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National Beef Quality Audit—2022: Transportation, mobility, live cattle, and hide assessments to determine producer-related defects that affect animal welfare and the value of market cows and bulls at processing facilities

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Abstract

The National Beef Quality Audit (NBQA)-2022 serves as a benchmark of the current market cow and bull sectors of the U.S. beef industry and allows comparison to previous audits as a method of monitoring industry progress. From September 2021 through May 2022, livestock trailers (n = 125), live animals (n = 5,430), and post-slaughter hide-on animals (n = 6,674) were surveyed at 20 commercial beef processing facilities across the U.S. Cattle were transported in a variety of trailer types for an average distance of 490.6 km and a mean transport time of 6.3 h. During transit, cattle averaged 2.3 m^2 of trailer space per animal indicating sufficient space was provided according to industry guidelines. Of all trailers surveyed, 55.3% transported cattle from an auction barn to a processing facility. When surveyed, 63.6% of all truck drivers reported to be Beef Quality Assurance certified. The majority (77.0%) of cattle were sound when evaluated for mobility. Mean body condition scores (9-point scale) for beef cows and bulls were 3.8 and 4.4, respectively, whereas mean body condition scores (5-point scale) for dairy cows and bulls were 2.3 and 2.6, respectively. Of the cattle surveyed, 45.1% had no visible live animal defects, and 37.9% had only a single defect. Of defects present in cows, 64.6% were attributed to an udder problem. Full udders were observed in 47.5% of all cows. Nearly all cattle were free of visible abscesses and knots (97.9% and 98.2%, respectively). No horns were observed in 89.4% of all cattle surveyed. Beef cattle were predominantly black-hided (68.9% and 67.4% of cows and bulls, respectively). Holstein was the predominant dairy animal observed and accounted for 85.7% of the cows and 98.0% of the bulls. Only 3.1% of all animals had no form of identification. Findings from the NBQA-2022 show improvements within the industry and identify areas that require continued education and research to improve market cow and bull welfare and beef quality.

Lay Summary

This aspect of the National Beef Quality Audit—2022 focused on transportation, mobility, and live animal conditions related to animal welfare and value of beef and dairy market cows and bulls. Cattle were transported, on average, 490.6 km, for 6.3 h, with 2.3 m^2 space per animal in

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a variety of trailer types. Upon unloading, most cattle walked normally (77.0%) or with minor stiffness or shortness of stride (18.0%) with only 5.0% having difficulties taking steps. Body Condition Scores indicated less condition (lower fatness) than the previous audit. The most common defects for both dairy and beef cows were udder problems, whereas, for bulls, it was swollen joints. Beef cattle were predominately black-hided (68.9% and 67.4% of cows and bulls, respectively), whereas dairy cattle were predominately Holstein (85.7% of the cows and 98.0% of the bulls). Most of the cattle (89.4%) had no horns. Only 3.1% of all cattle had no form of animal identification with most having one or more forms of identification. Improvements were observed in transportation, animal identification, and limited percentages of management-related defects. Timelier marketing of market cows and bulls assuring adequate muscling and finish may benefit both animal welfare and value.

Key words: animal welfare, audit, bull, cow, hide, transportation

Introduction

The first National Beef Quality Audit (NBQA) was conducted in 1991 to assess beef cattle for defects and examine the quality of beef being produced throughout the industry (Lorenzen et al., 1993). The NBQA has been repeated approximately every 5 yr to benchmark progress, and identify problems, changes, and areas that require further examination within the beef industry. Over the past 30 yr, the NBQA has been conducted six times. The original quality audit (Lorenzen et al., 1993) benchmarked the fed steer and heifer industry. The National Cattlemen's Beef Association (NCBA) launched a similar effort to benchmark the market cow and bull sector of the beef industry in 1994 (National Cattlemen's Beef Association, 1994) with subsequent audits in 1999 (Roeber et al., 2001) and 2007 (Nicholson et al., 2013). Initially, the market cow and bull audits were conducted separately from the fed audit; however, the 2016 audit was conducted in conjunction with the fed steer and heifer audit, making it the largest and most comprehensive survey of its kind (Harris et al., 2017, 2018). This combined effort increased the synergy of market evaluation across both sectors of the beef industry.

Market cow and bull audits will help beef and dairy cattle producers identify areas to improve beef quality, enhance consumer perception, and discover areas of advancement in research. The NBQA-2022 provides an update on cattle quality, industry improvements, and shortfalls with an additional focus on other areas of concern within the beef industry such as food safety and animal welfare. To accomplish this, efforts focused on key factors such as cattle transportation conditions, fitness for transport, live animal health, and presence of defects that could have resulted from management practices. The objectives of this portion of the NBQA-2022 were to quantify the status of the market cow and bull sector of the beef industry, compare the findings to previous studies, and establish new benchmarks that will serve as a basis for future research. The efforts of the findings from this study serve to improve beef quality, minimize economic losses, and aid in advancements in producer education for the U.S. beef industry.

Materials and Methods

Animal care and use committee approval was not required for this study. Live cattle transportation, mobility assessments, and live cattle evaluation data were collected strictly by observation. Data were collected on animals pre- or post-slaughter.

General Overview

Before data collection, a coordination meeting was held to discuss details of data collection, areas of assessment, and methods of data recording to ensure clarity and consistency among all 14 collaborating universities. Standardized data books were created to incorporate collection points from previous NBQAs and include additional areas of evaluation based on current industry concerns. Data collection were completed in 20 federally inspected beef processing facilities representing 12 states (Table 1) in 2021 and 2022. One-third of cattle and carcasses at each surveyed processing facility were audited over the course of one full production day. If the facility operated two shifts per day, data were recorded on cattle during both shifts. If possible, all cattle and carcasses were classified by breed type (beef or dairy) and sex (cow or bull).

Transportation and Mobility

Data were collected on trailer loads from approximately 10 percent ($n = 125$) that arrived at the facilities (minimum of 5/d). Trailers were evaluated for type, dimensions, and use of compartments and center gates. Drivers were interviewed to determine cattle origin (city and state), date and time loaded, distance and time traveled, location of origin of the cattle (ranch, dairy, feedlot, buying station, auction market, or other), number of cattle in the load, and if cattle were unloaded during transit. When drivers were unsure of the distance traveled, a map was used to estimate the distance from origin to processing facility. If the load included both cows and bulls, auditors noted whether animals were segregated based on sex. In addition, drivers were asked about their familiarity with the Beef Quality Assurance (BQA) Certification

Table 1. National Beef Quality Audit—2022: Name and location of beef processors surveyed for market cows and bulls

Company	Location
ABF Packing	Stephenville, TX
American Beef Packers	Chino, CA
American Foods Group—Cimpl Meats	Yankton, SD
American Foods Group—Gibbon Packing	Gibbon, NE
American Foods Group—Green Bay Dressed Beef	Green Bay, WI
American Foods Group—Long Prairie Packing	Long Prairie, MN
Cargill Beef Packers	Fresno, CA
Cargill Taylor Beef	Wyalusing, PA
Caviness Beef Packers	Hereford, TX
Central Valley Meat Company	Hanford, CA
CS Beef Packers	Kuna, ID
Florida Beef Inc.	Center Hill, FL
FPL Foods LLC	Augusta, GA
JBS Foods, Green Bay	Green Bay, WI
JBS Foods, Omaha	Omaha, NE
JBS Foods, Plainwell	Plainwell, MI
JBS Foods, Souderton	Souderton, PA
JBS Foods, Tolleson	Tolleson, AZ
Lone Star Beef Processors	San Angelo, TX
Nicholas Meats	Loganton, PA

Program and, if familiar, whether they had completed BQA certification.

All cattle (n = 3,124) unloaded from surveyed trailers were categorized based on type (beef or dairy) and sex. As cattle were moved to holding pens mobility score was evaluated using the North American Meat Institute's 4-point scale (North American Meat Institute Animal Welfare Committee, 2015). Mobility scores were: (1) walked easily and normal with no apparent lameness; (2) exhibited minor stiffness, shortness of stride, a slight limp, but were still able to keep up with normal cattle; (3) exhibited obvious stiffness, discomfort, and limp, and had a difficulty taking steps leading to them lagging behind normal cattle; and (4) extremely reluctant to move even when encouraged. Animals that were non-ambulatory on arrival or during unloading were classified as "downers." Following the conclusion of each shift, researchers spoke with yard supervisors and/or United States Department of Agriculture (USDA) inspectors to obtain and record the reasons cattle were classified as USDA Condemned.

Live Animal Evaluation

Cattle (n = 5,430) were surveyed by individuals of the research team for overall conditions and defects that could influence a producer's decision to cull. Each animal evaluated was assigned a muscle score (5-point scale: 1 = light muscled, 5 = heavy muscled) and body condition score (Lalman et al., 2017; Farmers Assuring Responsible Management, 2022) based on breed type (beef animal: 9-point scale; 1 = emaciated, 9 = obese; dairy animal: 5-pt scale; 1.0 = overly thin, and 5.0 = over-conditioned). Severity of bovine ocular neoplasia, or cancer eye, was recorded (5-point scale: 0 = normal eye, 5 = prolapsed eyeball or necrotic condition associated with the eye; Nicholson et al., 2013). Animal defect descriptions outlined in Harris et al. (2017) including the presence and location of abscesses (facial, knee/hock, or hooks/pins), reproductive or production problems (prolapse, bottle teats, mastitis, failed suspensory ligament, multiple udder problems, full bag, calf in pen, retained placenta, and broken penis), other animal health issues (broken tail, swollen joints, foot abnormalities, and lumpy jaw), or any unanticipated defect that researchers identified were noted.

Hide and Horn Characteristics, Animal Identification

Post-slaughter, hide-on animals (n = 6,674) were observed for hide color, knots, horns, and identification type. Hides were evaluated for primary color (color representing 51% or more of the hide) and pattern (none, baldy, roan, brindle, spots, or "other"). Holstein, Jersey, and dairy-cross cattle also were identified by color and pattern. Presence and location (neck, shoulder, top butt, and round) of knots were recorded. Presence and estimated length of horns also were recorded. Forms of animal identification—ankle tag, barcode, electronic identification tag (low frequency or high frequency), electronic identification tag with accelerometer (Merck Animal Health, 2024), individual ear tag, metal clip, lot tag, wattle, back tags, and "other"—were documented.

Statistical Analysis

Data were analyzed using JMP Pro, Version 16.0.0 Software (SAS Institute Inc., Cary, NC, 1989 to 2007) and Microsoft Excel 2018 (Microsoft Corporation, Redmond, VA). Frequencies, distributions, means, standard deviations, minimums, and maximums were calculated using the Distribution function of JMP.

Results and Discussion

Transportation

Transportation conditions for all trailer loads surveyed are presented in Table 2. Across all trailers surveyed, cattle traveled a mean distance of 490.6 km for a mean duration of 6.3 h. It is important to note that the maximum amount of time traveled for all trailer loads did not exceed 24 h. Only 2.0% of all trailer loads traveled for more than 20 h, and 4.1% of all drivers reported that the cattle were unloaded in route (not in tabular form). Traveling for extended duration poses a welfare concern if transporters do not stop to rest and water cattle. The BQA program does not recommend withholding feed and water for longer than 24 h, therefore, transporters should ensure adequate stops when hauling cattle for more than 24 h (Beef Quality Assurance, 2019).

It is important, especially for cattle traveling longer distances for longer periods of time, to have adequate room to minimize stress and crowding during transit. Load sizes ranged from 1 to 49 animals with an average of 28 cattle per load. It is crucial that animals are provided with the minimum space required as load size increases. Polled cattle should be provided between 1.1 and 1.7 m^2/animal and horned cattle weighing between 455 kg and 636 kg should be provided between 1.2 and 1.8 m^2/animal, as outlined in the Recommended Animal Handling Guidelines (Grandin and North American Meat Institute Animal Welfare Committee, 2021). Mean area allotted per animal (2.3 m^2) for all trailer loads complied with these standards. Cows and bulls arrived at processing facilities in trailers with sufficient space, thus

Table 2. National Beef Quality Audit—2022: Descriptive statistics for time and distance traveled, number of cattle in the load, trailer dimensions, and the subsequent area allotted per animal for all loads surveyed[1]

Transportation characteristics	Number of trailers	Mean	SD	Min	Max
Time traveled, h	114	6.3	5.47	0.1	24
Distance traveled, km	112	490.6	408.82	3.2	1,769.9
Number of cattle in load	123	28	12.86	1	49
Number of compartments used	119	4.0	1.73	1	8
Trailer area, m^2	102	35.3	10.5	5.6	41.9
Area allotted per animal, m^2	102	2.3	3.5	0.8	20.5

[1]Ten percent of cattle trucks were sampled within a day's production at each beef processing facility during the audit.

minimizing animal welfare concerns and chances of injury or animals becoming downers during transit.

Pot-belly trailers were the dominant type (73.5%) of trailers used to transport market cows and bulls to harvest facilities, followed by gooseneck trailers (21.2%). The term "pot-belly," refers to a trailer designed with a lower compartment that is below the tractor frame and is used to increase stabilization and space utilization. Of the pot-belly trailers surveyed (n = 83), 56.5% used the center gate to separate cattle. This is a slight decrease from the 63.5% observed in 2016 (Harris et al., 2017). Separating cattle into compartments should be encouraged because gates buffer the effect of mechanical forces on animals when a vehicle brakes abruptly or travels in rough conditions such as hilly, windy, or rough roads (Lapworth, 2008). In addition to the center gate, some pot-belly trailers have a "doghouse" or "jailhouse" to further separate cattle within loads and optimize space utilization in the trailer. The doghouse is located in the back upper area of the trailer and is typically reserved for smaller-framed cattle that weigh less than 317.5 kg (Beef Quality Assurance, 2006). Of the pot-belly trailers in this survey, 36.1% (data not shown in tabular form) used this compartment, which is a numerical increase compared to the 10.8% reported by Harris et al. (2017). Nicholson et al. (2013) reported several transporters loaded bulls in the doghouse to keep cows and bulls separate. While separation is recommended when hauling mixed-gender loads, these smaller compartments should not be used for large-framed, heavier-weight animals. Nicholson et al. (2013) stated that gender mixing during transportation can lead to increased bruising, hide damage, and lameness. Of the total mixed-gender loads surveyed (n = 51), 68.6% did not separate cows from bulls. This is a slight numerical increase from 64.4% observed in Harris et al. (2017). Transporters should make efforts to separate animals by gender when using appropriate-sized trailer compartments.

In data not reported in tabular form, the frequency of the origin of the cattle for all trailer loads surveyed were auction market, 55.3%; dairy, 18.7%; ranch, 11.4%; feedlot, 7.3%; and buying station, 7.3%. Cattle transported in pot bellies traveled further distances for longer periods of time compared to cattle transported in goosenecks. This could be due to the origin of the cattle transported in these different trailer types. Most of the cattle transported in pot-belly trailers originated from auction markets (68.7%), whereas most cattle transported in goosenecks originated from a ranch or dairy (79.2%) and were more likely to be located close to the processing facility. Cattle transported directly from auction barns to processing facilities tended to have greater amounts of bruising (McNally and Warriss, 1996). Incidences of bruising increased as animals were subjected to extra transport, handling, or comingling with animals of different origins during transport and when held at harvest facilities. Of all animals that arrived at the facility on the day of collection, 78.6% were scheduled for harvest on the day of arrival (data not shown in tabular form).

BQA is a national program funded by the Beef Checkoff that raises consumer confidence by outlining best management practices and encouraging a commitment to quality within every segment of the beef industry (Beef Quality Assurance, 2022). The goal of BQA is to assure consumers that all cattle shipped from a beef production unit are healthy, wholesome, and safe and that these cattle are produced using animal well-being, worker safety, and environmentally sound production practices (Beef Quality Assurance, 2019). Of all truck drivers surveyed (n = 118), 63.6% self-reported that they were BQA certified. This is the first NBQA where BQA certification was asked of the drivers.

Mobility

Mobility score data are presented in Table 3. Cattle that were sound (mobility score of 1) represented 77.0% of the observed population, a decrease from the 81.3% reported in 2016 (Harris et al., 2017). Beef cows and bulls had the highest percentage of no apparent lameness. Dairy cows and bulls had the highest incidence of minor stiffness, slight limp, or shortness of stride when unloaded from trailers (mobility score 2). Dairy cows exhibited the highest percentages of decreased mobility and displayed a 10.3% decrease in normal mobility compared to the cattle observed in 2016 (Harris et al., 2017). Approximately 20% of intensively managed dairy cows are lame at any one time (Cook and Nordlund, 2009). Lameness in dairy cattle is often caused by claw disorders, hock injuries, and udder defects, all of which can be attributed to poor housing conditions or management. Claw disorders arise from increased exposure to concrete flooring due to environmental factors such as obstructions to normal stall use, overstocking, prolonged milking times, and management tasks that keep cows away from resting (Cook and Nordlund, 2009). Additionally, an insufficient lying or resting surface leads to increased instances of hock injuries (Farmers Assuring Responsible Management, 2022). Therefore, the National Dairy Farmers Assuring Responsible Management (FARM) Program recommends that cows should be kept on clean, deep, loosely bedded stalls of sand to help control

Table 3. National Beef Quality Audit—2022: Percentage of mobility scores[1] and downers[2] in all cattle surveyed

		Mobility score				
Type of animal	n	1	2	3	4	Downers
Beef cows	1,375	86.3	11.6	1.9	0.0	0.2
Dairy cows	1,357	65.7	25.8	7.3	0.9	0.3
Beef bulls	338	85.8	11.8	2.4	0.0	0.0
Dairy bulls	54	72.2	24.1	3.7	0.0	0.0
Overall	3,124	77.0	18.0	4.4	0.4	0.2

[1]Mobility scores were assigned as follows: (1) walks normally with no apparent lameness; (2) exhibits minor stiffness, shortness of stride, and slight limp, but is still able to keep up with normal cattle; (3) exhibits obvious stiffness, difficulty taking steps, walks with an obvious limp and discomfort, and lags behind normal cattle; and (4) extremely reluctant to move even when encouraged (North American Meat Institute Animal Welfare Committee, 2015).
[2]Non-ambulatory cattle; unable to rise.

instances of hock injuries, and mastitis. In addition to an animal welfare concern, lameness can also result in economic consequences at the point of sale. Cattle experiencing lameness and not responding to treatment should be culled early to reduce profit loss before harvest. Even though mobility scores of 2 are not desirable, it is positive that the industry is seeing greater incidences of these scores rather than cattle with scores indicative of limited mobility. This could be an indicator that beef and dairy producers are recognizing early signs of lameness and are making an effort to treat or market their cattle before lameness becomes severe.

Live cattle that are deemed unfit for human consumption during antemortem inspection by USDA-FSIS inspectors at the plant are condemned and removed from the beef supply chain. The leading cause for antemortem condemnation in the current audit was due to non-ambulatory animals. Of all cattle condemned antemortem (n = 103), 39.2% were non-ambulatory. Malignant lymphoma was the second most prevalent cause of condemnations in live animals (17.6%). Other leading reasons for antemortem condemnation were septicemia (8.8%), peritonitis (6.9%), and emaciation (6.9%).

Live Cattle Evaluation

The decision when to cull an animal is the responsibility of the producer and is determined by what is best for their operation and most importantly, the animals' well-being. Body Condition Scoring (BCS) is a method of determining the relative fatness of cattle, which has been shown to influence productivity, reproduction, health, and longevity of cattle within the herd and can inform nutritional management decisions (Lalman et al., 2017; Heinrichs et al., 2023). The mean BCS (9-point scale) for beef cows (n = 2,194) was 3.8 and for beef bulls (n = 460) was 4.4 (not in tabular form). The mean BCS (5-point scale) for dairy cows (n = 2,728) was 2.3 and dairy bulls (n = 32) was 2.6 (not in tabular form). The distribution of BCS for beef and dairy animals in 2007, 2016, and 2022 are provided in Table 4 and Table 5, respectively. In 2016, it was reported that BCS in dairy cows had improved substantially, from 36.0% with a score of 3.0 or greater in 2007 to 45.0% in 2016 (Harris et al., 2017). Unfortunately, in the current audit, this percentage has decreased to 30.9%, indicating a greater percentage of underfinished cows at harvest. It is important to note that dairy cattle classified in the upper range of dairy condition scoring would not be considered overly finished for beef fabrication and retail marketing purposes whereas beef animals with condition scores greater than seven contribute to excessive fat trim at the packer (Harris et al., 2017). The current study displayed the highest percentage of cattle categorized as "too thin" (score of 1 or 2 on a 9-point scale or score of 1.0 or

Table 4. National Beef Quality Audit—2022: Percentage of Body Condition Scores for beef cows and bulls in previous and current audits

		Body condition score[1]								
	n	1	2	3	4	5	6	7	8	9
Cows										
2007[2]	2,800	0.9	9.1	19.9	21.2	21.2	15.5	8.0	3.0	1.2
2016[3]	1,910	1.9	5.7	17.1	22.5	21.4	17.8	9.9	2.8	0.8
2022	2,194	4.3	14.3	24.7	25.2	16.4	7.9	5.2	1.8	0.2
Bulls										
2007[2]	431	0.5	1.6	11.4	26.2	29.2	19.7	8.1	2.1	1.2
2016[3]	406	0.2	5.4	12.1	22.9	28.1	26.1	3.2	1.5	0.5
2022	460	1.3	8.3	10.6	30.4	33.7	8.3	5.9	1.3	0.2

[1]Beef animal scores on a 9-point scale: 1.0 = emaciated, 9.0 = obese (Lalman et al., 2017; Farmers Assuring Responsible Management, 2022).
[2]National Market Cow and Bull Beef Quality Audit—2007 (Nicholson et al., 2013).
[3]National Beef Quality Audit—2016 (Harris et al., 2017).

Table 5. National Beef Quality Audit—2022: Percentage of body condition scores[1] for dairy cows and bulls in previous and current audits

		Body condition score								
	n	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Cows										
2007[2]	2,103	6.0	16.2	19.4	22.4	16.4	10.7	6.4	2.1	0.5
2016[3]	2,878	0.8	8.5	19.5	26.1	26.3	14.9	3.6	0.2	0.0
2022	2,728	7.8	15.5	21.2	24.6	20.7	5.9	3.0	1.1	0.2
Bulls										
2007[2]	124	1.6	2.4	4.8	9.7	22.6	22.6	25.0	8.1	3.2
2016[3]	121	0.8	0.0	4.2	9.9	29.8	30.6	16.5	6.6	0.8
2022	32	0.0	9.4	15.6	12.5	15.6	12.5	25.0	0.0	9.4

[1]Dairy animal scores on a 5-point scale: 1.0 = overly thin, 5.0 = over-conditioned (Lalman et al., 2017; Farmers Assuring Responsible Management, 2022; Heinrichs et al., 2023).
[2]National Market Cow and Bull Beef Quality Audit—2007 (Nicholson et al., 2013).
[3]National Beef Quality Audit—2016 (Harris et al., 2017).

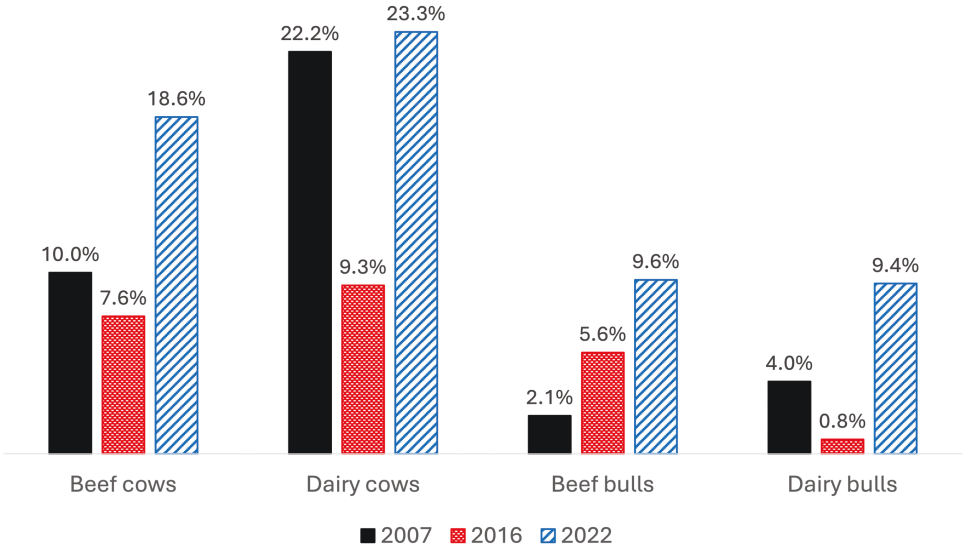

Figure 1. National Beef Quality Audit—2022: percentage of cattle classified as "too thin" (Body Condition Score 1 or 2 on a 9-point scale; Body Condition Score of a 1.0 or 1.5 on a 5-point scale). Total number of observations were National Market Cow and Bull Beef Quality Audit—2007 (Nicholson et al., 2013): beef cows (n = 2,800), dairy cows (n = 2,103), beef bulls (n = 431), dairy bulls (n = 124); National Beef Quality Audit—2016 (Harris et al., 2017): beef cows (n = 1,910), dairy cows (n = 2,878), beef bulls (n = 406), dairy bulls (n = 121); National Beef Quality Audit—2022: beef cows (n = 2,194), dairy cows (n = 2,728), beef bulls (n = 460), dairy bulls (n = 32).

Table 6. National Beef Quality Audit—2022: Percentage of muscle scores[1] in all cattle surveyed

		Muscle score[1]				
Type of animal	*n*	1	2	3	4	5
Beef cows	2,214	22.2	48.2	22.8	6.4	0.5
Dairy cows	2,721	64.6	30.9	4.4	0.1	0.0
Beef bulls	457	2.2	28.7	42.0	23.4	3.7
Dairy bulls	38	18.4	34.2	36.9	7.9	2.6

[1]1 = thin, light muscled, 5 = thick, heavy muscled.

1.5 on a 5-point scale) compared to previous audits (Figure 1). Condition scores that are too low result in a reduction of market potential, and animals with minimal fat deposition may mobilize muscle as a source of energy, decreasing muscle volume and carcass value.

In conjunction with body condition score, muscle score can be used to determine the fitness of animals intended for harvest. Table 6 shows the percentage of muscle scores assigned to all cattle types surveyed. Bulls had the highest frequency of muscle scores 3 or greater. The highest percentage (48.2%) of beef cows had a muscle score of 2 while the majority (64.6%) of dairy cows had a muscle score of 1. It is inherent that beef animals are typically heavier muscled compared to dairy animals, and bulls are heavier muscled compared to cows. However, the percentage of cattle that were considered "too light muscled" (scores of 1 and 2) should be noted. The mean muscle score for dairy cows was 1, and beef cows and dairy bulls had a mean score of 2, whereas beef bulls had a mean score of 3. Compared to the two previous audits, the current audit displayed the highest percentage of cattle that were too lightly muscled across all breed types and sexes (Figure 2).

Lightly muscled or too thin cattle may benefit from increased feeding before selling. With a decreased layer of protective tissue, cattle in poor flesh and condition are more prone to carcass bruising, produce fewer pounds of lean, attract the attention of animal welfare activists, and provide consumers with a poor perception of the beef industry. Producers may consider evaluating muscle scores and body condition before marketing to mitigate these repercussions and capture more economic returns for their operation. Cows or bulls with increased body condition and/or muscling weigh more and thus, have the potential to optimize economic returns by having a greater live and carcass value. Carter and Johnson (2007) reported cows fed ad libitum from 28 to 56 d before harvest had heavier carcass weights due to increases in lean and fat deposition. Additionally, Jones (1983) reported approximately 40% of weight gain over an 89-d feeding period in mature cows was attributed to muscle deposition. Feeding lean cows can increase meat production, and producers should consider the health status of their animals as well as economic factors such as time of year, market conditions, and commodity feed prices when determining the eligibility of an animal for feeding before harvest.

Physical defects that impair reproductive efficiency, prevent an animal from maintaining herd function, or result in economic losses are also considerations in determining the market readiness of cattle. The reason an animal is culled may be multifaceted. Therefore, the live animal evaluation

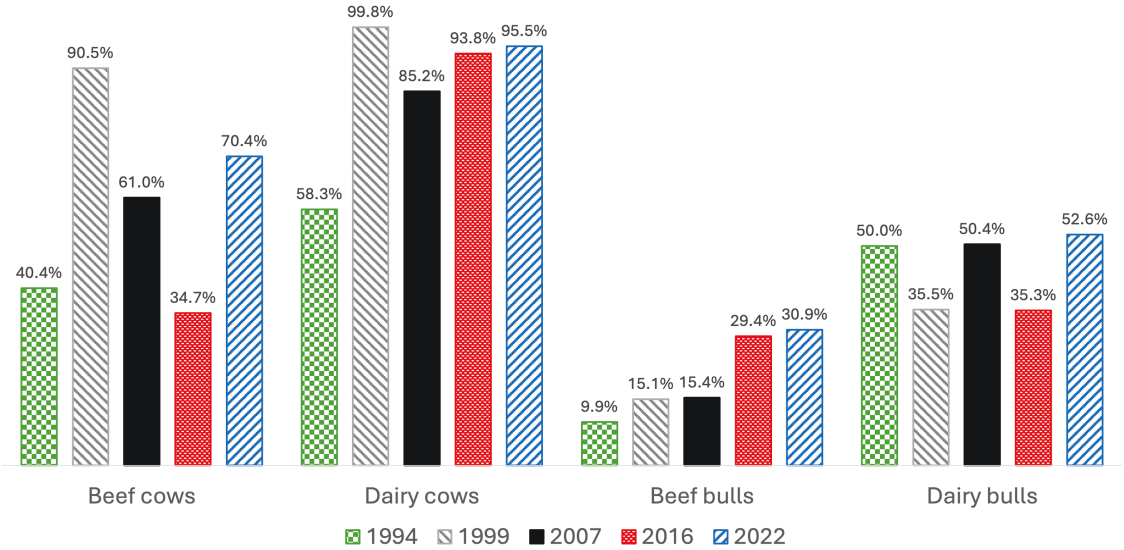

Figure 2. National Beef Quality Audit—2022: A comparison between the percentage of cattle that were inadequately muscled (muscle scores of 1 or 2) in 1994, 1999, 2007, 2016, and 2022. Total number of observations were National Non-fed Beef Quality Audit—1994 (Smith et al., 1994): beef cows (*n* = 1,548), dairy cows (*n* = 1,013), beef bulls (*n* = 254), dairy bulls (*n* = 38); National Market Cow and Bull Beef Quality Audit—1999 (Roeber et al., 2001): beef cows (*n* = 2,237), dairy cows (*n* = 1,108), beef bulls (*n* = 419), dairy bulls (*n* = 79); National Market Cow and Bull Beef Quality Audit—2007 (Nicholson et al., 2013): beef cows (*n* = 2,501), dairy cows (*n* = 1,954), beef bulls (*n* = 385), dairy bulls (*n* = 127); National Beef Quality Audit—2016 (Harris et al., 2017): beef cows (*n* = 1,860), dairy cows (*n* = 2,809), beef bulls (*n* = 399), dairy bulls (*n* = 119); National Beef Quality Audit—2022: beef cows (*n* = 2,214), dairy cows (*n* = 2,721), beef bulls (*n* = 457), dairy bulls (*n* = 38).

during this study strived to identify physical defects that could have persuaded a producer to cull the animal from the herd. Approximately 45.1% of all cattle surveyed had no visible defect (not in tabular form). This may include animals that were culled for reasons not visible to the researcher such as pregnancy status, financial, behavioral, or genetic deficiencies. Table 7 displays the percentages of defects recorded in cows and bulls. Most beef cows (66.0%), beef bulls (79.9%), and dairy bulls (78.4%) had no visible defect whereas most dairy cows (63.5%) had a single defect. Of all cattle surveyed, 37.9% had a single defect (not in tabular form). These frequencies indicate that producers were more likely to cull animals after noticing a single defect rather than retaining that animal until the defect progressed further or more defects presented.

Cow and bull reproductive soundness in both beef and dairy operations is of utmost importance. Cattle with defects that inhibit them from successful reproduction represent a common reason for culling. Reproductive defects in cows such as prolapses and retained placentas were minimal. Cows were also surveyed for visible defects related to udder conformation and health. Historically, beef cows have a greater frequency of bottled teats than dairy cows, and the current audit had the highest reported percentage (7.8%) compared to the 2007 (3.7%) and 2016 (6.3%) audits (Nicholson et al., 2013; Harris et al., 2017). Teat size influences the ease at which a calf can nurse. The more difficulty a calf has nursing, the less opportunity to properly grow and develop, or even survive. It has been reported that cows with smaller teats after calving were less likely to have calf losses than cows with larger teats (Bunter et al., 2014). Therefore, cows that have developed bottle teats should be considered for culling. Approximately 64.6% of all defects in cows were udder problems, with full bags being the most prevalent defect observed (47.5%). The majority of all dairy cows observed had a full bag at harvest (74.9%), a substantial increase from the 8.1% observed in 2016 (Harris et al., 2017). It is difficult to determine the reason for this increase; however, producers should consider the timeliness of marketing for cull cows. A management tactic for some beef producers is to wean calves from cull cows by marketing the cows the day they wean. Additionally, most cattle in this audit were sourced from an auction market. Cows in lactation that are left standing for periods of time before harvest at an auction market or at the processing facility develop a full bag as milk continues to be produced. Full bags in advanced condition can impact the animal's well-being and cause mobility issues. In addition to animal welfare, full bags at the time of harvest are a concern for the packer. Full bags can be difficult to remove during harvest and can decrease chain speed. Additionally, the risk of full bags releasing milk while being removed, poses a threat to food safety. Milk can be a primary avenue for the spread of pathogens and is considered a contaminant in slaughter establishments (USDA-FSIS, 2019). Therefore, Food Safety and Inspection Services (FSIS) enforces a "zero tolerance" standard for visible milk on carcasses at the time of inspection.

Bulls are often culled for their inability to breed cows resulting from infertility, a loss of libido, or a physical defect that would inhibit the bull's physical ability to breed such as a broken penis or feet or leg abnormalities. Of all bulls surveyed, 3.4% had a broken penis, 9.2% had swollen joints, and 6.3% had a foot abnormality. Compared to the previous audit (Harris et al., 2017), there was a decrease in the percentage of beef bulls that had a broken penis (6.7% vs. 3.4%), whereas dairy bulls had an increase (0.0% vs. 2.7%).

Similar to the 2007 audit, foot abnormalities were found to be the most common in dairy cows, with a slightly greater rate observed in the current study (7.2% vs. 9.1%, respectively; Nicholson, 2008). The prevalence of foot abnormalities observed in dairy cows could be attributed to claw disorders that commonly result from diets and housing

Table 7. National Beef Quality Audit—2022: Percentage of defects[1] in surveyed cows and bulls

Defects[2]	All cows (*n* = 4,497)	Beef cows (*n* = 2,057)	Dairy cows (*n* = 2,440)
No defect	41.7	66.0	21.2
Single defect	45.8	24.9	63.5
Multiple defects	12.5	9.1	15.3
Defect type			
Bottle teats	4.7	7.8	2.1
Mastitis	2.1	1.6	2.5
Failed suspensory ligament	5.4	4.1	6.4
Multiple udder problems	4.9	6.1	3.9
Full bag	47.5	15.0	74.9
Calf in pen	0.04	0.1	0.0
Retained placenta	0.4	0.3	0.5
Prolapse	0.1	0.3	0.0
Broken tail	4.5	0.5	7.8
Swollen joints	9.6	3.8	14.5
Foot abnormality	6.2	2.8	9.1
Lumpy jaw	0.6	1.1	0.1
Other	1.9	1.9	2.0
Defects	**All bulls (*n* = 445)**	**Beef bulls (*n* = 408)**	**Dairy bulls (*n* = 37)**
No defect	79.7	79.9	78.4
Single defect	16.9	16.9	16.2
Multiple defects	3.4	3.2	5.4
Defect type			
Broken penis	3.4	3.4	2.7
Broken tail	0.2	0.2	0.0
Swollen joints	9.2	9.1	10.8
Foot abnormality	6.3	6.9	0.0
Lumpy jaw	1.6	1.7	0.0
Other	2.9	2.0	13.5

[1]Percentages for both cows and bulls exceed 100% due to animals having multiple defects.
[2]Detailed animal defect descriptions are reported by Harris et al. (2017).

Table 8. National Beef Quality Audit—2022: Percentages of location of abscesses present in surveyed live cattle

Abscess location	All cattle (*n* = 125)	Beef cows (*n* = 40)	Dairy cows (*n* = 63)	Beef bulls (*n* = 21)	Dairy bulls (*n* = 1)
Facial	26.4	35.0	15.9	42.8	0.0
Knee/hock	49.6	32.5	61.9	42.8	100.0
Hooks/pins	21.6	27.5	22.2	4.8	0.0
Other	3.2	5.0	0.0	9.6	0.0

environments that dairy cattle are provided. Less than one percent (0.7%) of all cattle evaluated exhibited symptoms of *Actionomyosis bovis* infection or "lumpy jaw." Lumpy jaw is a chronic bone and soft tissue infection that is not responsive to treatment. Cattle should be culled as soon as this infection is detected. Only 2.3% of all cattle evaluated had an abscess (not in tabular form). Table 8 displays the percentage of abscesses by location in cattle with abscesses present. Most abscesses observed in dairy cows and bulls were in the knee or hock, remaining consistent with the findings of NBQA-2016 (Harris et al., 2017). In 1994, 13.4% of all dairy cattle had visible abscesses on the hindquarter that appeared to be the result of swelling associated with intramuscular injections (National Cattlemen's Beef Association, 1994). The BQA program was established in the mid-1990s to improve animal welfare with a primary objective to remove the incidence of injection-site lesions by encouraging producers to administer injections in the neck (Klopatek

et al., 2022). The current audit demonstrated an improvement with fewer abscesses present in the hindquarters with 0.6% of dairy cattle with abscesses present around the hooks or pins (not in tabular form). Additionally, knots visible on the surface of the animal are areas of swelling generally resulting from intramuscular or subcutaneous injections of animal health products. Knots are often iceberg indicators of potential injection-site lesions lying beneath the surface of the hide or within the muscle, thus posing a potential meat quality concern. Of all cattle surveyed, 98.2% displayed no visible knots, a slight increase from the 97.9% observed in 2016 (Harris et al., 2017). Of the knots observed (n = 121), 55.4% were in the neck, 18.1% were in the shoulder, 11.5% were in the top butt, 6.6% were in the round, and 11.5% were observed in a location not specified by the recorder (not in tabular form). Table 9 displays the percentages of knots and their location in all cattle evaluated in 2007, 2016, and 2022. Findings compared across audits confirm the efforts of producer education and BQA training have been effective in reducing injection-site lesions.

Bovine ocular neoplasia, or cancer eye, was not observed in 96.5% of all animals. This is a slight decrease from the previous audit which reported that cancer eye was not observed in 99.0% of all cattle surveyed (Harris et al., 2017). The highest occurrence of cancer eye was displayed in beef bulls at 6.1%, followed by beef cows (4.7%). Of all reported cases of cancer eye, 73.7% (n = 140) were given a score of 1, exhibiting a small, benign tumor. The majority of cancer eyes reported were in the earliest stage, again indicating that producers are noticing these defects and are choosing to market animals before their condition progresses.

Horn and Hide Characteristics

Since the first market cow and bull audit was conducted in 1994, producers have been cautioned about the presence of horns, and the greater instances of bruising associated when horned cattle are comingled with other animals (National Cattlemen's Beef Association, 1994). Therefore, horn length and presence were once again evaluated in the current audit. Table 10 shows the percentage of horn presence and size in surveyed cattle. Beef bulls had the highest percentage (9.1%) of horns greater than 12.7 cm in length, followed by beef cows (4.8%). Harris et al. (2017) reported greater frequencies of cattle evaluated without horns when compared to the 2007 audit. The current audit revealed a slight increase in the percentage of animals without horns compared to 90.3%, 87.9%, 82.7%, and 69.0% of beef cows, dairy cows, beef bulls, and dairy bulls in 2016, respectively. The decrease in percentage of animals with horns over the previous audits may indicate that producers are adapting genetics of cattle that are naturally polled or performing management practices to remove horns to increase safety for handlers and other animals in the production setting.

Table 11 shows the primary hide color observed for surveyed cattle. Most beef cows (68.9%) and beef bulls (67.4%) had black hides. Cattle with red hides were the second most prevalent in beef animals; 19.7% and 20.2% of cows and bulls, respectively. Overall, 76.7% of beef cows and 81.2% of beef bulls were solid, displaying no color pattern (Table 12). A white face, or "baldy," was the most common color pattern observed in beef animals, indicating color patterns derived from Hereford genetics. Nicholson (2008) reported that 44.2% of beef cows and 52.3% of beef bulls were black-hided, whereas Harris (2017) reported an increase in the percentage of black-hided beef animals in 2016 (68.0% of cows and 67.2% of bulls), which are similar percentages to the current findings. Over the past two audits, the percentage of black-hided beef market animals has drastically increased, indicating a continuous increase in Angus genetics within the national beef herd across the United States. Due to their well-known beef quality attributes, cattle with Angus genetics are often sought after in feeder cattle. This results in premiums offered for cattle with solid black hides. Because of this, the market cow and bull segment has seen an increase in black-hided animals over the years due to the incorporation of Angus genetics into many breeding operations.

In 2016, 48.8% of all cattle surveyed appeared to be Holstein. This percentage remains consistent with the findings of the current audit that displayed a slight 2.4% decrease in the percentage of Holsteins observed in all cattle surveyed. Most dairy cows (99.7%) and dairy bulls (100%) were classified with a primary pattern. Of the patterned animals, 85.7% of dairy cows and 98.0% of dairy bulls were Holstein. This is no surprise considering the Holstein breed is known for high milk production and makes up most of the U.S. dairy population. The increase in black-hided cattle and

Table 9. National Beef Quality Audit—2022: percentages of knot presence and location[1] in surveyed cattle in previous and current audits

Location	2007[2] (n = 5,520)	2016[3] (n = 5,160)	2022 (n = 6,605)
No knots	92.1	97.9	98.2
Neck	2.6	0.9	1.0
Shoulder	4.6	0.3	0.3
Top butt	0.2	0.3	0.2
Round	0.5	0.1	0.1

[1]Percentages do not add to 100% due to knots present in locations not specified by the recorder.
[2]National Market Cow and Bull Beef Quality Audit—2007 (Nicholson et al., 2013).
[3]National Beef Quality Audit—2016 (Harris et al., 2017).

Table 10. National Beef Quality Audit—2022: percentages of horn presence and estimated length in surveyed cattle

Estimated horn length	All cattle (n = 6,564)	Beef cows (n = 2,475)	Dairy cows (n = 3,542)	Beef bulls (n = 496)	Dairy bulls (n = 51)
No horns	89.4	91.0	89.2	84.5	70.6
<2.54 cm	4.1	1.7	6.1	1.6	7.8
2.54 to 12.7 cm	3.7	2.5	4.2	4.8	19.6
>12.7 cm	2.8	4.8	0.5	9.1	2.0

Table 11. National Beef Quality Audit—2022: percentage[1] of each primary hide color observed in cattle surveyed

Hide color	All cattle (*n* = 6,662)	Beef cows (*n* = 2,527)	Dairy cows (*n* = 3,568)	Beef bulls (*n* = 516)	Dairy bulls (*n* = 51)
Patterned animal[2]	64.1	22.5	99.7	18.2	100.0
Black	33.2	68.9	3.5	67.4	0.0
White	1.3	2.3	0.3	4.1	0.0
Yellow	1.4	3.4	0.0	1.4	0.0
Red	9.5	19.7	0.8	20.2	0.0
Brown	1.4	2.0	1.0	1.2	0.0
Gray	1.2	2.1	0.1	4.1	2.0
Tan	0.8	1.5	0.0	2.3	0.0

[1]Percentages exceed 100% due to animals being classified as having a primary color and a pattern.
[2]Includes: Holstein cattle, Jersey cattle, dairy-cross cattle, and cattle with a hide that did not have a primary color covering 51% or more of the hidden surface.

Table 12. National Beef Quality Audit—2022: Percentage[1] of hide pattern observed in cattle surveyed

Pattern	All cattle (*n* = 6,362)	Beef cows (*n* = 2,425)	Dairy cows (*n* = 3,387)	Beef bulls (*n* = 500)	Dairy bulls (*n* = 50)
None	36.7	76.7	2.0	81.2	0.0
Baldy	7.8	17.4	0.1	14.4	0.0
Roan	0.5	0.7	0.3	0.4	0.0
Brindle	0.9	2.2	0.0	1.2	0.0
Spots	1.2	1.8	0.6	2.2	0.0
Holstein	46.4	nd[2]	85.7	nd	98.0
Jersey	5.0	nd	9.5	nd	0.0
Dairy cross	1.6	nd	2.9	nd	2.0
Other	1.4	2.6	0.4	2.6	0.0

[1]Percentages exceed 100% due to animals being classified by multiple pattern types.
[2]nd, not determined.

decrease in Holstein prevalence in addition to the percentage of Holstein cows and bulls remaining constant likely reflects the use of beef semen by dairy producers to yield beef × dairy calves.

Animal Identification

Accurate identification of individual animals and a system for keeping valid records are crucial in effective management of cattle herds. Individual animal identification supports the tracking of performance characteristics that are important as producers make selection decisions (Beef Quality Assurance, 2019). The majority (72.3%) of all cattle surveyed had multiple forms of identification. Over many decades, advancements in technologies used for livestock identification have been made to aid cattle producers in animal identification, pest control, and traceability. Ear tags, specifically individual animal identification tags, were the most common form of identification observed in all animals surveyed (Table 13). The second most prevalent form of animal identification were backtags. Most cull cows and bulls pass through an auction barn at least once in their lifetime before going to harvest, thus receiving a backtag as a method of identification. The next most abundant form of identification observed was the electronic tag. With a growing public concern for traceability, the popularity of electronic tags is rising in the cattle industry. Compared to NBQA-2016, electronic identification tags have increased from 13.2% (*n* = 5,242) to 20.5% of all cattle. Of all cattle surveyed, only 3.1% of animals had no form of individual identification, which is a decrease from the 8.3% reported in 2016 (Harris et al., 2018).

Conclusions

Results from NBQA-2022 indicate that the market cow and bull sector of the cattle industry has made improvements when compared to previous audits: most notable were in transportation conditions as well as proper animal management through increased use of identification and limited percentages of management-related defects. However, NBQA-2022 identified areas for continued focus in the market cow and bull sector of the beef industry. Producers should consider the eligibility of cows and bulls for feeding before harvest or cull animals in a timelier manner to avoid incidences of under-conditioned and light-muscled cattle at the point of harvest. Emphasis on producer and transporter education through Extension and BQA programs should be focused on the appropriate management, handling, and marketing of cull cows and bulls to increase animal value and welfare.

Table 13. National Beef Quality Audit—2022: percentage of identification types[1] in surveyed cattle

Identification	All cattle (*n* = 6,699)	Beef cows (*n* = 2,531)	Dairy cows (*n* = 3,599)	Beef bulls (*n* = 518)	Dairy bulls (*n* = 51)
No ID	3.1	5.7	0.6	8.3	2.0
Single ID	24.6	28.6	19.3	40.9	33.3
Multiple ID	72.3	65.7	80.1	50.8	64.7
Identification type					
Ankle	0.8	0.0	1.5	0.0	0.0
Barcode	1.9	2.7	1.1	3.9	0.0
Electronic (low frequency or high frequency)	20.5	4.1	34.0	6.2	23.5
Electronic with accelerometer[2]	0.04	0.1	0.0	0.0	0.0
Ear tag	81.9	72.9	91.5	59.7	76.5
Metal clip	30.1	41.5	24.5	14.7	15.7
Lot tag	6.2	6.0	6.5	4.4	13.7
Wattles	0.2	0.3	0.1	0.4	0.0
Back tag	56.7	53.9	57.8	62.9	60.8
Other	4.6	2.0	6.9	1.2	3.9

[1]Percentages exceed 100% due to animals having multiple forms of identification.
[2]Merck Animal Health (2024).

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Conflict of interest statement

There are no known conflicts of interest by any of the authors.

Literature Cited

Beef Quality Assurance. 2006. Master cattle transporter guide. Centennial (CO): National Cattlemen's Beef Association.

Beef Quality Assurance. 2019. National manual. National Cattlemen's Beef Association, Centennial (CO). https://www.bqa.org/Media/BQA/Docs/bqa_manual_final.pdf

Beef Quality Assurance. 2022. Beef quality assurance. Centennial (CO): Beef Quality Assurance. https://www.bqa.org/

Bunter, K. L., D. J. Johnston, M. L. Wolcott, and G. Fordyce. 2014. Factors associated with calf mortality in tropically adapted beef breeds managed in extensive Australian production systems. Anim. Prod. Sci. 54:25–36. doi: 10.1071/an12421

Carter, J. N., and D. D. Johnson. 2007. Improving the value of cull cows by feeing prior to slaughter. Gainesville (FL): AN169. Animal Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Cook, N. B., and K. V. Nordlund. 2009. The influence of the environment on dairy cow behavior, claw health and herd lameness dynamics. Vet. J. 179:360–369. doi: 10.1016/j.tvjl.2007.09.016

Farmers Assuring Responsible Management. 2022. Animal care: reference manual version 4, 2020-2022. Arlington (VA): National Dairy FARM Program. https://nationaldairyfarm.com/wp-content/uploads/2021/12/FARM_Animal-Care-4-Manual_Layout_FINAL_112921.pdf

Grandin, T., and North American Meat Institute Animal Welfare Committee. 2021. Recommended animal handling guidelines & audit guide: a systematic approach to animal welfare. Washington (DC): North American Meat Institute. https://www.meatinstitute.org/sites/default/files/original%20documents/Animal_Handling_Guide_English.pdf

Harris, M. K. 2017. National beef quality audit – 2016: a survey of the market cow and bull industry to discover avenues for improving quality and enhancing value of beef. M.S. thesis, College Station: Texas A&M University.

Harris, M. K., L. C. Eastwood, C. A. Boykin, A. N. Arnold, K. B. Gehring, D. S. Hale, C. R. Kerth, D. B. Griffin, J. W. Savell, K. E. Belk, et al. 2017. National Beef Quality Audit – 2016: Transportation, mobility, live cattle, and carcass assessments of targeted producer-related characteristics that affect value of market cows and bulls, their carcasses, and associated by-products. Transl. Anim. Sci. 1:570–584. doi: 10.2527/tas2017.0063

Harris, M. K., L. C. Eastwood, C. A. Boykin, A. N. Arnold, K. B. Gehring, D. S. Hale, C. R. Kerth, D. B. Griffin, J. W. Savell, K. E. Belk, et al. 2018. National Beef Quality Audit – 2016: Assessment of cattle hide characteristics, offal condemnations, and carcass traits to determine the quality status of the market cow and bull beef industry. Transl. Anim. Sci. 2:37–49. doi: 10.1093/tas/txx002

Heinrichs, J., C. M. Jones, and V. A. Ishler. 2023. Body condition scoring as a tool for dairy herd management. University Park (PA): The Pennsylvania State University. https://extension.psu.edu/body-condition-scoring-as-a-tool-for-dairy-herd-management#:~:text=Body%20condition%20scoring%20in%20dairy,indirect%20estimate%20of%20energy%20balance

Jones, S. D. M. 1983. Tissue growth in young and mature cull Holstein cows fed a high energy diet. J. Anim. Sci. 56:64–70. doi: 10.2527/jas1983.56164x

Klopatek, S. C., A. M. Cantwell, L. Roche, K. Stackhouse-Lawson, and J. W. Oltjen. 2022. Beef Quality Assurance national rancher survey: program participation, best management practices, and motivations for joining future sustainability programs. Transl. Anim. Sci. 6:txac094. doi: 10.1093/tas/txac094

Lalman, D., G. Selk, and D. Stein. 2017. Body condition scoring of cows. Stillwater (OK): Oklahoma State University. https://extension.okstate.edu/fact-sheets/body-condition-scoring-of-cows.html

Lapworth, J. W. 2008. Engineering and design of vehicles for long distance road transport of livestock: the example of cattle transport of Northern Australia. Vet. Ital. 44:215–222.

Lorenzen, C. L., D. S. Hale, D. B. Griffin, J. W. Savell, K. E. Belk, T. L. Frederick, M. F. Miller, T. H. Montgomery, and G. C. Smith. 1993. National beef quality audit: survey of producer-related defects and carcass quality and quantity attributes. J. Anim. Sci. 71:1495–1502. doi: 10.2527/1993.7161495x

McNally, P. W., and P. D. Warriss. 1996. Recent bruising in cattle at abattoirs. Vet. Rec. 138:126–128. doi: 10.1136/vr.138.6.126

Merck Animal Health. 2024. SenseHub Feedlot. Rahway (NJ): Merck & Co., Inc. https://www.merck-animal-health-usa.com/species/cattle/sensehub/sensehub-feedlot

National Cattlemen's Beef Association. 1994. The National Non-Fed Beef Quality Audit. Centennial (CO): National Cattlemen's Beef Association. http://meat.tamu.edu/files/2015/11/NCBA-1994-Non-fed-audit.pdf

Nicholson, J. D. W. 2008. National market cow and bull beef quality audit - 2007: a survey of producer-related defects. M.S. thesis, College Station: Texas A&M University.

Nicholson, J. D. W., K. L. Nicholson, L. L. Frenzel, R. J. Maddock, R. J. Delmore, Jr, T. E. Lawrence, W. R. Henning, T. D. Pringle, D. D. Johnson, J. C. Paschal, et al. 2013. Survey of transportation procedures, management practices, and health assessment related to quality, quantity, and value for market beef and dairy cows and bulls. J. Anim. Sci. 91:5026–5036. doi: 10.2527/jas.2013-6283

North American Meat Institute Animal Welfare Committee. 2015. Mobility Scoring for Cattle. Washington (DC): North American Meat Institute. https://www.youtube.com/watch?v=QIslfHCvkpg

Roeber, D. L., P. D. Mies, C. D. Smith, K. E. Belk, T. G. Field, J. D. Tatum, J. A. Scanga, and G. C. Smith. 2001. National market cow and bull beef quality audit-1999: a survey of producer-related defects in market cows and bulls. J. Anim. Sci. 79:658–665. doi: 10.2527/2001.793658x

Smith, G. C., J. B. Morgan, J. D. Tatum, C. C. Kukay, M. T. Smith, T. D. Schnell, and G. G. Hilton. 1994. Improving the consistency and competitiveness of non-fed beef, and, improving the salvage value of cull cows and bulls: the final report of the National Non-Fed Beef Quality Audit-1994. Fort Collins (CO): Colorado State University.

USDA-FSIS. 2019. FSIS Directive 6420.2 Revision 2. Washington (DC): Food Safety and Inspection Service, United States Department of Agriculture.