the total number of pregnant animals divided by the number of females exposed [(number pregnant/number exposed) x 100 = % pregnant]. Determining calving percentage [(number of live calves born/ number of pregnant females) x 100 = % calving] can also be valuable in identifying problems that may have occurred between pregnancy detection and calving, and(or) related to dystocia or calving issues.

Calving distribution can also be a worthwhile measurement to evaluate. Determining what proportion of the herd calved by day 21, 42, and 63 of the calving season can help further identify reproductive performance within the herd. Ideally, the majority of calves are born early in the calving season, and assessment of calving distribution can provide insight into the impact of management pre-breeding and throughout the breeding season. Nutritional management pre- and post-breeding, body condition at calving and breeding, and herd health can significantly affect success during the breeding season. In addition, calving distribution in your heifers and young cows can also allow for evaluation of the current heifer development program and management of your first calf heifers. Combined, pregnancy rate and calving distribution within the different groups of animals can help assess the success of the current breeding program or determine if animals are good candidates for AI. Pregnancy rates after a 60 to 70-day breeding season should be 85% or higher in your cows and heifers before implementing a synchronization and AI program.

Calculating weaned calf percentage can also be a valuable measurement to consider when evaluating reproductive efficiency in the cow herd. Weaned calf percentage is calculated by dividing the number of calves weaned by the number of females exposed. While pregnancy rates describe success during the breeding season, weaned calf percentage will allow for evaluation of the number of cows and heifers that were bred, maintained a pregnancy, had live calves, and raised calves to weaning. The goal of cow-calf operations is for every cow to wean a marketable calf each year, therefore, assessment of the full system from breeding through weaning is an important tool. Using this information, management throughout the full production system can be assessed to identify weak spots that will allow for improvement of the quality of the system.

SYSTEMS APPROACH

Beef production is a complex system that is influenced not only by management decisions made throughout the year related to nutrition, genetics, reproduction, health, and marketing, but also by external factors such as the cattle market, feed prices, weather and drought, land availability and values, labor costs and availability, to name a few. Appreciating the complexity of the overall system, as well as the relationships and interactions among the components can be helpful in understanding the system, as well as specific problems and leverage points.

Taking a systems approach to reproduction by evaluating all the factors that influence fertility and reproductive performance not only during the breeding season but throughout the year will allow for identification of areas to improve efficiency and(or) performance. Assessing variability within each component can allow for better management of the factors, as well as identification of leverage points that may help improve the quality of the overall system resulting in increased efficiency and productivity. It will also provide an opportunity to create a proactive plan for the upcoming year. For example, this may include identification of different nutritional strategies such as calving and managing cattle more in synch with grazing or feed resources. Placing selection pressure for early calving heifers and cattle that are adapted to the current production environment. Evaluating the timing of vaccination protocols to minimize negative impacts on fertility. Shortening the breeding season to allow for a tighter calving window that can concentrate labor, as well as improve the efficiency of nutritional and health management. Finally, considering the use of reproductive technologies such as estrus synchronization or AI. Evaluating both short-term and long-term opportunities and solutions within the system, including the consequences of each decision, may allow for improvements in the efficiency of the production system.

MANAGEMENT FACTORS THAT INFLUENCE REPRODUCTION

The goal of cow-calf production is to efficiently wean a marketable calf each year from every cow. Therefore, cow-calf operations rely on reproductive efficiency of cows and heifers within the system. Managing for reproductive success should not be limited to just the time associated with the breeding season but be considered throughout the year and production cycle. Decisions made throughout the year can impact the fertility of both cows and heifers during the next breeding season, as well as influence the future reproductive performance of the gestating calf. Understanding the relationship between management and reproduction can allow for effective planning and management of fertility.

Nutritional Management: Nutritional management represents a crucial aspect of cow-calf operations where management practices and decisions can have a significant influence on reproductive performance. Significant research has been conducted to understand the relationship between nutrition and reproduction in both heifers and cows (reviewed by Hess et al., 2005; Summers et al., 2019). Proper nutrition throughout the production cycle is important; however, several time points are crucial to reproductive success during the breeding season.

Nutritional management of heifers during the first year of life is critical in establishing the foundation for fertility, productivity, and longevity in a beef herd. Decisions made regarding the nutritional management of heifers can help program puberty attainment and fertility, potentially allowing for increased reproductive performance and longevity, resulting in improved profitability. Considerable research has been conducted evaluating the nutritional management of heifers, specifically targeting the post-weaning development period. Traditional post-weaning heifer development systems have targeted heifers to achieve 60 to 65% of mature body weight by the start of the first breeding season in order to maximize the number of heifers cycling at the start of the breeding season and pregnancy rates (Patterson et al., 1992). More recent heifer development research has emphasized the comparison of traditional, more intensive systems to low-input extensive development systems. Increased development costs, driven by increased feed costs, have been a significant driver behind the investigation of low-input heifer development systems. Low-input heifer development systems have typically relied on grazing heifers on dormant forages or native range, developing heifers to a lighter percent mature body weight, and(or) relying on periods of compensatory gain. The objective of more extensive low-input systems has been to develop management strategies that are more economically efficient for producers while maintaining reproductive performance in heifers (reviewed in Summers et al., 2019). Overall heifer pregnancy rates have been demonstrated to be similar regardless of if heifers were managed in low-input heifer development systems or traditional heifer development systems (reviewed in Summers et al., 2019). Management of heifers to maximize economic efficiency and ensure development costs can be recuperated in a timely manner is an important consideration when making decisions regarding how to develop replacement heifers. Furthermore, available resources vary among operations, therefore, development systems are unique to each operation. Effective utilization of resources that allows for optimal reproductive performance of heifers not only in their first breeding season but over their lifetime is an essential component of heifer development systems.

Evaluating the long-term implications of management decisions is an important aspect of systems thinking. The interaction between nutrition and reproduction in heifer development has been well established, however, research regarding the impacts of heifer development systems on cow longevity is limited. The effect of post-weaning development strategies on cow longevity and lifetime productivity is complex as it can be influenced by the environment, nutritional status, and management practices utilized throughout the animal's life. Heifers developed on restricted gain to 53% of mature body weight had similar pregnancy rates through the fourth calving season compared to heifers developed to 58% of mature body weight (Funston and Deutscher, 2004). Heifer development systems that manage heifers in extensive systems may better prepare heifers for future production environments and positively impact survivability. Mulliniks et al. (2013) reported a greater retention rate through 5 years of age in range-developed heifers receiving a high-RUP supplement (68%) compared with range-developed counterparts fed a low-RUP supplement (41%) and heifers fed in the drylot (41%). These data indicate that where a heifer is managed during pre-breeding development (drylot vs. extensive), as well as specific nutrient content may influence survivability. Heifer development systems focused on acclimation of heifers to extensive production environments may allow heifers to be better adapted for future challenges facing the grazing animal. Understanding the demands of future production environments and the influence of development strategies on heifer performance and longevity must be considered when designing heifer development systems.

Nutrition pre- and post-calving can directly influence the length of the postpartum interval, first service conception rates, and overall pregnancy rates during the breeding season. Failing to meet energy and(or) protein requirements throughout the different production phases will not only result in loss of body weight and body condition but decreased reproductive performance. It is important to have a strong understanding of the nutrient requirements for the different groups of animals (growing heifers, young cows, mature cows, bulls, etc.) and the different phases of production (growth, lactation, gestation) to ensure all requirements are being met. In addition to understanding the nutrient requirements, evaluation of forage quality and quantity can assist in developing a nutritional management plan or supplementation program.

Body condition scoring (BCS) can be a valuable tool that producers can utilize in preparing for winter and spring calving. Body condition scoring provides a consistent, systematic way to quantify energy reserves in beef cattle. Changes in muscle and fat reserve can be visually evaluated using the BCS system (scale of 1-9) and utilized as an indicator of the nutritional status of the animal. Previous research has established that BCS at calving has a significant impact on reproductive performance during the next breeding season (Spitzer et al., 1995; Bohnert et al., 2013). As BCS decreases in females at calving, length of the postpartum interval (PPI) increases (Houghton et al., 1990). Cows with a BCS $\geq$ 5 at calving returned to estrus sooner than cows with a BCS $\leq$ 4 (Spitzer et al., 1995). Additionally, pregnancy rates were greater in cows with a BCS $\geq$ 5 at calving compared with cows with a lower BCS (Spitzer et al., 1995; Bohnert et al., 2013). Furthermore, adaptability of cows to their production environment and long-term selection for cows to perform in limited feed environments can result in cows that can perform at lower BCS. Specifically, Mulliniks et al. (2012) reported similar pregnancy rates between cows at a BCS 4, 5, or 6 at calving (92% vs. 91% vs. 90%, respectively).

Assessing cow BCS at strategic times throughout the year can allow for evaluation of the nutritional management plan and for producers to ensure that cows are at an appropriate BCS at calving. An important time point to evaluate cow body condition is at weaning. With decreased cow nutrient requirements following weaning and adequate time before calving, this is an economical time to improve condition if needed. In general, a cow must gain 80 lb to increase one BCS (depending on cow size), not including the weight of a gestating calf and associated fluids. Knowing how much weight needs to be gained and the number of days until calving will allow for calculation of average daily gain needed to achieve the targeted BCS goal. Winter weather, as well as feed availability and quality, can make adding additional body condition prior to calving challenging. After calving, however, increasing body condition may require large amounts of high-quality feeds to meet increased nutrient requirements due to lactation.

As discussed above, pre-calving nutrition and body condition influence the duration of postpartum anestrus and, thus, the proportion of cows cycling at the start of the breeding season. Post-calving nutrition and ensuring that cows are in a positive energy balance is an important factor in ensuring cows resume normal estrus cycles and influences conception rates. Previous research has established that reproductive performance is decreased in lactating beef cows in a negative energy balance (Randal et al., 1990; Hess et al., 2005). Randal et al. (1990) summarized results from several studies, reporting that first service conception rates and overall pregnancy rates are affected by energy and(or) protein intake of postpartum beef heifers and cows. Lower first service conception and pregnancy rates were reported when heifers and cows were fed inadequate amounts of protein and(or) energy (Randal et al., 1990). Ensuring nutrient requirements of cows and heifers are being met pre- and post-calving will result in success during the breeding season.

Post-breeding nutritional management is an important component of a reproductive management program. Management decisions made during the first approximately 60 days after insemination or breeding can have a significant impact on reproductive success. In spring calving herds, there is often a transition in nutritional management as forage availability and quality increase in late spring and early summer. Additionally, heifers are often developed in a drylot over the winter and early spring before being turned out on pasture. This transition frequently occurs at the start of the breeding season either immediately following AI or when bulls are turned out. Previous research has established that nutritional and metabolic stress that occurs during this crucial period of early embryonic development, maternal recognition, and attachment can affect embryonic mortality and first service conception rates (Perry et al., 2013a; Kruse et al., 2017). If heifers were consuming an energy dense diet in the drylot pre-breeding, transitioning to even high-quality spring pasture can result in a decline in energy density and a decrease in the plane of nutrition. Adaptation of animals to a grazing environment can also result in increases in nutritional requirements due to an increase in activity level in grazing animals, creating a short-term energy deficit for heifers transitioning from drylot to pasture (Perry et al., 2015).

Maintaining heifers and cows on the same plane of nutrition for the first month post-breeding can help alleviate alterations in the plane of nutrition during early embryo development. If heifers are developed on a high plane of nutrition in the drylot, keeping heifers in the drylot on the same diet for an additional 30 days may help minimize nutritional stress. Previous research has also determined that if heifers transitioned to pasture immediately following AI are supplemented to prevent weight loss, pregnancy rates are not negatively impacted (Perry et al., 2015). Supplementation may provide an option for operations that cannot maintain heifers in the drylot for an extended period of time. An additional strategy could be to adapt animals to a range-based grazing situation before breeding (~ 30 days), allowing changes in the plane of nutrition to occur prior to breeding and more animals to maintain their pregnancies early in the breeding season. Overall, consistency in pre- and post-breeding nutrition is critical to maintain reproductive performance.

Health Management: Establishment of a herd health program is an important component of overall management in a beef cattle operation. Development of a strong immune system and prevention of disease are crucial to productivity within the herd and can also impact reproductive performance. Biosecurity, parasite control, and vaccination are key elements of a complete herd health program. Numerous diseases and pathogens can influence fertility and reproduction either directly or indirectly. Infectious diseases, such as vibriosis, brucellosis, infectious bovine rhinotracheitis, bovine viral diarrhea virus, trichomoniasis, leptospirosis, etc. can directly impact fertility or cause abortion, and can have substantial economic impacts if there is exposure to inadequately protected herds. Biosecurity practices are essential to reducing exposure to disease. Purchasing animals with known vaccination history from reputable sources, quarantining new animals, testing for high-risk diseases, and ensuring that new animals are well vaccinated are important aspects of a biosecurity plan. Consult with your veterinarian for guidance on developing an appropriate biosecurity plan and guidance on required testing and vaccination in your area.

Vaccination is an important component of a herd health program and a valuable tool to aid in the prevention of disease. Vaccination protocols should be designed to fit the specific management system and production goals of the operation and protect against diseases that pose a threat to the cowherd. The influence of vaccination on reproductive performance, specifically on estrus synchronization and conception, is variable. Several studies have been conducted to evaluate the relationship between vaccination timing and type in both naïve and previously vaccinated animals. In naïve animals, previous research has reported decreases in fertility when naïve heifers are vaccinated with a modified live vaccine (MLV) around the time of breeding (Perry et al., 2013b; Perry et al., 2018). Previous research has suggested decreased fertility associated with vaccination of naïve animals around the time of breeding is likely mediated by negative impacts on the dominant follicle and corpus luteum (reviewed in Moorey et al., 2022). In previously vaccinated animals, Perry et al. (2018) reported conception rates to AI were greater in chemically altered vaccine treated animals compared to the MLV treated animals (60% vs. 52%). Additionally, animals vaccinated 27 to 30 days pre-breeding and animals vaccinated 30 to 37 days pre-breeding had similar (52% vs. 52%, respectively) conception rates, however, both groups were decreased compared to animals vaccinated 38 to 89 days pre-breeding (64%; Perry et al., 2018). Combined, this research establishes the importance of properly vaccinating females entering the breeding herd as replacements and timing of vaccination before the breeding season. A more in-depth discussion of the influence of vaccinations on reproduction can be found in the Range Beef Cow Symposium proceedings entitled “Reproductive Vaccine Effects on Reproduction” by Dr. George Perry.

Selection for early calving: Optimizing the number of cows and heifers that conceive early in the breeding season can improve overall productivity as well as increase reproductive efficiency and longevity. Cows that conceive late in the breeding season will calve late in the calving season and wean calves that are younger and lighter compared to cows that conceive and calve early. In addition, previous research has indicated that animals that calve late in the calving season have an increased chance of calving late or not calving the next year (Burris and Priode, 1958). Funston et al. (2012) reported heifers born in the first 21 days of the calving season had increased body weight at weaning, prebreeding, and pregnancy diagnosis compared to heifers born later in the calving season. Heifers born in the first 21 days of the calving season had a greater percentage of heifers cycling at the beginning of the breeding season and increased pregnancy rates compared to heifers born later in the calving period (Funston et al., 2012). Moreover, Funston et al. (2012) reported steers born during the first 21 days of the calving season had increased weaning weights, increased hot carcass weights, greater marbling scores, and an increase in carcass value compared to steers born later in the calving period. Therefore, increasing the number of calves born early in the calving season can result in heavier calves at weaning, improved carcass characteristics, and increased reproductive performance of heifers.

Increasing the number of cows and heifers that conceive early can also benefit lifetime productivity and longevity. Previous research has indicated that heifers calving in the first 21-day period of their first calving season have increased calf weaning weights through the first 6 calves compared to their contemporaries calving later in their first calving season (Cushman et al., 2013). Heifers calving early in their first calving season wean more pounds of calf over their lifetime, which amounts to the production of an extra calf during their lifetime (Cushman et al., 2013). This represents a significant financial advantage for the operation. Furthermore, heifers calving in the first 21-day period of their first calving season remained in the herd longer compared to heifers calving for the first time in the second or third 21 days of the calving season (Cushman et al., 2013). The development and utilization of management strategies that focus on heifers conceiving early in their first breeding season can help increase the survivability and lifetime productivity of heifers. Producers that can afford to develop extra heifers could have the option to place additional selection pressure for heifers that conceive early in the breeding season. Breeding extra heifers would provide the opportunity to select replacement heifers that conceived early in the breeding season by estimating fetal age at pregnancy diagnosis. A similar strategy would be to develop additional heifers and utilize a shorter breeding season (approx. 30 days) and make selection decisions from pregnant heifers at pregnancy diagnosis. Open heifers would still be in the age range to be marketed in the feeder cattle market. Lastly, utilization of estrus synchronization can allow more females to be bred earlier in the breeding season, as well as hasten the onset of puberty attainment and shorten the PPI in late-calving females (when using a progestin-based protocol), allowing them to conceive earlier in the breeding season.

Cows and heifers that calve late often don’t have adequate time to resume cycling and conceive before the end of the breeding season. Females calving early in the calving season have more time to resume cyclicity before the breeding season, making them more likely to not only become pregnant during a defined breeding season but become pregnant early. Additionally, having a defined breeding season and even decreasing the length of the breeding season can increase efficiency within the herd. A defined breeding season will allow for a shortened calving season, providing cows and heifers time to return to estrus cyclicity prior to the breeding season, allow concentration of labor during the calving season, increase uniformity of the calf crop, and allow for more efficient nutritional and health management. An extended calving season can result in periods of over- or under-nutrition for different groups of cows depending on the stage of production (gestation or lactation) the diet is balanced to meet. Overall, tightening the calving window and maximizing the number of females calving early in the calving season can increase calf performance and improve reproductive efficiency in the herd.

Reproductive Management: To maintain a 365-day calving interval, beef cows must recover from the nutrient and physical demands of calving and lactation and will have 80 to 85 days to return to estrus after calving. Failure to successfully manage the PPI is one of the major causes of reproductive failure, especially in young cows. After calving, cows go through postpartum anestrus, a period in which cows do not experience estrous cycles. This period can vary in length due to factors such as uterine involution, short estrus cycles, nutritional status, and suckling effect. Uterine involution can be defined as the structural and functional regression of the uterus to a status that can support another pregnancy. This includes returning to a non-pregnant size, shape and position, shedding of all fetal membranes, and repair of uterine tissues. This process is completed in approximately 20 to 40 days following calving if no complications arise. However, factors such as nutrient restriction, calving difficulty, and disease can delay normal involution.

During the first ovulation postpartum, why is the first estrous cycle short? The corpus luteum during a short estrous secretes less progesterone, is smaller, and is less responsive to stimulation (Short et al., 1990). Therefore, fertility is decreased (Short et al., 1990) and the majority of cows will experience a short estrous cycle (an estrous cycle of ≤ 10 days). When a short estrous cycle occurs, the corpus luteum will regress and the cow will return to heat before maternal recognition of pregnancy occurs (Odde et al., 1980). That means that cows need to initiate estrous cycles prior to the start of the breeding season to become pregnant. If cows do not exhibit estrus or are still in anestrus, the chances for those females to cycle or get bred early in the breeding season decreases. In addition, the act of suckling and presence of a calf has a significant effect on PPI length. Management strategies that reduce suckling frequency have been utilized to reduce PPI length and facilitate rebreeding (reviewed in Moorey et al., 2022). Temporarily removing calves from cows for 48 hours or early weaning calves has been shown to trigger anestrus cows in a body condition of 4 or 5 to start cycling. Evaluation of consequences associated with temporary removal of calves or early weaning should be evaluated before being utilized.

Estrus synchronization can be employed to potentially decrease the length of the PPI, tighten up the calving season, and maximize the number of females conceiving early in the breeding season. In herds with a large proportion of prepuberal heifers or anestrous cows, progestin pretreatment can simulate a short cycle and initiate normal estrous cycles. Utilizing a controlled intravaginal drug release (CIDR), a slow-release progesterone device, is a common estrus synchronization tool that can be used to "jump start" the cycle of late calving cows or manipulate the cycle in cows and heifers. Melengestrol Acetate (MGA) is also a progestin product available for use in heifers. Even if AI is not being utilized, estrus synchronization can help decrease the PPI of thin BCS cows in the breeding season.

Utilization of reproductive technologies can also increase reproductive efficiency and profitability within cow-calf production systems. Estrus synchronization and AI are both tools that can benefit cattle producers. In addition to being used to potentially decrease the PPI, estrus synchronization can increase the number of females calving early in the calving season, shorten the calving season, and improve calf uniformity. Estrus synchronization can be used with natural service (bull-bred) herds, as well as facilitate the use of AI or fixed-time AI (FTAI). Artificial insemination can allow producers to improve genetic traits of their cattle through use of proven high-quality bulls that they may not normally have access to or the ability to afford. Advancements in our understanding of the bovine estrous cycle and reproductive technologies have allowed for the continued development and refinement of protocols to manipulate the estrous cycle and control ovulation in cattle. When considering implementing estrus synchronization or AI, producers should consider the short- and long-term implications (both positive and negative) and how it may influence efficiency, productivity, and profitability within the system. Additional resources for selecting and implementing estrus synchronization protocols, as well as information about AI and reproductive management of beef cattle can be found on the Beef Reproduction Task Force website (https://beefrepro.org/).

CONCLUSIONS

Management decisions made throughout the year directly impact fertility and reproductive efficiency of the cow herd. Taking a systems approach by evaluating all of the factors that influence reproductive performance, not only during the breeding season but throughout the year, will allow for the identification of areas to increase efficiency or quality of the system. Increasing the proportion of females conceiving early in the breeding season is crucial for maximizing lifetime productivity and longevity. Attention to detail related to management (nutrition, health, selection, etc.) will also help improve fertility and reproductive performance. Moreover, evaluating both short-term and long-term opportunities and solutions within the system, including the consequences of each decision, may allow for improvements in the efficiency of the production system. Overall, identification of management strategies that effectively utilize resources and enhance reproduction and longevity will improve the profitability and sustainability of the operation.

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T.R.A.C. 2022 Priority Report

COLORADO COW-CALF BUSINESS BENCHMARKS

COLLEGE OF
AGRICULTURAL SCIENCES
COLORADO STATE UNIVERSITY

T.R.A.C. 2022 PRIORITY REPORT

COLORADO COW-CALF BUSINESS BENCHMARKS

Benchmarking for The Cow-Calf Business

The purpose of this report is to describe production and financial benchmarks for cow-calf operations in Colorado. While no two operations are alike, complied benchmark data can be a useful tool to evaluate performance and measure progress. Benchmarking is the process of conducting a comparative analysis of your cow-calf business with the averages of the benchmark herds. This process can help you identify strengths and weaknesses and allow you to focus your limited management time on the critical areas. However, there are certain considerations to keep in mind when using benchmark data. As the ranch manager, you must be the final decision maker on what is a strength and weakness. Unique circumstances can make your herd's performance logically differ from the benchmark herds. If so, then ignore the benchmark signal and use your own judgment. Additionally, you should take a systems approach to utilizing benchmark information to make changes. Most of the time focusing on one metric will not improve overall ranch performance.

T.R.A.C. Program Description

Total Ranch Analysis for Colorado (T.R.A.C.) was developed as a statewide collaborative partnership in Colorado State University (CSU) extension programming involving campus faculty, extension personnel, cattlemen's associations, and beef producers. Participant ranches are provided an in-depth financial, production, and management analysis of the ranch, using a standardized methodology. T.R.A.C. team members make on-site ranch visits to meet with producers, listen to their unique successes and challenges, and collect an array of production and financial data. Data collected is analyzed to determine critical production, financial and integrated measures. A customized report with benchmarks is given to the ranch which provides a unique opportunity to identify areas to reduce cost of production and improve production and marketing efficiency.

T.R.A.C. Program Approach

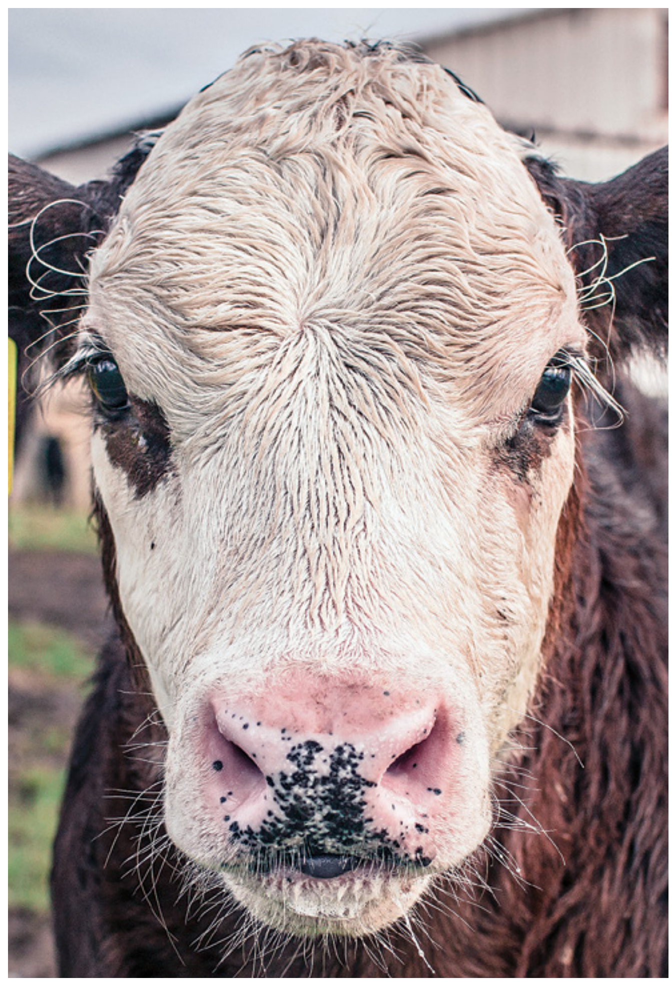
Our mission is to provide ranchers with the most accurate analysis possible by using accrual adjustments, including non-cash expenses (depreciation), and allocating overheads based on AUMs. An enterprise analysis of stockers, hay production, and raised replacement heifers is conducted when applicable. Participants also complete a survey to help us identify current management strategies. We assess livestock production and financial performance and use data from these ranches to establish Key Performance Indicators (KPI) and benchmarks. We understand that livestock production and financial performance are only two of the many key components of ranch sustainability. Therefore, we are actively developing new KPIs/metrics related to the human and ecological dimensions of ranch sustainability to create a more holistic approach to ranch management and analysis.

T.R.A.C. Program Goals

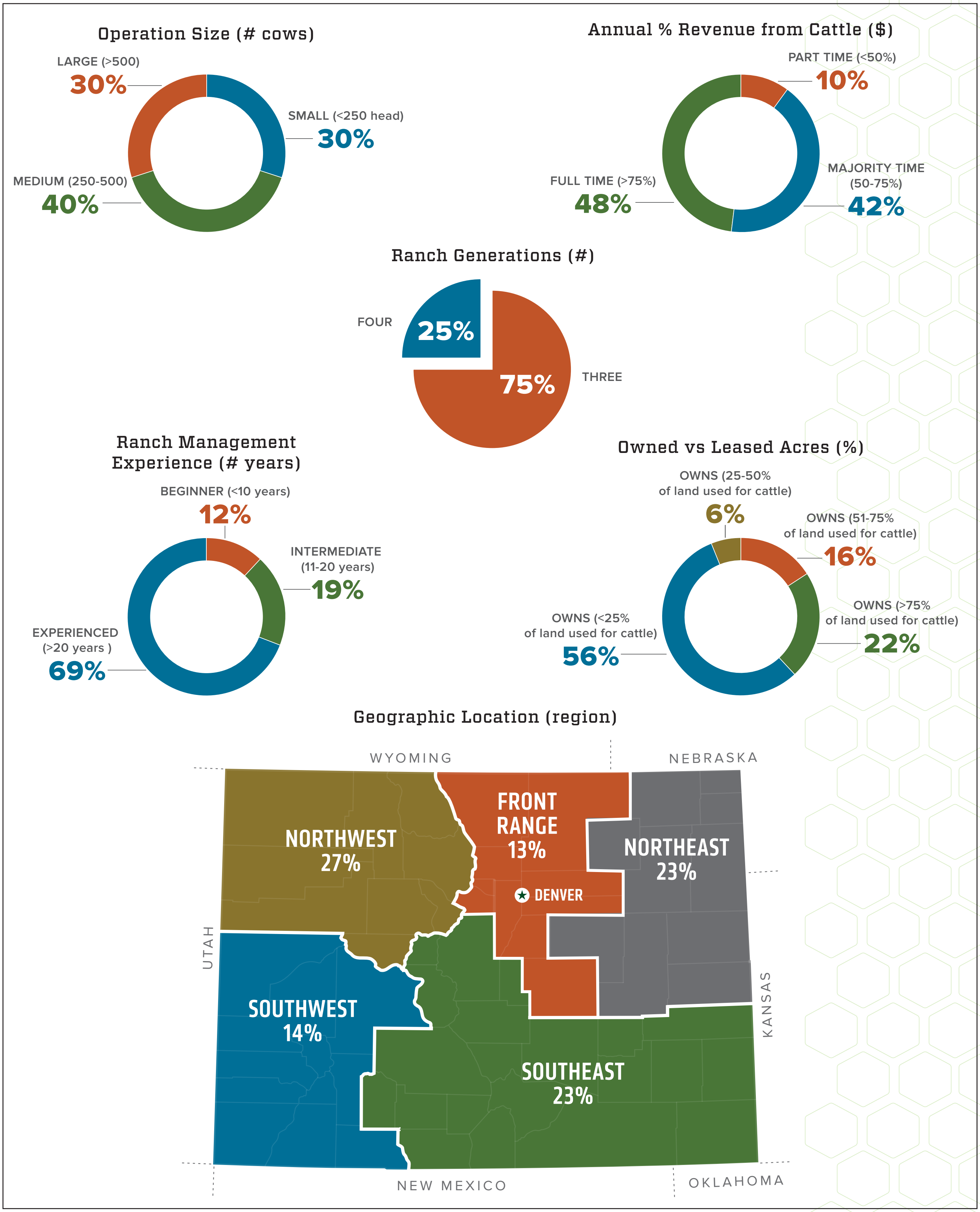
(1) Develop a comprehensive ranch scorecard that can be used internally by individual operations to set targets and track performance in all areas of ranch management.

(2) Develop a robust database to generate regional benchmarks that can be used by producers to help make more informed ranch management decisions.

(3) Improve ranch family livelihoods through a dedicated partnership around continual analysis and integration of animal-, human-, and resource-oriented program pillars.



T.R.A.C. Data Overview



T.R.A.C. Ranch Benchmarks Summary Statistics

In total, the program benchmarks over (20) different production, financial, and cost of production key performance indicators (KPI). They are summarized in the tables and figures below. We identified (6) of these KPI's as significant and described in more depth.

(1) Production Metrics

KPI #1: *Pounds Weaned/Exposed Female*

A product of weaning weight and weaning percentage, this is a critical production measure to track for benchmarking. It reflects the number of saleable pounds a ranch has produced and can be influenced by environment, management, and genetics.

Table 1. Ranch Production Metrics

Metric	Top 30% (9 Herds)	Bottom 30% (9 Herds)	Median (30 Herds)
Pregnancy (%)	96.0	89.5	93.0
Calving (%)	93.0	85.0	89.1
Weaning (%)	90.0	81.0	85.0
Weaning Wt. (lbs)	608	480	558
Pounds Weaned/ Exposed Female (lbs)	528	417	487
Acres/Female	18.4	81.0	43.5
Pounds Weaned/ Acre (lbs)	29.0	6.00	11.6

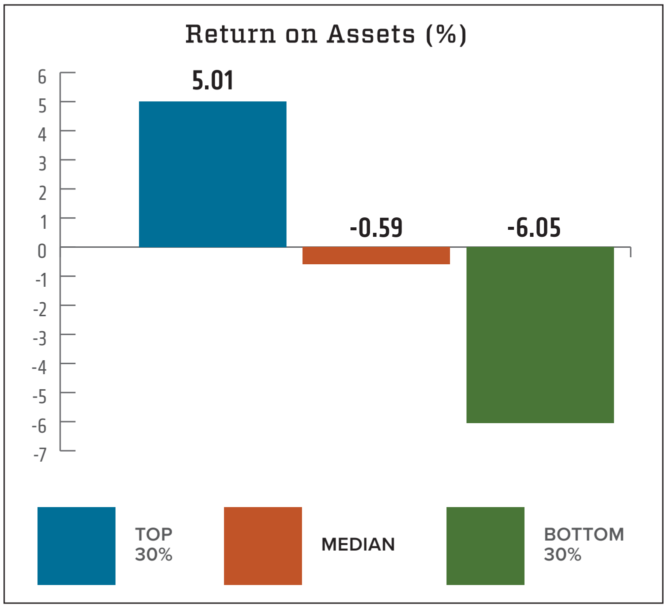
Table 2. Calving Distribution Metrics (% of Cow Herd)

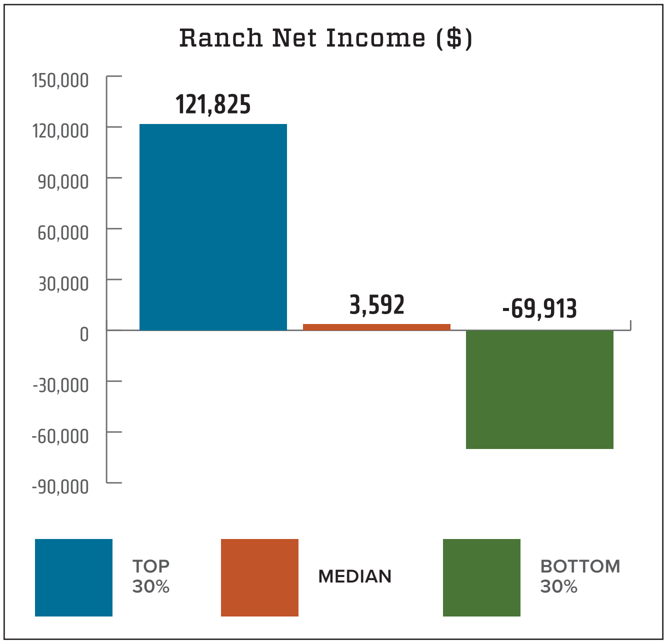
Days of Calving Season	Mean	Minimum	Maximum
1-21	46.5	6.3	80.1
22-42	38.8	14.8	60.9
43-63	11.1	0.0	30.8
63+	3.6	0.0	17.8

(2) Financial Metrics

KPI #2: *Return on Assets*

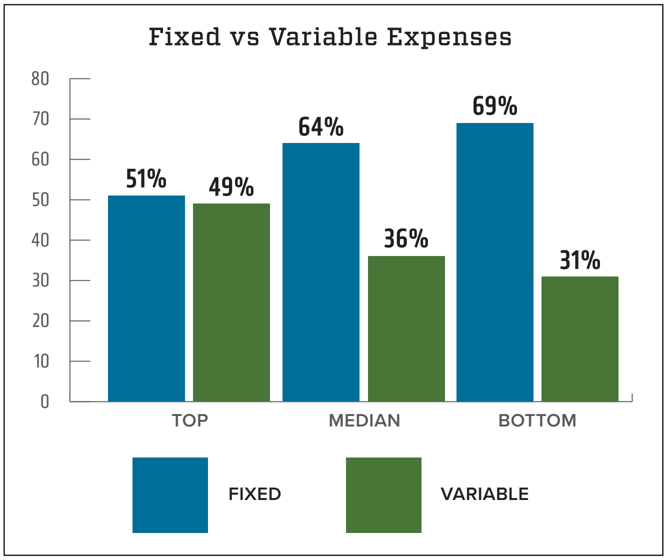
Calculated by dividing ranch net income (including interest expenses) by total ranch assets. Because cow-calf producers are first and foremost asset managers, whereas the other segments of the supply chain are margin-based businesses (buying low selling high), this metric demonstrates how efficiently the assets on the ranch are returning the owner a profit.





KPI #3: *Fixed vs Variable Expenses*

Fixed expenses are those that do not change (to a point) based on the number of animal units on the ranch. Variable expenses increase with each additional unit on the ranch. By knowing the fixed cost structure on a ranch, managers can project how stocking density and expansion opportunities will affect the efficiency of their operation.



(3) Cost of Production Metrics

KPI #4: *Total Cow-Cost*

Calculated by collecting actual data from participating ranches. Included in the cost of production is depreciation of vehicles, machinery, equipment, buildings and improvements, and raised and purchased livestock. Also included in the calculation is a conservative management salary if one is not already assumed by the owner or manager. Opportunity cost is not included in these calculations. If a ranch owns the assets (land, cattle etc.) a charge for that owned land or an interest charge for the assets are not included.

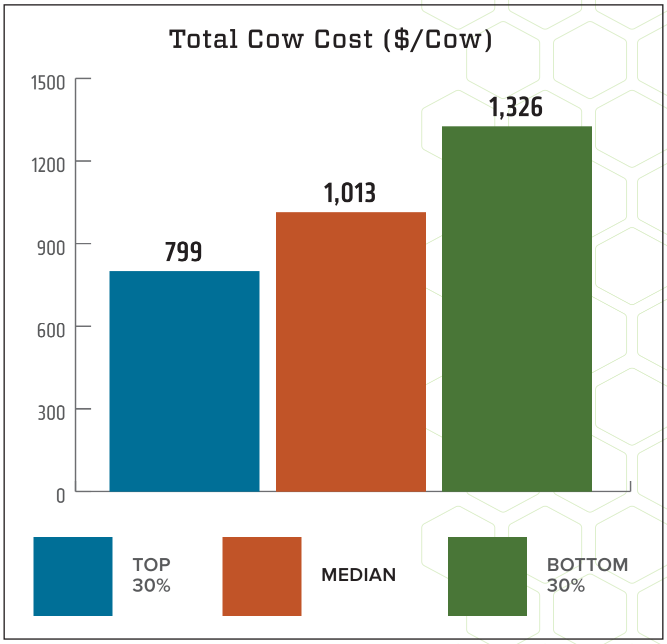
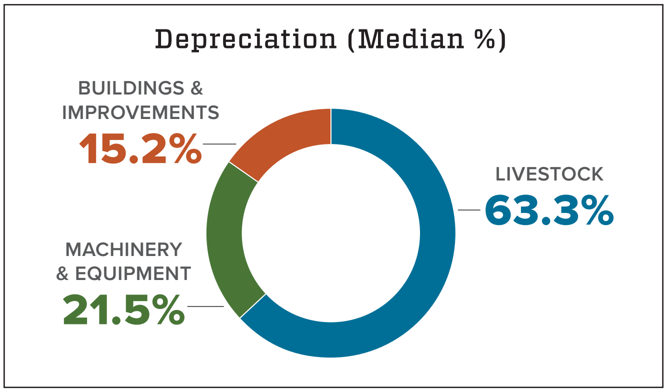


Table 3. Significant Cow Costs ($/Cow)

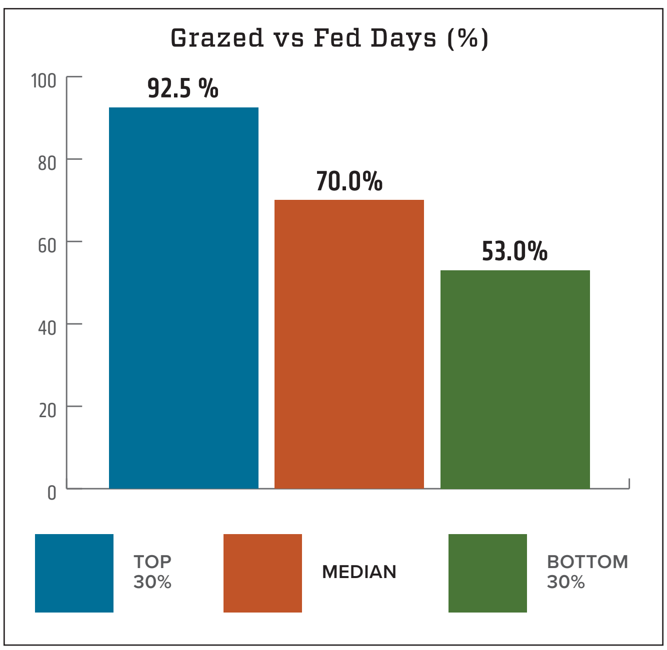
Metric	Top 30% (9 Herds)	Bottom 30% (9 Herds)	Median (30 Herds)
Depreciation	116.95	320.51	231.51
Labor	65.61	241.77	163.46
Feed	73.06	297.15	187.12
Pasture	49.69	213.52	112.08
Interest	7.45	130.31	40.59
Repairs & Maintenance	14.48	85.01	40.44
Vet & Breeding	20.76	55.20	31.41
Utilities	10.36	59.26	26.69
Taxes & Insurance	16.81	86.62	42.52
Fuel	22.01	65.08	33.39
Freight & Trucking	3.36	28.66	6.12
Supplies	15.45	46.59	24.01

(3) Cost of Production Metrics, continued



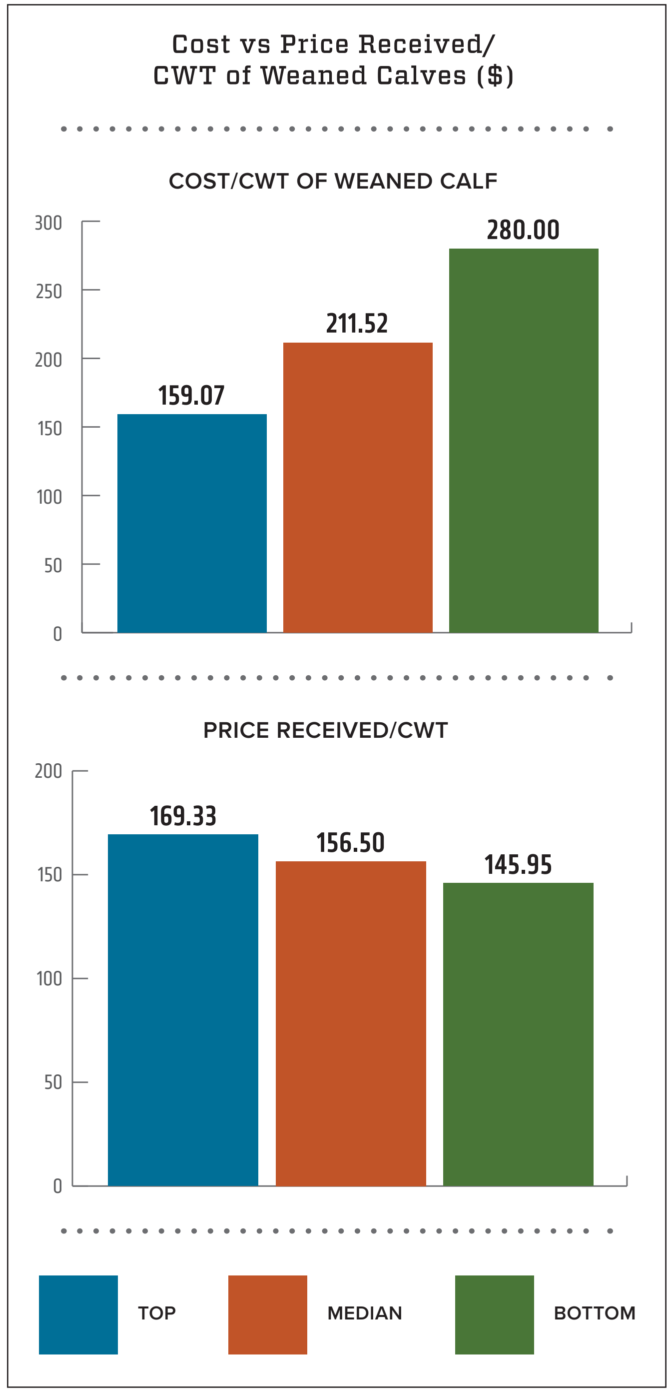
KPI #5: *Grazed vs Fed Days*

Calculated as a percent of days cattle graze pastures annually. Percent grazed days is determined by recording AUMs of each livestock class spent grazing pasture with no fed feed. Livestock class size is adjusted to fit a standard animal unit so class of animal can be compared uniformly. Fed feed costs are typically one of largest and most variable costs of production on a ranching operation. Maximizing the percentage of grazed days can help reduce this cost.



KPI #6: *Cost/CWT of Weaned Calf*

The same methodology to calculate cow-cost is used to calculate cost per cwt of weaned calves, but instead of dividing the total cow-calf enterprise expenses by the beginning fiscal year number of breeding females, those expenses are divided by the total amount of weaned pounds produced by the ranch.



(4) Cost Centers

Cost centers are units on the ranch that do not contribute to generating revenue or profit. Essentially, they are holding tanks for costs that can then be allocated to the appropriate enterprise. On most ranches in our dataset the major cost centers are raised replacement heifers (RRH) and hay production.

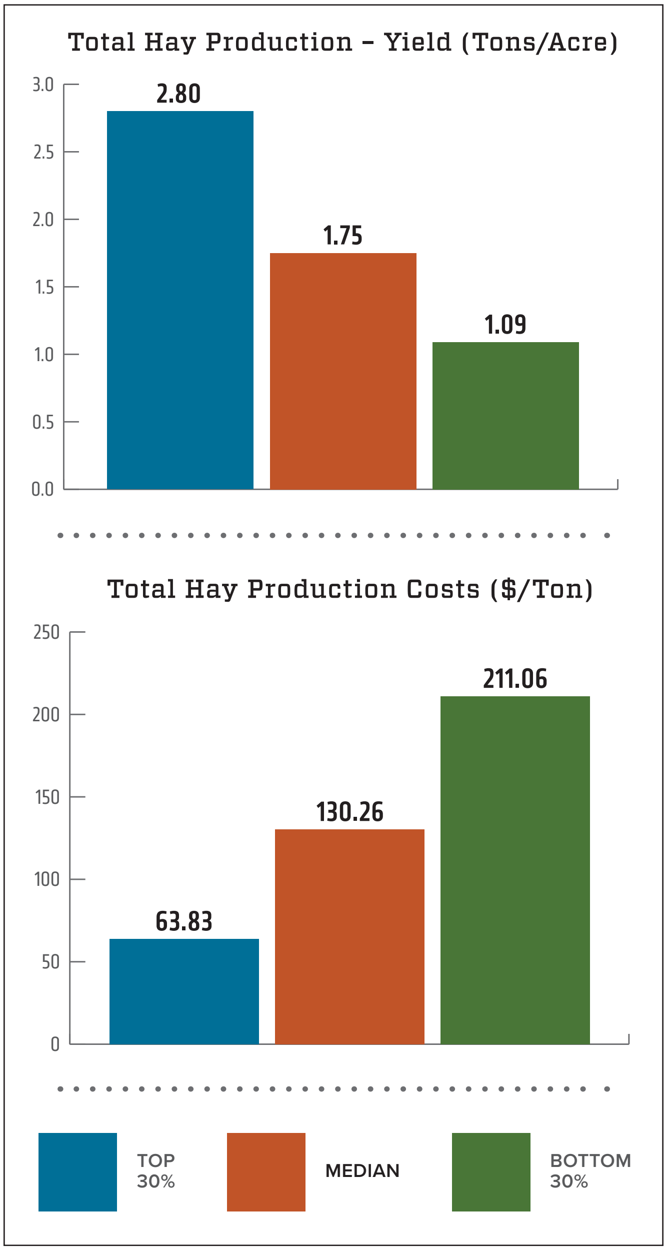
Table 4. Replacement Heifer Development ($/Female)

Metric	Top 30% (4 Herds)	Bottom 30% (4 Herds)	Median (13 Herds)
Cost to Wean Calf ($)	921.50	1376.00	1152.00
Year 2 Heifer Expense ($)	270.00	621.00	453.00
Total RRH Cost ($)	1200.00	1947.00	1585.00

Table 5. Hay Production Costs ($/Ton)

Metric	Top 30% (4 Herds)	Bottom 30% (4 Herds)	Median (13 Herds)
Depreciation	6.61	26.88	20.34
Labor	5.99	79.55	42.78
Rent or Lease	1.97	15.59	7.46
Repairs & Maintenance	1.54	30.76	9.09
Range Improvement	1.26	6.92	3.77
Utilities	0.76	20.55	4.74
Taxes & Insurance & Interest	0.62	14.35	0.98
Fuel-Oil	5.11	19.54	7.11
Freight & Trucking	0.93	25.17	6.47
Fertilizer & Lime	10.72	22.51	16.07
Supplies	1.42	6.78	2.70
Irrigation	6.68	18.56	8.73
Miscellaneous	0.80	7.42	2.20

(4) Cost Centers, continued



T.R.A.C. Ranch Management Concluding Comments

(1) Production benchmarks (i.e., pregnancy %, weaning %, pounds weaned/exposed female, etc.) remain a challenge for a few, but not most. Management impacts productivity but the greatest influencer is rainfall. Therefore, a resource limitation prevents producers who currently operate at or above median production benchmarks from cost effectively increasing productivity further. Additionally, as costs continue to rise, it is imperative for all ranch managers to carefully evaluate the marginal return of increasing productivity.

(2) Financial situation is the #1 barrier to success. Ranch net income and return on assets varies considerably between top and bottom 30% producer groups. Most operations that struggle financially have higher fixed costs. Cow-calf businesses are asset based and fixed costs (equipment, labor, and cows) on benchmark operations accounted for 50-70% of every dollar spent. Fixed costs structure on a ranch is difficult to change once assets have been acquired. The most effective way to lower fixed costs is to spread it out over more units or increase cow numbers. Maintaining or even increasing stocking rate (rainfall dependent) relative to fixed cost is an important concept to remain efficient and profitable.

(3) Total costs to own a cow will continue to rise due to inflation. Substantial variation in cow costs exists between top and bottom 30% producers in the benchmark group. The significant cow cost list (Table 3) can be used to identify which specific expenses might need improvement. The top four expenses are typically depreciation, labor, feed, and pasture. Costs per CWT of weaned calf (i.e., breakeven) could be the most important number to focus on and compare against. Although every ranch has different resources available, this metric incorporates expenses and productivity.

(4) The goal of most cow-calf operations is to wean the most profitable calf possible. To do so takes excellent management, which requires 1) a clear view of the financial position of the ranch and drivers of net income and return on assets; 2) making a multitude of small decisions to collectively keep costs low relative to the value of weaned calves; and 3) finding leverage in the production system that can have long-lasting systematic benefit to the operation. Good records and accounting systems are key to accurate financial information. Benchmarking and completing an in-depth ranch enterprise analysis can assist with decision making and continuous improvement that leads to performance management.

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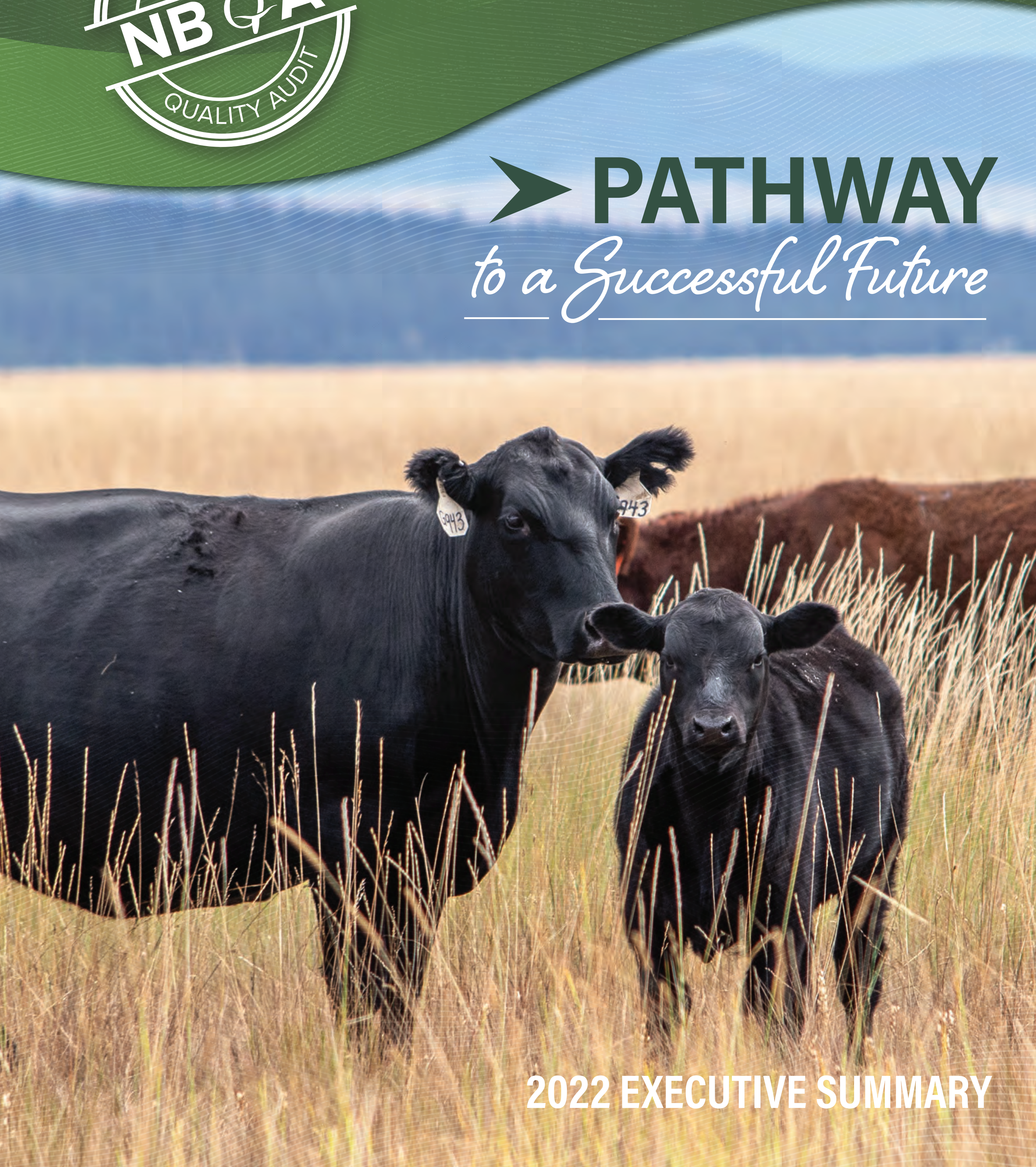
COLORADO STATE UNIVERSITY

NATIONAL BEEF 2022 NBQA QUALITY AUDIT

PATHWAY

to a Successful Future



2022 EXECUTIVE SUMMARY

Dear Fellow Beef Industry Members,

One thing that has become abundantly clear in the past few years is that the beef industry is both strong and resilient. This is due to the hard work that we all put into continual improvement in the processes of raising beef. The 2022 National Beef Quality Audit (NBQA) continued our 30-year legacy of measuring progress and evaluating opportunities to enhance consumer confidence in beef. The results of this audit again give us valuable science-based information to help guide our path forward.

The data from this audit clearly show that progress has been made in areas such as efficiency, the quality of beef produced, a lower incidence of carcass lesions, and a better focus on food safety. The data also show that there are areas for improvement, such as minimizing bruising, better mobility scores in fed cattle, and eliminating any foreign objects found in beef. The results also revealed the need for a continued focus on disease traceability and systems to improve animal health and well-being.

A key strategy, which is consistent with the Beef Industry Long Range Plan, is to encourage more Beef Quality Assurance (BQA) certifications and awareness. BQA, which is a voluntary education effort, is a producer-owned program that uses information like that collected in the 2022 NBQA to improve consumer confidence in and acceptance of beef. It has worked in the past and it will continue to be a catalyst for improvement in our industry.

Now, more than ever, BQA is being leveraged in our industry to show consumers that we are working to make continual strides in beef quality while focusing on how animals are raised and cared for. Let's get on board with these efforts to help assure that beef remains the choice protein for our consumers. This is the right time to make sure you have a current BQA certification.

The hard work that is put into the NBQA is much appreciated. This information is critical to helping us along the path of continual improvement. We have a bright future to look forward to!

Trey Patterson, PhD

Chair, Beef Quality Assurance Advisory Group

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INTRODUCTION

Since 1991, the Beef Checkoff-funded National Beef Quality Audit (NBQA) has delivered a set of guideposts and measurements for cattle producers and other stakeholders to help determine quality conformance of the U.S. beef supply.

GLOSSARY OF TERMS

Dark Cutter: A carcass subjected to undue stress before slaughter. The beef appears darker and less fresh, making it undesirable to consumers.

Dressing Percentage: Based on the relationship between the dressed carcass weight and the live animal weight after hide and internal organs have been removed. Dressing percentage = (weight of the carcass/ weight of live animal) x 100.

Fat Thickness: Refers to the thickness of subcutaneous fat; used to determine yield grade.

Hot Carcass Weight (HCW): The un-chilled weight of the carcass after slaughter and the removal of the head, hide, intestinal tract and internal organs. It is used to determine Yield Grade and dressing percentage.

KPH: The internal fat surrounding the heart, kidneys and in the pelvic area; used to determine Yield Grade.

LM/Ribeye Area: The longissimus muscle is exposed when a beef carcass is ribbed between the 12th and 13th rib; used to determine Yield Grade.

Marbling Score: Intermingling or dispersion of fat within the lean. Degree of marbling is the primary determination of the Quality Grade.

Quality Grade: Composite evaluation of factors that affect palatability of meat, such as tenderness, juiciness and flavor. Beef carcass quality grading is based on degree of marbling and maturity. Quality Grades include Prime, Choice, Select and Standard/Commercial.

Yield Grade: Estimates the amount of boneless, closely trimmed retail cuts from the high-value parts of the carcass (round, loin, rib, chuck). Rated numerically from 1 to 5, Yield Grade 1 denotes the highest yielding carcass and 5 the lowest.

Early NBQAs focused on the physical attributes of beef and beef by-products such as marbling, external fat, carcass weight and carcass blemishes. These cattle industry concerns have evolved to include food safety, sustainability, animal well-being and the growing disconnect between producers and consumers. As a result, over the past 30 years, NBQA researchers have made significant changes to the research, leading to an increasingly meaningful set of results.

With supply chain disruptions and a backlog of cattle due to the COVID-19 pandemic, the data from the 2022 National Beef Quality Audit was collected under extraordinary circumstances and stands apart from previous (and future) audits. Weather impacts, such as drought across most of the country, also impacted 2022 NBQA results. It is important to note that data was collected at a specific point in time and results provide a representation of what was occurring in the industry at that time.

The NBQA provides an understanding of what quality means to the various industry sectors, and the value of those quality attributes. This research helps the industry make modifications necessary to increase the value of its products. The efforts of the findings from the 2022 NBQA serve to improve quality, minimize economic loss, and aid in advancements in producer education for the U.S. beef industry.

The 2022 NBQA provides valuable information about the production of live cattle into beef carcasses and serves as a benchmark for the beef industry. This document provides a summary of results as well as industry implications for both fed cattle and market cows and bulls.

Table 1

INDUSTRY PRIORITIES, RANKED BY IMPORTANCE, 1991 VS. 2022

1991	2022
External Fat	Food Safety
Seam Fat	Cattle Genetics
Overall Palatability	Eating Satisfaction
Tenderness	Weight and Size
Overall Cutability	Visual Characteristics
Marbling	Lean, Fat and Bone

Beef farmers and ranchers are dedicated to producing beef in a way that prioritizes the planet, people, animals, and progress. Sustainability continues to be an area of focus for the beef supply chain with many end users establishing beef sustainability goals.

SUSTAINABILITY

WHAT IS SUSTAINABILITY?

A sustainable food system is comprised of three different, but intersecting, pillars: social responsibility, economic viability and environmental stewardship. True sustainability is a balance of these three aspects.

Investigating the importance of sustainability to the beef industry was incorporated into the 2022 NBQA to create an initial benchmark of where market segments are in terms of understanding and implementing sustainability initiatives.

The top two definitions of sustainability across market sectors interviewed were "environmentally friendly practices" and "using practices to keep current and future generations in business." The majority of companies interviewed also indicated that they had sustainability goals, primarily related to environmental goals, with more than half claiming goals encompassing the entire supply chain.

DISEASE TRACEABILITY

Interviewees noted that increased traceability could improve the beef industry's ability to combat animal diseases and potentially increase export opportunities. Concerns of animal disease and continued international trade success were top of mind for many individuals in the Government/Trade Organization (GTO) portion of the survey. Many GTO respondents were concerned with the lack of traceability in the U.S. beef supply chain, citing that if a disease like Foot and Mouth were to come to the U.S., it would be catastrophic.

TRANSPORTATION

Transportation, especially time and distance traveled, continues to be a focus area for the National Beef Quality Audit.

According to the Federal "Twenty-Eight Hour Law" enforced by USDA, cattle can only be on the trailer for 28 hours without feed, water or space to rest and must be provided five hours of rest time after 28 hours of confinement.

The average time traveled for fed cattle was 2.9 hours for 152.4 miles, and the maximum was 23 hours for 1,320 miles. The average area allotted per head was 12.5 square feet.

Table 2

TRANSPORTATION FACTORS FOR FED CATTLE

Transportation Characteristic	*n*	Mean	Min	Max
Time traveled (h)	203	2.9	0.10	23.0
Distance traveled (mi)	198	152.4	2.0	1,320.0
Number of cattle in load	215	36.0	8.0	47.0
Number of compartments used	216	3.7	2.0	6.0
Trailer dimensions (ft^2)	187	444.5	100.0	715.5
Area allotted per head (ft^2)	186	12.5	6.3	32.0

For all trailer types surveyed, approximately 10% of cattle trucks sampled within a day's production at each plant.

Table 3

TRANSPORTATION FACTORS FOR MARKET COWS AND BULLS

Transportation Characteristic	*n*	Mean	Min	Max
Time traveled (h)	114	6.3	0.10	24.0
Distance traveled (mi)	112	304.8	2.0	1,099.8
Number of cattle in load	123	27.2	1.0	49.0
Number of compartments used	119	4.0	1.0	8.0
Trailer dimensions (ft^2)	102	380.0	3.2	451.0
Area allotted per head (ft^2)	102	25.5	8.7	221.0

For all trailer types surveyed, approximately 10% of cattle trucks sampled within a day's production at each plant.

The average time traveled for market cows and bulls was 6.3 hours for 304.8 miles, and the maximum was 24 hours for 1,099.8 miles. The average area allotted per head was 25.5 square feet.

THE RESEARCH PROCESS

The 2022 National Beef Quality Audit was comprised of three major components including individual interviews, in-plant research and a strategy session.

INDIVIDUAL INTERVIEWS

Individual interviews with representatives of the different market sectors (packers, retailers, foodservice operators, further processors and government/trade organizations) were conducted between July 2021 and November 2022 to help determine how seven different quality categories (how and where cattle are raised, lean fat and bone, weight and size, visual characteristics, food safety, eating satisfaction, cattle genetics) are defined, and also establish the relative importance and "must-have" requirements and "willingness to pay" quantification for those qualities.

IN-PLANT RESEARCH

Fed Cattle

» To assess the current quality and consistency status of U.S. fed steers and heifers, researchers evaluated nearly 8,000 live cattle for attributes related to transportation, and approximately 23,000 carcasses on the harvest floor for characteristics that can affect quality and value of cattle, carcasses and by-products. This research was conducted at 22 U.S. beef processing facilities from September 2021 through November 2022.

Market Cows and Bulls

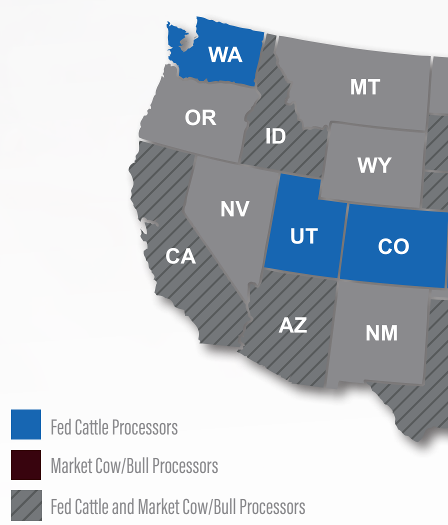
» Market cow and bull research was designed to benchmark shortfalls and gauge industry progress towards improvements in this segment of the industry. Conducted from September 2021 through May 2022, trailers, live animals, hide-on carcasses, hide-off hot carcasses, offal items and chilled carcasses were surveyed in 20 commercial packing facilities throughout the United States.

"Unsafe product means bad business; we want to make a good product that people love."

—Further Processor

Figure

PLANT SURVEYED
CATTLE AND MARKET C



STRATEGY SESSION

Individuals representing every sector of the beef industry met in Denver, Colorado, December 13-14, 2022, to review the results of the individual interviews and in-plant research and discuss implications for the U.S. beef industry. Outcomes from that meeting provide quality guidance to the industry for the next five years, providing "how" answers for developing a pathway to a successful future.

FED CATTLE OVERVIEW

According to audit interviews, since 2016 the industry has increased efficiency.

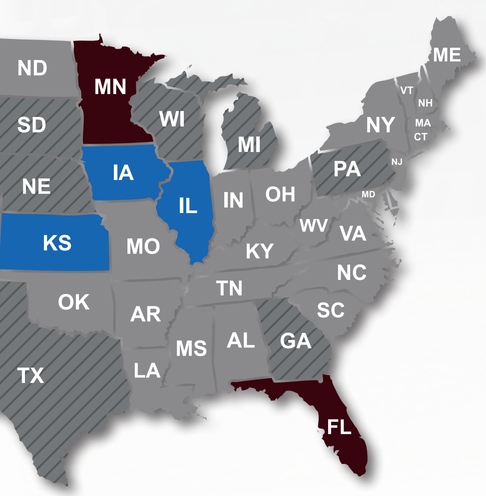
However, animal and carcass data show that larger cattle resulted in increased bruising frequency and hot carcass weight while mobility scores decreased. Ultimately, interviews suggest the industry is producing a high-quality product that consumers want more efficiently than five years ago.

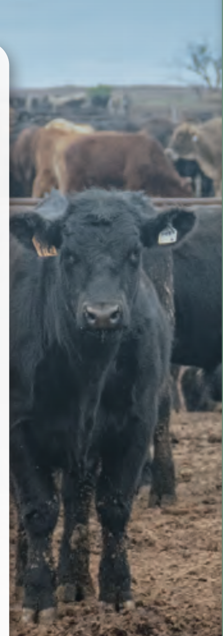
Transportation, mobility and harvest floor assessments evaluated various characteristics that determine quality and value, including the number of blemishes, condemnations and other attributes that may impact animal value. Transportation and mobility observations were recorded on roughly 10% of all trailers arriving at each beef harvest facility, and approximately 23,200 carcasses were evaluated on the harvest floor.

In-plant research captured data on quality and yield grade attributes and carcass defects and compared it with that of the previous surveys to assess progress in improving quality. It also provides a benchmark for future beef industry educational and research efforts.

1

LOCATIONS FOR FED
OWS AND BULLS & BULLS





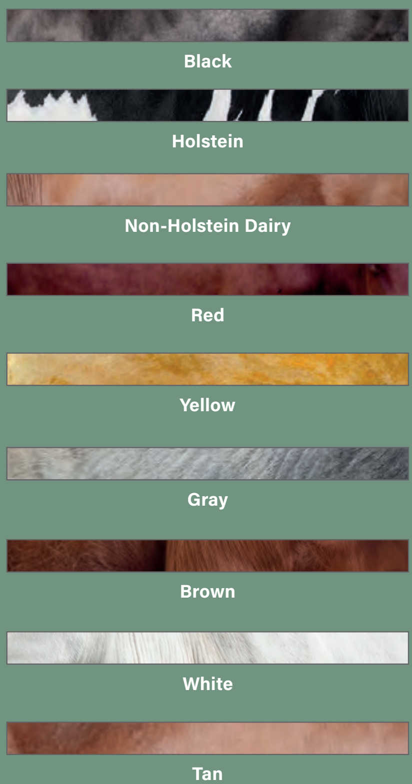
2022 NBQA KEY FINDINGS FOR FED CATTLE

- Market segments no longer consider food safety as a purchasing criterion, but an expectation.
- Participation in branded beef programs has increased since previous NBQAs, showing the industry is meeting consumer demands for differentiated beef products.
- When comparing 2016 and 2022 NBQAs, the largest improvement was overall increased efficiency across the beef supply chain.
- Genetics, namely hide color, are attributed to high quality beef that consumers are demanding, and the industry is providing.
- Market sectors indicated that their companies strive to increase their sustainability, and work with the entire beef supply chain to do so.
- The entire industry felt the effects of the COVID-19 pandemic, nonetheless, beef proved to be a choice of consumers, and the industry persevered to provide products.
- Due to pandemic pressures, more cattle over 30 months of age were harvested.
- The beef industry's image improved within fed cattle market sectors.
- Foreign objects continue to present a problem, but the industry is making strides to decrease incidence.
- Nearly 93% of transportation service providers interviewed were familiar with the Beef Quality Assurance Transportation (BQAT) program and 91% are BQAT certified.
- There was an increase in usage of electronic identification (EID).

Continued on following page:

2022 NBQA KEY FINDINGS FOR FED CATTLE *(CONTINUED)*

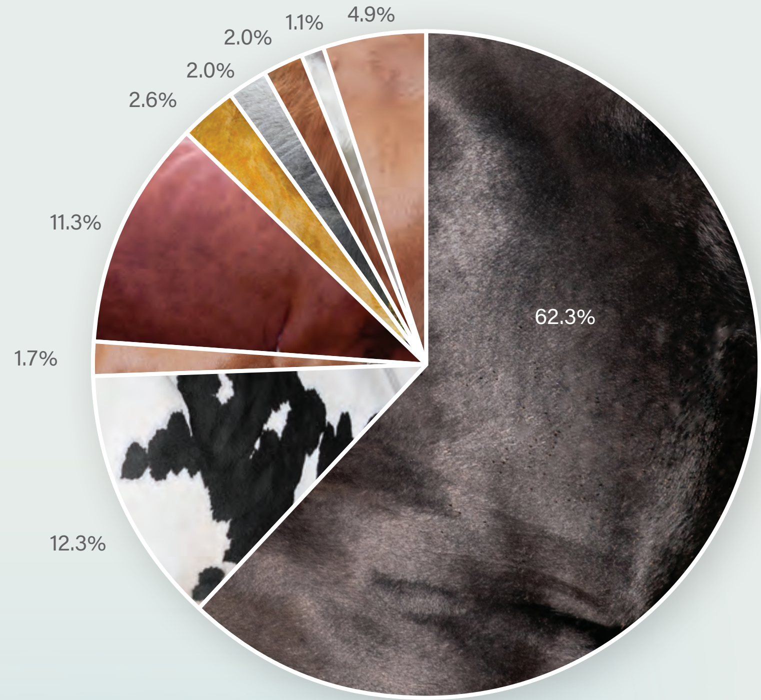
HIDE COLOR/BREED TYPE:



Black-hided cattle increased to 62% versus 58% in 2016 and 45% in 2000. Holstein hide color decreased to 12.3%; confirming the industry trend of beef sires being used on dairy cattle.

Figure 2

HIDE-ON CARCASSES WITH PROMINENT HIDE COLOR OR BREED TYPE (%)



While the industry is improving the quality of beef being produced, that quality is being accompanied by an increase in carcass weight and fat thickness, as well as large increases in percentages of Yield Grade 4 and 5 carcasses.

Figure 3

CARCASS WEIGHT DISTRIBUTION (%)

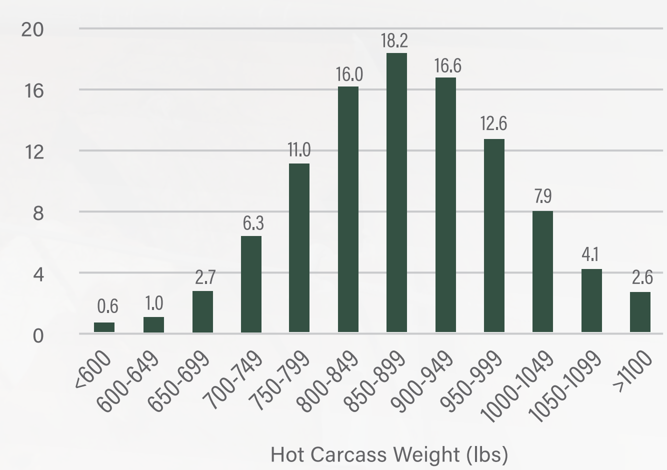


Figure 4

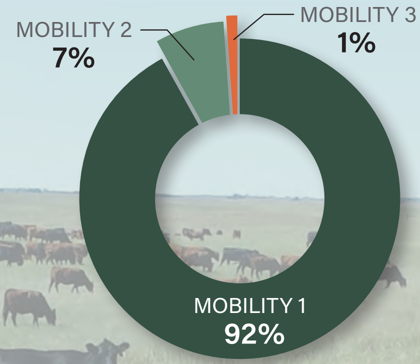
MOBILITY SCORE OF FED CATTLE ENTERING PACKING PLANTS

Mobility Score 1 - Normal, walks easily with no apparent lameness or change in gait.

Mobility Score 2 - Exhibits minor stiffness, shortness of stride or a slight limp but keeps up with normal cattle in the group.

Mobility Score 3 - Exhibits obvious stiffness, difficulty taking steps, an obvious limp or obvious discomfort and lags behind normal cattle walking as a group.

Mobility Score 4 - Extremely reluctant to move even when encouraged by a handler. Described as statue-like.

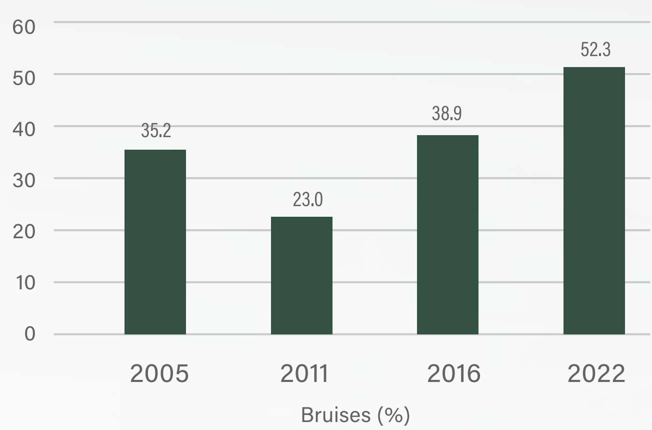


Nearly 92% of cattle received a mobility score of 1, with the animal walking easily and normally, with no apparent lameness.

This was a decrease from 97% in 2016 and is attributed to larger cattle and longer time spent during transport.

Figure 5

CARCASSES WITH BRUISES (%)

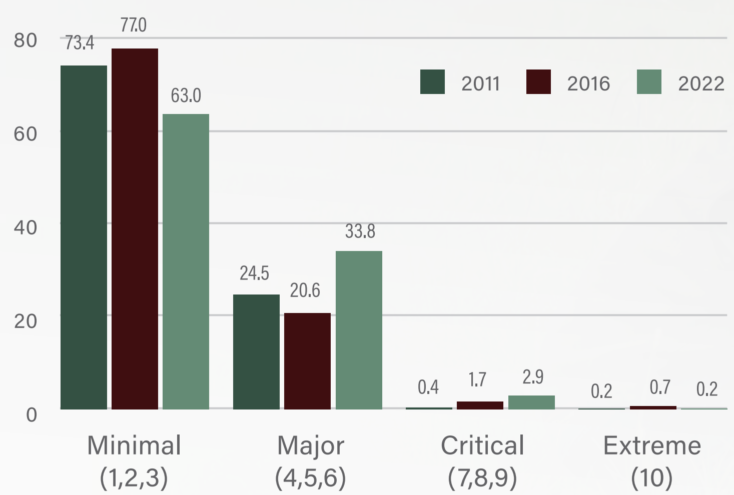


The 2022 NBQA displayed the highest frequency of carcass bruising (52.3%) recorded since audits began.

BRUISE SIZE KEY			
Minimal (<1lb-surface)	1 = a quarter size	2 = a silver dollar size	3 = a deck of cards size
Major (1-10 lbs)	4 = 1-3 lbs	5 = 4-7 lbs	6 = 8-10 lbs
Critical (>10 lbs)	7 = 11-20 lbs	8 = 21-30 lbs	9 = 31-40 lbs
Extreme	10 = Entire Primal		

Figure 6

BRUISE SEVERITY (% OF BRUISES OBSERVED)



POSITIVE CHANGES

"A lot of people out there [are] for the fake meat, but the pandemic showed people wanted beef."
—Packer

There were several notable results in the 2022 NBQA, including a reduction in horn presence and an increase in use of electronic identification.

HORN PRESENCE DECREASES

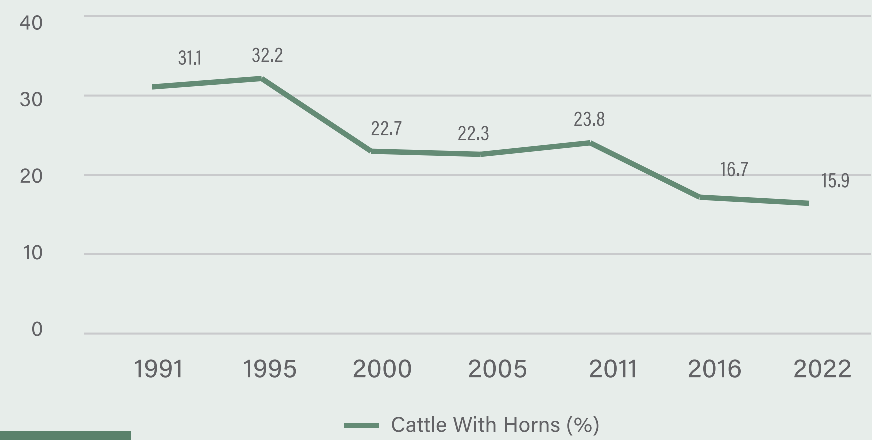
Cattle with horns can potentially cause injury or muscle bruising to other animals, damage to hides and can pose risks to humans.

Horn presence has steadily decreased since audits started in 1991. Cattle evaluated for the 2022 NBQA displayed the lowest percentage of horns thus far (15.9%).

As producers get further away from breeds that have horns, and management practices (dehorning) become more efficient, the number of cattle free of horns should continue to improve.

Figure 7

PRESENCE OF HORNS (%)



ELECTRONIC IDENTIFICATION

BQA promotes total quality management to producers, encouraging management steps that improve day-to-day activities through all aspects of the animal's life, including nutrition, herd health, well-being, biosecurity, and other aspects. These seemingly small changes, like improved animal identification and record keeping, can positively affect the entire operation and its end products. The increase in individual animal identification, including electronic identification, within the cattle industry contributes to several important aspects of the BQA program.

Figure 8

CATTLE BRANDS AND LOCATION (%)

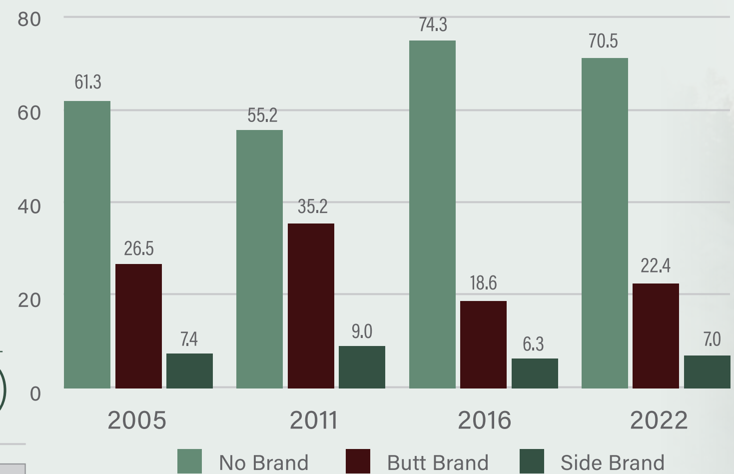
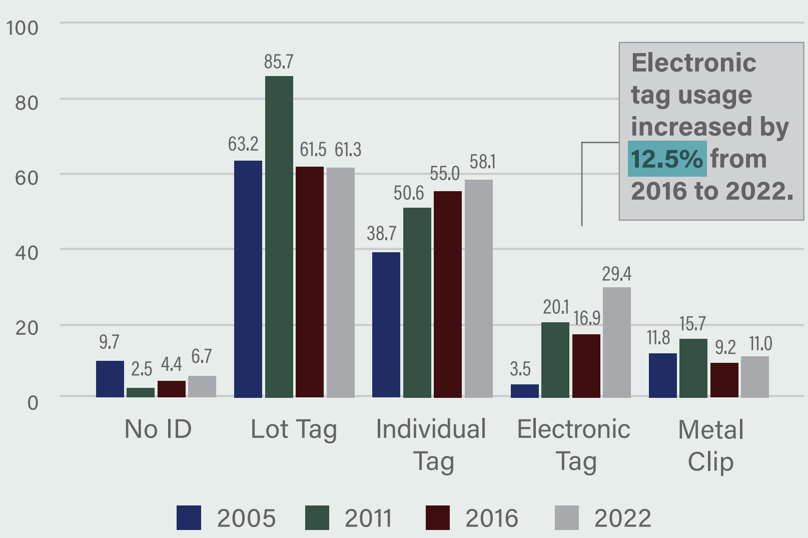


Figure 9

PRESENCE AND TYPES OF CATTLE IDENTIFICATION (%)



Improved record keeping at the animal level can better track genetic contribution and performance throughout the life of that calf, leading to better decision making at the cow-calf level and potential marketing benefits. As processing, treatment, and other herd health records expand at all levels of cattle production, this contributes to a continuous commitment to animal welfare, antimicrobial stewardship, and food safety, which are integral to the beef industry and its customers.

Table 4

USDA CARCASS GRADE TRAITS

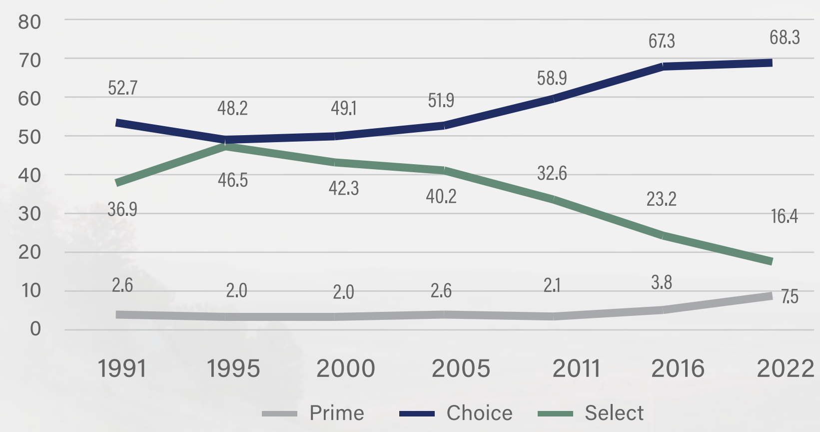
Trait	1991 n=7,375	1995 n=11,799	2000 n=9,396	2005 n=9,475	2011 n=9,802	2016 n=9,106	2022 n=9,746
USDA Yield Grade	3.2	2.8	3.0	2.9	2.9	3.1	3.3
USDA Quality Grade[1]	686	679	685	690	693	696	716
Adjusted Fat Thickness (in)	0.59	0.47	0.47	0.51	0.51	0.56	0.59
HCW (lbs)	760.6	747.8	768.8	793.4	824.5	860.5	886
Ribeye Area (in^2)	12.9	12.8	13.1	13.4	13.8	13.9	14.1
Marbling Score[2]	424	406	423	432	440	470	498

[1]600 = Select^{00}, 700=Choice^{00}, 800 = Prime^{00}

[2]400 = Small, 500 = Modest^{00}, 700 = Slightly Abundant^{00}, and 900 = Abundant^{00} (USDA, 2017)

Figure 10

CHANGES IN QUALITY GRADE OVER TIME (%)



There was an increase in the frequency of Prime and Choice quality grades, while Select decreased drastically.

"Positive is new customers have tried new beef items for the first time. Secondly, COVID has forced our hands to do things we should have done 10 years ago. Like move into retail and c-stores more aggressively."

—Foodservice

AREAS FOR FOCUSED IMPROVEMENT

While there is evidence of improvements in the fed cattle segment, there is also room for advancement, especially in the following areas:

EATING QUALITY AND CONSISTENCY

- There was an increase in the number of Yield Grade 4 and 5 cattle, and improved genetics could maintain the ideal of Yield Grade 3 or better, while maintaining marbling necessary to achieve desired quality grades.
- Utilize advancements in genetic selection technologies to breed for carcasses with increased eating satisfaction, uniformity, and desirable end-product specifications.

FOOD SAFETY AND ANIMAL HEALTH & WELL-BEING

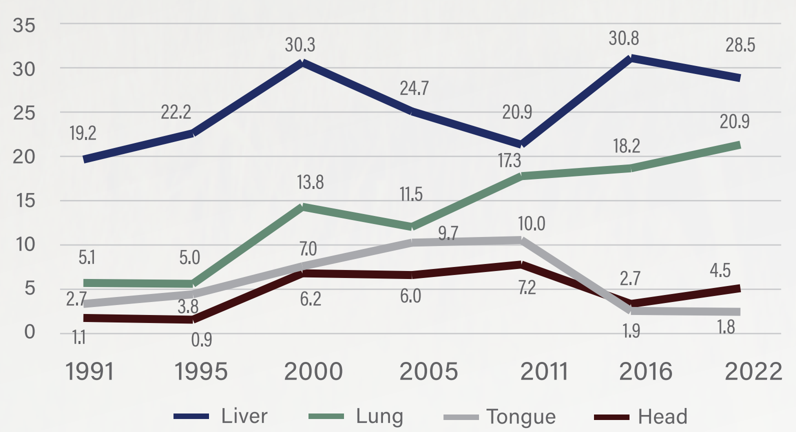
- Although the percentage of producers using technology for recordkeeping and data collection has increased, there is a concern among the beef supply chain that animal disease could impact the industry and current traceability efforts do not provide a robust enough system in the U.S. to combat this potential threat.
- Improve uptake of preventive health strategies and good cattle husbandry techniques to ensure future effectiveness of antimicrobials.
- Carcasses were discounted for liver abscesses, causing product loss and decreased profitability.
- Continue efforts to increase BQA certifications and awareness.
- Heat stress and other environmental factors caused increased bruising, dark cutters and heart issues as well as decreased mobility.
- Increased bruising frequency should be addressed through facility and trailer design as well cattle handler training.

"The better it looks the better it sells."

—Retailer

Figure 11

PERCENT OF OFFAL CONDEMNATIONS BY TYPE (%)



Lost opportunities are calculated for each audit to give perspective to the value of industry losses for not producing cattle that meet industry targets.

LOST OPPORTUNITES

During the strategy workshop, participants set a target consensus for Quality Grade, Yield Grade and carcass weight.

This target consensus, presented in Table 5, identifies projections for the industry to meet by the next audit. These goals, with the actual prevalence of each from the audit and summary prices for 2022, as reported by USDA, are used to calculate values in Table 6. The total lost opportunities for previous audits are adjusted to 2022 prices to give an accurate comparison between years.

Since 2016, improvements have been made in capturing more value of each carcass, however, larger cattle have led to lost opportunities in Yield Grade. While value is being lost in Yield Grade, the industry is meeting market signals for larger cattle.

The 2022 NBQA exceeded industry goals for Quality Grades set during the 2016 audit, which led to increasing the Prime and Choice targets for the next audit. The 2016 consensus Quality Grade target was 5% Prime, with the 2022 NBQA finding that 7.5% of carcasses were grading Prime. The new target consensus is 10% Prime by the next audit.

Since lost opportunities are calculated based on 2022 dollars, coupled with the 10% Prime goal, we are giving up more money in Quality Grade at this time when compared to 2016. However, the industry has made outstanding strides and sees the improvement in higher quality cattle as a success.

When comparing lost opportunities of hide/branding and offal to the 2016 NBQA, hide pricing impacted value and contamination during the fabrication process increased offal condemnations. These factors impacted 2022 lost opportunities in these categories, which the industry will continue to monitor and make improvements as necessary.

Table 5

TARGET CONSENSUS FOR QUALITY GRADE, YIELD GRADE AND CARCASS WEIGHT

QUALITY GRADE:

Grade	Target
Prime	10%
Upper 2/3 Choice	40%
Low Choice	35%
Select	15%
Standard/Ungraded	0%

YIELD GRADE:

Grade	Target
1	10%
2	35%
3	45%
4	10%
5	0%

CARCASS WEIGHT:

Range	Target
<700 lb.	0%
700-800 lb.	20%
801-1000 lb.	65%
1001-1100 lb.	15%
>1100 lb.	0%

Table 6

LOST OPPORTUNITIES IN QUALITY ISSUES (USING 2022 PRICES)

Trait	2022	2016	2011	2005	2000	1995	1991
Quality Grade	-$27.17	-$17.26	-$36.64	-$36.27	-$40.80	-$44.47	-$45.77
Yield Grade	-$18.21	-$13.38	-$5.80	-$15.33	-$15.13	-$9.99	-$21.76
Carcass Weight	-$2.97	-$6.94	-$6.12	-$4.07	-$3.76	-$7.24	-$5.59
Hide/Branding	-$4.16	-$3.05	-$5.53	-$4.85	-$6.32	-$6.58	-$5.71
Offal	-$6.33	-$6.52	-$8.66	-$8.77	-$8.45	-$4.87	-$3.17
TOTAL:	**-$58.84**	**-$47.15**	**-$62.75**	**-$69.29**	**-$74.46**	**-$73.15**	**-$82.00**

MARKET COWS AND BULLS OVERVIEW

Cows and bulls are the foundation of cattle herds. They are also sources of beef that are significant and worth understanding.

The beef industry conducted its first Market Cow and Bull Audit in 1994 to complement the National Beef Quality Audit for Fed Cattle. That initial Market Cow and Bull Audit found that carcasses had excessive bruising and were often condemned, too many market cows and bulls were disabled prior to harvest, cows and bulls frequently had inadequate muscling, and animals were often not marketed in a timely manner. Since then, the industry has made significant improvements in herd management techniques; animal well-being and handling; injection-site location; and mobility. The 2022 research assessed progress in managing these issues and suggested improvements for increasing the value and marketability of cows and bulls.

2022 NBQA KEY FINDINGS FOR MARKET COWS AND BULLS

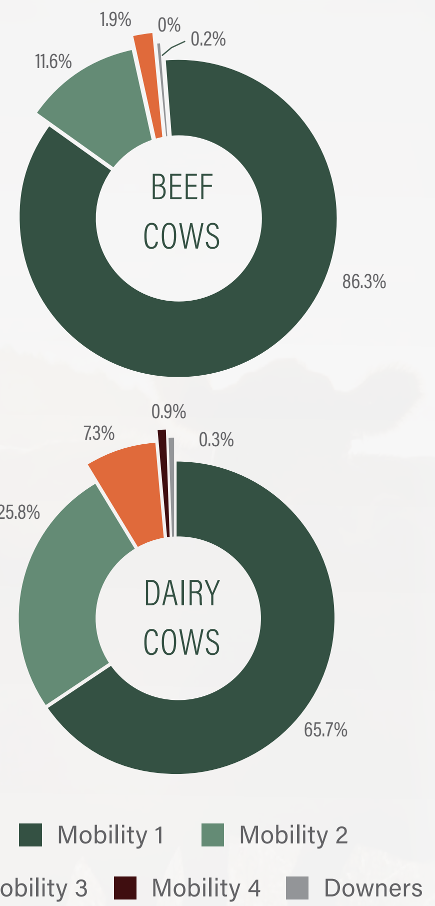
- Food safety is non-negotiable and an expectation for those who purchase beef.
- Market cows and bulls have the potential to yield valuable retail cuts, beyond ground beef.
  - Reducing defects allows the market cow and bull sector to capture additional value.
- Appropriate management of market cows and bulls can increase muscle condition before harvest.
- Animals should be culled before physical defects are severe, and there should be more timeliness in the marketing of animals at both ranch and dairy.
- Although the percentage of producers using technology for recordkeeping and data collection has increased, there is a concern among the beef supply chain that animal disease could impact the industry and current traceability efforts do not provide a robust enough system in the U.S. to combat this potential threat.
- Producer education on the use of projectiles when handling cattle could help to reduce food safety concerns due to foreign objects and further improve animal well-being.
- Animal well-being has improved through a focus on better animal handling at all levels.
- Education in the Dairy FARM and Beef Quality Assurance programs can propel the momentum of the market cow and bull industry.
- The Beef Quality Assurance Transportation program can improve communication about animals that are not fit for transport.
- Full udders are considered a defect and a contaminant if milk gets onto the carcass at the processing facility causing food safety issues, and they impact the animal's well-being.

POSITIVE CHANGES

Results from the 2022 National Beef Quality Audit for Market Cows and Bulls show that there have been improvements made in the quality of market cows and bulls since the first non-fed beef audit in 1994. The following areas have seen improvements since the last audit:

Figure 12

MOBILITY SCORE OF MARKET COWS (BEEF AND DAIRY) ENTERING PACKING PLANTS



MOBILITY AND DEFECTS

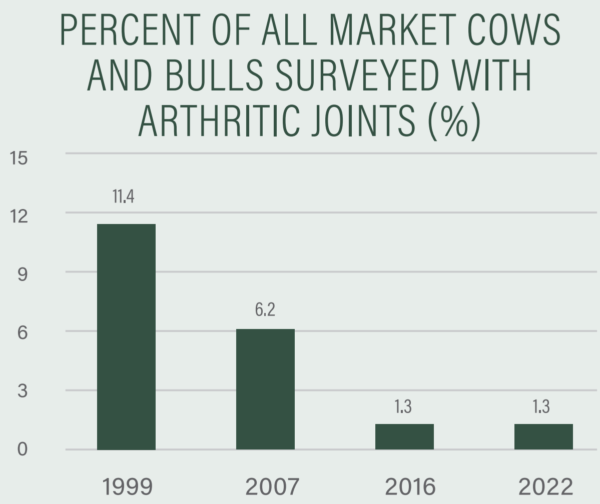
Of market cows and bulls entering the packing facility, 77% were sound with a mobility score of 1. There was a higher incidence of cattle with a mobility score of 2, compared to downers and scores of 3 and 4, displayed in the current audit. Approximately 45.1% of all cattle surveyed had no visible defects and 37.9% of cattle with defects only displayed a single defect. This demonstrates that producers are making an effort to market cows and bulls before mobility issues and health-related defects progress further, however, there is still room for improvement.

A very large majority of cattle and carcasses surveyed had no instances of knots (98.2%) or injection site lesions (97.1%) visible on the exterior carcass surface, indicating great strides in producer education on the proper administration of injections.

There was a high frequency of native hides (88.3%), and of branded hides, the majority of brands were located in the rump or hip area to preserve hide quality as recommended by the Beef Quality Assurance National Manual.

Arthritic joints can impact animal welfare and can cause significant contamination in the plant. Similar to injection site lesions, dramatic improvement was made related to arthritic joints. Of all market cows and bulls surveyed, only 1.3% demonstrated arthritic joints, a decrease from 11.4% in 1999.

Figure 13



IMAGE

The market cow and bull sector is viewed more favorably by the beef supply chain than in the past because it provides an alternative product and a secondary value to animals once their original purpose is no longer suitable. When it comes to product fabrication, market cows and bulls are typically associated with ground beef production. Over time, the industry has realized that some market cows and bulls have the potential to yield valuable primals to be fabricated and sold as retail cuts and to the restaurant trade.

TRANSPORTATION

Since 2016, there has been an increase in the amount of trailer loads that allotted sufficient space as outlined in the Animal Handling Guidelines. In addition, there were no cattle in the current survey that were hauled longer than 24 hours. Of truck drivers surveyed, 63.6% reported to be BQA certified. This was a new area of research for the 2022 NBQA, added to gather data since the launch of BQA Transportation certification options in 2017. Increased trucker training provides confidence that animals coming to harvest are being handled properly, thus reducing the risks of bruising, downers, stress and negative public perception.

AREAS FOR FOCUSED IMPROVEMENT

BODY CONDITION SCORE

The current audit displayed the highest percentage of cattle that were too light muscled across all audits for the past 27 years, and there was an increase in the percentage of cattle categorized as too thin, according to body condition scores.

Producers should consider market cows and bulls and their eligibility for feeding prior to harvest to increase their muscling and finish, thus returning more revenue.

DEFECTS

Full udders are considered a defect at the plant, and of all the defects in cows identified in this year's audit, 47.5% were due to full udders. When full udders are removed, milk can potentially empty in the plant and contaminate product causing food safety issues. Full udders can also cause mobility issues, impacting the animal's well-being. In addition, 25.4% of the cows surveyed carried a fetus. Cows should be checked for pregnancy prior to harvest or culled prior to breeding.

Instances of liver condemnations remained stable since the last audit, with 45% condemned in 2022 compared to 44.6% in 2016. Abscesses continue to be the leading cause of liver condemnations. In addition to condemnations, liver abscesses that have progressed far enough have the potential to adhere to the body wall of the animal, resulting in trim loss. If producers elect to feed cattle high concentrate diets prior to harvest for improvements in fat deposition and color as well as muscle, caution should be taken to ensure liver abscesses are not being caused as a result.

FOREIGN OBJECTS

All plants reported finding foreign objects during the harvest and fabrication of market cows and bulls, and a majority of surveyed plants (53.3%) reported instances of customers finding foreign objects in their products. While plants have installed metal detectors and x-rays to help prevent adulterated product from reaching the consumer, foreign objects remain a problem throughout the beef supply chain.

Table 7

PERCENTAGE OF PLANTS THAT REPORTED FOREIGN OBJECTS FOUND IN BEEF FROM MARKET COWS AND BULLS

Objects Found	*Percentage (%)*
Buckshot/Birdshot	**100.0**
Bullets	18.8
Needles	18.8
Wire	18.8
Darts	18.8
Other	12.5

50% of plants reported customer complaints.

Detection Systems: X-Ray: 87.5%
Metal Detectors 75.0%

BRUISING

Today, 68.6% of all trailers with mixed-gender loads surveyed did not separate cows from bulls, leading to an increased risk of bruising and injury. Bruise damage is still a leading cause of trimming and finding ways to eliminate bruising should be a priority for the industry. Fewer instances of bruising allow for less trim loss and therefore increase the value of market cow and bull carcasses.

A continued emphasis on producer, transporter, and packer education through extension, the BQA program, and other avenues for research should be focused on the appropriate management, handling, and marketing of market cows and bulls to increase their overall value and enhance animal well-being.

> *"Top priority that animals are treated with respect and dignity."*
>
> ***—Packer***

Bruise damage is still a leading cause of trimming and finding ways to eliminate bruising should be a priority for the industry.

Fewer instances of bruising allow for less trim loss and therefore increase the value of market cow and bull carcasses.

Figure 14

PRESENCE AND SEVERITY OF BRUISING IN MARKET COWS (%)

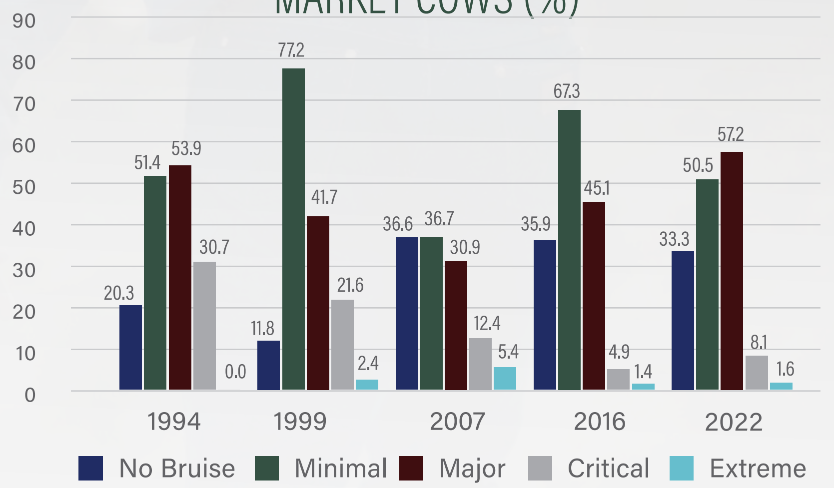
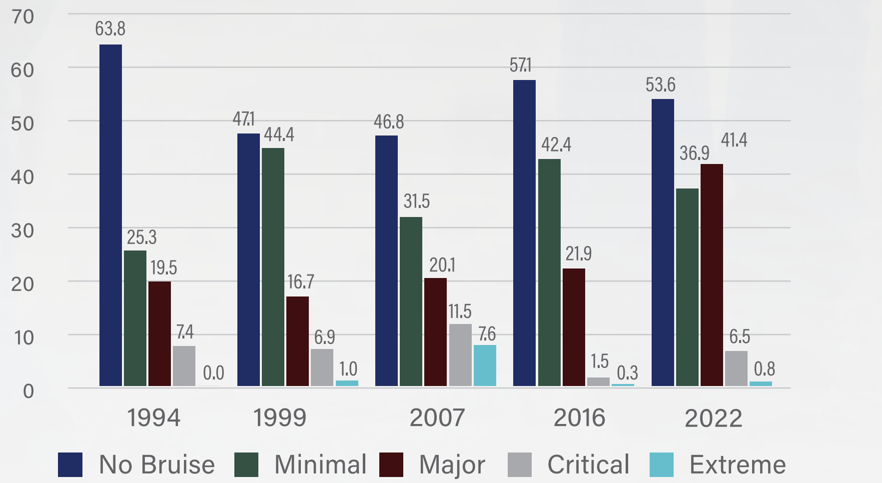


Figure 15

PRESENCE AND SEVERITY OF BRUISING IN MARKET BULLS (%)



BRUISE SIZE KEY	
Minimal	< 1 lb surface trim loss
Major	1-10 lbs trim loss
Critical	>10 lbs trim loss
Extreme	Entire Primal

LOST OPPORTUNITIES

Declines in market cow and bull quality such as live animal defects, carcass defects and the market or sale of animals unfit for consumption leave dollars on the table for cattle producers. In order to capture these lost opportunities for economic return, producers should abide by the "Three M's": manage cattle to minimize defects, monitor the health and condition of their cattle, and market their cattle in a timely manner.

Depending on market status and cattle condition, market cows and bulls can be sold for ample market prices. The market effects of the COVID-19 pandemic are a prime example of this. By monitoring the health and condition of their animals, ensuring proper animal husbandry practices, and monitoring the market, cattle producers can capture profit off their market cows and bulls.

Table 8

MEAN VALUES FOR YIELD GRADE FACTORS IN ALL SURVEYED MARKET COWS AND BULLS

Factor	2007[1]	2016[2]	2021
Adjusted Fat Thickness (in)	0.24	0.24	0.16
HCW (lb)	671.3	686.7	703.1
LM Area (in^2)	10.0	10.1	10.0
KPH (%)	0.6	1.7	1.8
USDA Yield Grade	2.6	2.9	2.6

[1]Nicholson (2008) [2]Harris (2017)

CONCLUSION

The beef industry is focused on continuous improvement, especially in the areas of safeguarding the food supply and cattle care and handling.

An important strategy for improved industry health and success was evident in the research: utilizing BQA and its principles to improve cattle well-being, increase consumer confidence, and enhance industry commitment could encourage greater beef demand, and improve industry harmonization. Carrying this BQA message throughout the industry all the way to consumers benefits every audience.

The NBQA remains an important measure for the U.S. beef industry as it strives to improve quality and consumer demand. Results from the 2022 NBQA can be utilized by all segments of beef production to improve upon current management practices and implement innovative techniques ultimately enhancing consistency and quality of cattle and beef products across the U.S. beef supply chain.

ACKNOWLEDGMENTS

The National Beef Quality Audit is funded by the Beef Checkoff.

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Additional information about the 2022 NBQA and previous audits can be found on the Beef Quality Assurance website at *www.bqa.org*.

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