I. Full Project Report

National Beef Quality Audit – 2016: In-plant survey phase

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1. Harvest-Floor Assessment

ABSTRACT

The National Beef Quality Audit-2016 (NBQA-2016) was conducted to assess current transportation, mobility, and quality characteristics of U.S. fed steers and heifers. Data were collected at 17 beef processing facilities between March and November 2016. About 8,000 live cattle were evaluated for transportation and mobility, and about 25,000 carcasses were evaluated on the slaughter floor. Cattle were in transit to the slaughter facility for a mean duration of 2.7 h from a mean distance of 218.5 km using trailers with dimensions ranging from 17.84 m^2 to 59.09 m^2. Area allotted per animal averaged 1.13 m^2 and ranged from 0.85 m^2 to 2.28 m^2. A total of 96.8% of cattle received a mobility score of 1 (walks easily, no apparent lameness). Identification types (35.1% had multiple) were lot visual tags (61.5%), individual tags (55.0%), electronic tags (16.9%), metal-clip tags (9.2%), bar-coded tags (0.05%), wattles (0.01%), and other (2.6%). Cattle were predominately black-hided (57.8%), Holstein (20.4%), red-hided (10.5%), yellow-hided (4.8%), gray-hided (2.9%), brown-hided (1.3%), and white-hided (1.1%). Unbranded hides were observed on 74.3% of cattle; 18.6% had brands located on the butt, 6.3% on the side, and 1.3% on the shoulder (values exceed 100% due to multiple brands). For hide-on carcasses, 37.7% displayed no mud or manure; specific locations for mud or manure were legs (40.8%), belly (33.0%), tail region (15.5%), side (6.8%), and top-line (3.9%). Cattle without horns represented 83.3% of the sample, and cattle that did have horns measured: < 2.54 cm (5.5%), 2.54 to 12.7 cm (8.3%), and > 12.7 cm (2.9%). Carcasses without bruises represented 61.1% of those sampled, whereas 28.2% had 1, 8.2% had 2, 2.1% had 3, and 0.3% had 4 bruises. Of those carcasses with a bruise, the bruise was located on the loin (29.7%), round (27.8%), chuck (16.4%), rib (14.4%), and brisket/plate/flank (11.6%). Frequencies of offal condemnations were livers (30.8%), lungs (18.2%), viscera (16.3%), hearts (11.1%), heads (2.7%), and tongues (2.0%). Compared to NBQA-2011, fewer cattle were identified for traceability, fewer were black-hided, a greater number were Holstein cattle, more with no brand and no horns, fewer without bruises, more liver, lung, and viscera condemnations, and fewer heads and tongues were condemned. The NBQA remains an influential survey for the U.S. beef industry to provide benchmarks and strategic plans for continued improvement of beef quality and consistency.

INTRODUCTION

The National Beef Quality Audit (NBQA) is conducted about every 5 years to assess and benchmark characteristics associated with producer-related beef quality. Characteristics related to quality and carcass merit are evaluated and relayed back to multiple segments of the beef production industry. Findings of this review are utilized by various segments of the beef industry to set strategic plans for continued improvement. Evaluation of quality traits allows the industry to identify deficiencies in product quality and opportunities for advancement. Previously, this audit has been conducted 5 times: 1991, 1995, 2000, 2005, 2011(Lorenzen et al., 1993; Boleman et al., 1998; McKenna et al., 2002; Garcia et al., 2008; McKeith et al., 2012). Similar audits have been conducted in Canada to assess quality characteristics of cattle in the Canadian beef supply (Van Donkersgoed et al., 1997; Van Donkersgoed et al., 2001). Over time, the NBQA has been an influential tool to objectively evaluate how cattle producers have improved overall quality and consistency of beef in the U.S.

Objectives of NBQA-2016 included measuring specific quality characteristics of cattle and carcasses associated with transportation, mobility, and the harvest-floor that impact the value of beef and by-products. By measuring and trending lost opportunities, the beef industry will be better able to strategize and manage production practices that impact beef quality and consistency.

MATERIALS AND METHODS

Over the course of this study (March to November 2016), 17 in-plant harvest floor assessments were conducted (Table 1-1). For each in-plant audit, data were collected from the entire day's production. If a beef processor harvested cattle in 2 shifts per day, data were collected during both shifts to capture the entire day of production. Beef processors from which data were obtained were selected to reflect the current fed cattle beef supply in the U.S. Before collecting data, all collaborating institutions participated in a correlation meeting to standardize data collection and recording methodology.

Transportation and Mobility of Live Cattle

NBQA-2016 was the first audit to include evaluation of transportation conditions and cattle mobility for fed steers and heifers. Collection of this information is necessary for setting a benchmark related to current trends in cattle transportation and mobility. About 10% of trucks arriving at selected beef slaughter facilities within a production day were sampled (n = 220). Surveyed trucks were evaluated for trailer type (bumper pull, gooseneck, single deck, pot belly, and other), trailer dimensions, number of compartments used, origin of cattle, time and distance traveled, number of cattle, and type of cattle.

To evaluate mobility, 100% of cattle exiting trucks where transportation data were collected were scored (n = 8,051). Cattle were scored for mobility once all four hooves had transitioned to the hard surface of the holding pens and as they walked toward a scale or holding pen. Mobility scores were assigned as 1 - normal, walks easily, no apparent lameness; 2 - exhibits minor stiffness, shortness of stride, slight limp, keeps up with normal cattle; 3 - exhibits obvious stiffness, difficulty taking steps, obvious limp, obvious discomfort, lags behind normal cattle; and 4 - extremely reluctant to move even when encouraged, statue-like (North American Meat Institute, 2015).

Harvest Floor Assessments: Before Hide Removal

About 50% of cattle were sampled per production lot at selected beef processors. For animal identification (n = 24,615 cattle), the type of identification was recorded and categorized as: none identified, electronic tag, barcode, individual tag, lot tag, metal clip, wattles, or other. Hide color (n = 24,672 cattle) was determined based on primary hide color (> 50% of total hide surface area; black, red, yellow, brown, gray, white, tan) or apparent breed type (i.e., Holstein). Presence of hide brands (n = 24,685 cattle) was assessed and categorized by location: butt (round), side, shoulder (chuck). Quantification of brands was determined based upon estimated size (length x width). Presence of mud/manure on the hide was evaluated (*n* = 22,483 cattle) based on location (none visible, legs, belly, side, top line, tail region) and amount using a pictorial reference (none, small, moderate, large, extreme), if present (Savell, 2016). Presence of cattle horns was evaluated (*n* = 24,588 cattle), and if present, approximate length of horns were recorded (< 2.54 cm, 2.54 to 12.7 cm, and > 12.7 cm). This audit also assessed the frequency in which slaughter cattle/carcasses were dragging and unintentionally touching the floor or equipment (*n* = 22,373). This information was captured to assess how beef processors were able to accommodate the ever-increasing size of live animals.

Harvest Floor Assessments: After Hide Removal

Following hide removal, carcasses were evaluated (*n* = 24,366) for the number (0, 1, 2, 3, or 4) of bruises present, location on the carcass (round, loin, rib, chuck, or brisket/plate/flank), and severity (minimal, major, critical, or extreme). Bruise severity was determined based on a 10-point scale: minimal (1, 2, 3); major (4, 5, 6); critical (7, 8, 9); extreme (10). Trim losses from these bruises would be < 0.45 kg for minimal, 0.45 to 4.54 kg for major, > 4.54 kg for critical, and the loss of the entire subprimal for extreme bruising. Where observed, subcutaneous injection-site lesions were noted. Apparent chronological age of cattle was determined using dentition (*n* = 24,382 heads) by counting the number of permanent incisors present. Offal (*n* = 24,940 carcasses; liver, lung, heart, and viscera) and heads and tongues (*n* = 26,657 heads) were inspected for wholesomeness by USDA Food Safety and Inspection Service personnel, and where applicable, condemnations and reasons for condemnations were recorded. Additionally, females with a fetus presence was recorded at the viscera table.

Statistical Analyses

All data were analyzed using JMP Pro, Version 12.0.1 (SAS Institute Inc., Cary, NC). Frequency distributions were evaluated using the distribution function of JMP for all quality traits assessed. Means, standard deviations, minimums, and maximums also were evaluated. Tests of hypotheses regarding changes in prevalence of specific traits (bruise location and offal condemnations) between NBQA-2011 and NBQA-2016 were conducted at $P = 0.05$ using χ^2 analysis.

RESULTS AND DISCUSSION

Transportation and Mobility of Live Cattle

Means, standard deviations, minimums, and maximums for time and distance traveled, number of cattle in the loads, trailer dimensions, and the trailer area allotted per head for all trailer types are shown in Table 1-2. Based on data collected from the truck drivers, cattle were in transit to the beef processing facilities for a mean duration of 2.7 h, covering a mean distance of 218.5 km. While the average distance traveled to beef processing facilities was within a 250-km radius, some cattle traveled from a maximum distance of 1,400.1 km. Additionally, the maximum time traveled was 12h. The number of cattle in a load averaged 36.6 and ranged from 10 to 47 head, whereas the number of compartments used in the trailer averaged 3.5 and ranged from 2 to 6. Trailer dimensions ranged from 17.84 m^2 to 59.09 m^2 with a mean of 40.85 m^2. The wide range of trailer dimensions was a result of different trailer types arriving at the beef processors. Area allotted per animal was 1.13 m^2 and ranged from 0.85 m^2 to 2.28 m^2. Based on recommended animal handling guidelines (Grandin, 2013), hornless cattle weighing 455 kg, 545 kg, and 636 kg, should have 1.1 m^2, 1.4 m^2, and 1.7 m^2 per animal during transport, respectively. Therefore, the NBQA-2016 data suggest that not all fed cattle were allowed adequate space in the trailer during transportation to slaughter. González et al. (2012a) noted that the area allotted per animal, whether too small or too large, could increase incidence of lameness during transportation. Furthermore, González et al. (2012b) recognized that other factors including duration of transportation, trailer design, weather, and horn presence can influence cattle condition after transport.

Evaluators scored 96.8% of cattle as a 1, suggesting that most cattle have normal mobility when arriving at slaughter facilities. Remaining were 3.0% with mobility score of 2; 0.1% with mobility score of 3; 0.02% with mobility score of 4; and 0.0% classified as downers (data not shown in tabular form). These data indicate that the majority of cattle arriving for slaughter exhibit normal mobility, and thus provides a vital benchmark for animal welfare. Moreover, researchers have acknowledged the necessity for continued improvement of animal handling to reduce cattle stress (Swanson and Morrow-Tesch, 2001; Frese et al., 2016).

Animal Identification Method

Animal identification data were collected in the previous two audits (Garcia et al., 2008; McKeith et al., 2012). For the current audit, 95.6% of cattle sampled had some form of identification, which decreased numerically from the previous audit. Types and frequency of identification observed in the NBQA-2016 (Table 1-3) were lot visual tags (61.5%), individual tags (55.0%), electronic tags (16.9%), metal-clip tags (9.2%), bar-coded tags (0.05%), wattles (0.01%), and other (2.6%). Compared to the previous audit, incidence of lot visual tags, electronic tags, metal-clip tags, wattles, and other forms of identification were lower (McKeith et al., 2012). However, incidence of individual visual tags increased by 4.4 percentage points. Many animals surveyed had more than one form of identification, and therefore, frequencies of identification types added to greater than 100%. The total number of forms of identification present on a single animal were 1 (60.4%), 2 (22.1%), 3 (11.5%), 4 (1.5%), or 5 (0.03%).

During the NBQA-2011, Country of Origin Labeling (COOL) was a great consideration for packers and may have influenced increased frequencies of cattle identification in that NBQA (McKeith et al., 2012). However, in 2015, the World Trade Organization (WTO) determined that COOL unnecessarily discriminated against imported cattle from Canada and Mexico (Greene, 2015). This ruling led to the removal of muscle cuts and grinds from beef and pork as covered commodities under COOL (USDA-AMS, 2017b). The removal of COOL may have resulted in a decline in the number of cattle bearing individual identification in NBQA-2016 due to no or limited premium for age and source verified cattle.

Hide Color

Hide color information was collected in the three previous audits (McKenna et al., 2002; Garcia et al., 2008; McKeith et al., 2012). Apparent breed type and predominant hide color has become increasingly important within the industry. Currently, about 70% of certified beef programs utilize phenotypic characteristics for claiming live animal Angus influence or predominately black-hided (USDA-AMS, 2017a). Predominately black-hided cattle represented 57.8% of total cattle surveyed followed by, Holstein (20.4%), then red-hided (10.5%), yellow-hided (4.8%), gray-hided (2.9%), brown-hided (1.3%), and white-hided (1.1%) cattle (Table 1-4). Remaining sample cattle were categorized as “other” (< 1.5%). The percentage of black-hided cattle steadily increased from NBQA-2000 to NBQA-2011; however, it declined 3.3 percentage points from NBQA-2011 to NBQA-2016 (McKeith et al., 2012). Additionally, Holstein-influenced cattle in the population increased 14.9 percentage points from the previous audit. Changes in relative abundance of black-hided cattle (declined) and Holstein cattle (increased) were likely due to a shift in cattle supply in the beef industry over the last several years. Factors such as drought and the rebuilding of the U.S. herd may have impacted the type of cattle on feed. Thus, a higher percentage of Holstein cattle was recorded in the fed beef market during NBQA-2016. Furthermore, frequencies of predominately red-hided, yellow-hided, gray-hided, brown-hided, and white-hided cattle declined from the 2011 survey (McKeith et al., 2012).

Hide Brand Assessment

Hot-iron brands have been evaluated in all previous audits (Lorenzen et al., 1993; Boleman et al., 1998; McKenna et al., 2002; Garcia et al., 2008; McKeith et al., 2012). Of the hide-on carcasses sampled in NBQA-2016, percentages of 0, 1, 2, or 3 brands present were 74.3%, 24.1%, 1.4%, and 0.2%, respectively (data not shown in tabular form). Additionally, 18.6% of hide-on cattle displayed a brand located on the butt, 6.3% with a brand located on the side, and 1.3% with a brand located on the shoulder (Table 1-5). Cattle with multiple brands represented 1.6% of hide-on carcasses sampled (Table 1-5). Over time, the frequency of hide-on carcasses with no brands has fluctuated; however, compared with the NBQA-2011, hide-on carcasses without a brand increased by 19.1 percentage points in 2016 (McKeith et al., 2012). Furthermore, incidence of cattle with butt, side, shoulder, and multiple brands, showed a numerical decrease from the previous audit. Mean hot-iron brand sizes were 173.8 cm^2 for butt brands, 584.1 cm^2 for side brands, and 226.6 cm^2 for shoulder brands (data not shown in tabular form). Compared to the 2011 survey (butt brands: 205.5 cm^2; side brands: 476.4 cm^2; shoulder brands: 200.7 cm^2), butt brands decreased in size, whereas both side and shoulder brands increased in size (McKeith et al., 2012). The greatest and most notable difference compared to NBQA-2011, was increased mean size of side brands. Programs such as Beef Quality Assurance (BQA) have worked to transition producers into branding cattle on either the butt or shoulder to increase overall hide value. Additionally, Marti et al. (2011) noted that cattle hides account for 30 – 75% of cattle by-product value. Much of the variation in cattle hot-iron branding over time may relate to the region of cattle origin and cultural history of brand usage (USDA-APHIS, 1993). Further, many states still mandate branding cattle as a form of identification. In a survey by (USDA-APHIS, 2009), hot-iron brands were the most common form of herd identification and were more common among large operations. The NBQA-2016 data shows that overall incidence of hot-iron brands has drastically decreased over the last five years. This trend is likely due to increased producer participation and implementation of programs such as BQA.

Mud or Manure Evaluation

Mud and manure are possible sources of contaminants in the beef slaughter process, and therefore the presence of mud and manure on hide-on carcasses is of utmost concern from a food safety standpoint (Dorsa, 1997; Bacon et al., 2000; Elder et al., 2000; Huffman, 2002; Bosilevac et al., 2005; Koohmaraie et al., 2005). In the current audit, 37.7% of hide-on carcasses displayed no mud or manure at the time of slaughter, which was down from 50.8% in the NBQA-2011 (data not shown in tabular form) (McKeith et al., 2012). Of cattle with mud or manure present on the hide, specific locations included legs (40.8%), belly (33.0%), tail region (15.5%), side (6.8%), and top-line (3.9%). Furthermore, for carcasses with quantifiable mud or manure on the hide, 70.3% had a small amount, 22.9% moderate, 5.0% large, and 1.7% extreme. Slight numerical differences were seen when comparing mud and manure locations to NBQA-2011 (legs: 36.8%, belly: 23.7%, side: 14.9%, tail region: 13.7%, and top-line: 11.0%) and were likely due to weather and seasonality differences (McKeith et al., 2012).

Direct or indirect contamination of carcasses with pathogens such as *E. coli* O157:H7 or *Salmonella* on beef hides is an important consideration when converting live animals to meat, and thus extreme care must be used when opening and removing the hide at slaughter (Bacon et al., 2000; Baird et al., 2006). Additionally, some studies have shown that use of pre-harvest interventions and hide-on washes may reduce prevalence of *E. coli* O157:H7 before slaughter (Bosilevac et al., 2005; Loneragan and Brashears, 2005; Baird et al., 2006). Factors such as weather, lairage conditions, and seasonality can impact presence and amount of mud or manure on cattle arriving at harvest facilities (Barkocy-Gallagher et al., 2003; Arthur et al., 2010). Therefore, multiple interventions are employed throughout the beef slaughter process to reduce prevalence of pathogenic bacteria on carcasses (Hardin et al., 1995; Graves Delmore et al., 1997; Castillo et al., 1998, 1999; Gill and Landers, 2003; Bosilevac et al., 2005; Koohmaraie et al., 2005; Bosilevac et al., 2006; Rekow et al., 2011).

Horn Evaluation

Horn prevalence has been evaluated since the original NBQA in 1991 (Lorenzen et al., 1993; Boleman et al., 1998; McKenna et al., 2002; Garcia et al., 2008; McKeith et al., 2012). For NBQA-2016, of total hide-on carcasses surveyed, 16.7% of cattle had horns and 83.3% did not have horns (Table 1-6). For all cattle sampled, horns were < 2.54 cm (5.5%), 2.54 to 12.7 cm (8.3%), and >12.7 cm (2.9%) in length. A study by Meischke et al. (1974) reported that the amount of trimmed bruised tissue from horned cattle was greater compared to hornless cattle. The percentage of cattle with horns has decreased by 7.1 percentage points from NBQA-2011 to NBQA 2016 (McKeith et al., 2012). This trend suggests that management practices have positively influenced prevalence of horns on cattle in the fed cattle population.

Carcasses dragging floor or equipment

New information was collected as part of the NBQA-2016 to determine the frequency in which slaughter cattle/carcasses were dragging the floor or unintentionally touching equipment during various stages of slaughter and dressing. These will allow different segments of the industry to understand ability of beef packers in the U.S. to accommodate increasing slaughter cattle/carcass sizes (Gray et al., 2012). The NBQA-2016 observed that 6.3% of slaughter cattle/carcasses were touching or dragging the floor or equipment (data not shown in tabular form). While these data suggested that a large percentage of slaughter cattle/carcasses do not drag across floors or equipment, it does sometimes occur and the trend toward longer and heavier carcasses will continue to affect sanitation/food safety in beef. Further, with the greater number of Holstein cattle in the present audit, this change in apparent breed type likely had an additional influence on size of cattle at slaughter.

Carcass Bruises

Carcasses historically have been assessed during the NBQA to determine bruise presence, location, and severity of bruises at the time of slaughter and dressing (Lorenzen et al., 1993; Boleman et al., 1998; McKenna et al., 2002; Garcia et al., 2008; McKeith et al., 2012). Cattle without bruises represented 61.1% of all carcasses sampled, whereas 28.2% had 1 bruise, 8.2% had 2 bruises, 2.1% had 3 bruises, 0.3% had 4 bruises, and 0.0% had more than 4 bruises (Table 1-7). Of those carcasses with a bruise, the bruises were located on the loin (29.7%), round (27.8%), chuck (16.4%), rib (14.4%), and brisket/plate/flank (11.6%). Furthermore, 77.0% of bruises were categorized as minimal, 20.6% as major, 1.7% as critical, and 0.7% as extreme (data not shown in tabular form). Subcutaneous injection-site lesions were only observed on 0.5% of all carcasses sampled (data not shown in tabular form).

The number of carcasses without a bruise has decreased by 15.9 percentage points from NBQA-2011 (McKeith et al., 2012). Additionally, there has been an increase in the number of carcasses with 1, 2, 3, and 4 bruises (Table 1-7). For all carcasses sampled, prevalence of bruises on the round, loin, rib, and chuck increased ($P < 0.05$) compared to NBQA-2011 (Figure 1-1) (McKeith et al., 2012). Bruise locations have shifted over time. Of cattle with bruising, there were fewer loin and rib bruises, but there was a greater incidence of round, chuck, and brisket/plate/flank bruising compared to NBQA-2011 (Table 1-7) (McKeith et al., 2012). Furthermore, live cattle have become larger and handling equipment will need to accommodate that growth to reduce potential carcass bruising (Gray et al., 2012).

Bruising is a detrimental loss to the overall value of a beef carcass and can result in a net loss of weight and product yield (Ferguson and Warner, 2008). Transportation is a necessary component of beef production and maximizing coordination between segments could reduce bruise related losses (Miranda-de la Lama et al., 2014). Transportation duration and distance, area allotted per animal during transport, presence of horns, and animal handling practices may influence the presence and severity of bruising in cattle at slaughter (Meischke et al., 1974; Jarvis et al., 1995; Ahola et al., 2011b; González et al., 2012b, a; Miranda-de la Lama et al., 2014; Frese et al., 2016).

Dentition

Dentition has been assessed in the past two NBQA surveys (Garcia et al., 2008; McKeith et al., 2012). For all cattle surveyed, 80.5% had 0 permanent incisors (Table 1-8). Compared to previous audits, current data suggested fewer cattle at slaughter with 0 permanent incisors (Garcia et al., 2008; McKeith et al., 2012). The remaining sample population exhibited the following number of permanent incisors: 1 (4.1%), 2 (12.7%), 3 (0.8%), 4 (1.4%), 5 (0.07%), 6 (0.2%), 7 (0.02%), and 8 (0.2%). Additionally, cattle deemed over 30-mo represented 2.7% of heads assessed for dentition characteristics.

Offal and By-Product Condemnations

Offal and by-product condemnations were assessed in all previous audits (Lorenzen et al., 1993; Boleman et al., 1998; McKenna et al., 2002; Garcia et al., 2008; McKeith et al., 2012). Frequencies of offal condemnations by USDA-FSIS are reported in Table 1-9. Reasons for liver condemnation included minor abscesses (11.8%), major abscesses (6.0%), flukes (1.1%), contamination (10.1%), and other reasons (1.8%). Reasons for condemnation of lungs included mild pneumonia (4.0%), moderate pneumonia (2.3%), severe pneumonia (1.1%), contamination (8.7%), and other reasons (2.0%). Hearts were condemned on 11.1% of all viscera sampled (data not shown in tabular form). Reasons for viscera condemnations included contamination (13.4%) and abscesses (2.8%). Fetuses were reported in 0.6% of full viscera sampled. From NBQA-2011 to NBQA-2016 (Figure 1-2), condemnations due to liver abscesses, liver contamination, and lung contamination increased ($P < 0.05$), whereas condemnations due to liver flukes and lung pneumonia declined ($P < 0.05$) (McKeith et al., 2012). When comparing NBQA-2016 to all previous audits, incidence of liver abscesses increased greatly (Lorenzen et al., 1993; Boleman et al., 1998; McKenna et al., 2002; Garcia et al., 2008; McKeith et al., 2012). Prevalence of lung and viscera condemnations also increased, mostly attributed to contamination. Liver abscesses are a leading cause for condemnations at slaughter and result in significant economic loss (Nagaraja and Lechtenberg, 2007; Brown and Lawrence, 2010; Reinhardt and Hubbert, 2015). Brown and Lawrence (2010) noted that carcasses with abnormal livers were less valuable than normal carcasses and recognized the implementation of technologies to reduce prevalence of abscesses to reduce this economic loss.

While not recorded previously, information for both the amount of trimming required and the rate of condemnations of heads and tongues was collected. Heads were trimmed (T) or condemned (C) for: inflamed lymph nodes – T (0.1%), inflamed lymph nodes – C (0.4%), abscesses – T (0.01%), abscesses – C (0.1%), contamination – T (1.0%), contamination – C (1.9%), and other reasons (0.2%). Additionally, tongues were trimmed (T) or condemned (C) for: inflamed lymph nodes – T (2.0%), inflamed lymph nodes – C (0.3%), hair sore – T (3.2%), hair sore – C (0.03%), cactus tongue – T (0.1%), cactus tongue – C (0.0%), contamination – T (1.8%), contamination – C (0.7%), and for other reasons (0.9%). Over time, both head and tongue condemnations have declined. Specifically, compared to the previous audit, head condemnations have decreased by 4.5 percentage points and tongue condemnations by 8.1 percentage points (McKeith et al., 2012).

Data from Marti et al. (2011) showed that the market for beef by-products has grown to nearly 19 billion pounds in recent years. Use of by-products allows the beef industry to realize revenue that would otherwise be lost, and reduces the cost of disposal of such products (Marti et al., 2011). By-products from beef carcasses are an important economic consideration for the viability of the beef trade. By-products are utilized extensively in export trade, but also for pharmaceutical, cosmetic, and industrial products.

Conclusions

The NBQA remains an important measure for the U.S. beef industry as it tries to improve quality and consumer demand. Characteristics evaluated in this audit will be relayed to cattle producers, which can ultimately enhance consistency and quality of cattle and beef products in the U.S. beef supply chain. Trends observed in NBQA-2016 included fewer cattle having identification; fewer black-hided cattle and more Holstein cattle; more cattle without a brand or horns; fewer carcasses without bruises; more liver, lung, and viscera condemnations; and fewer head and tongue condemnations. Data from this survey can be utilized in all segments of beef production to improve upon current management practices and implement innovative techniques to enhance beef quality and consistency in the U.S. supply chain.

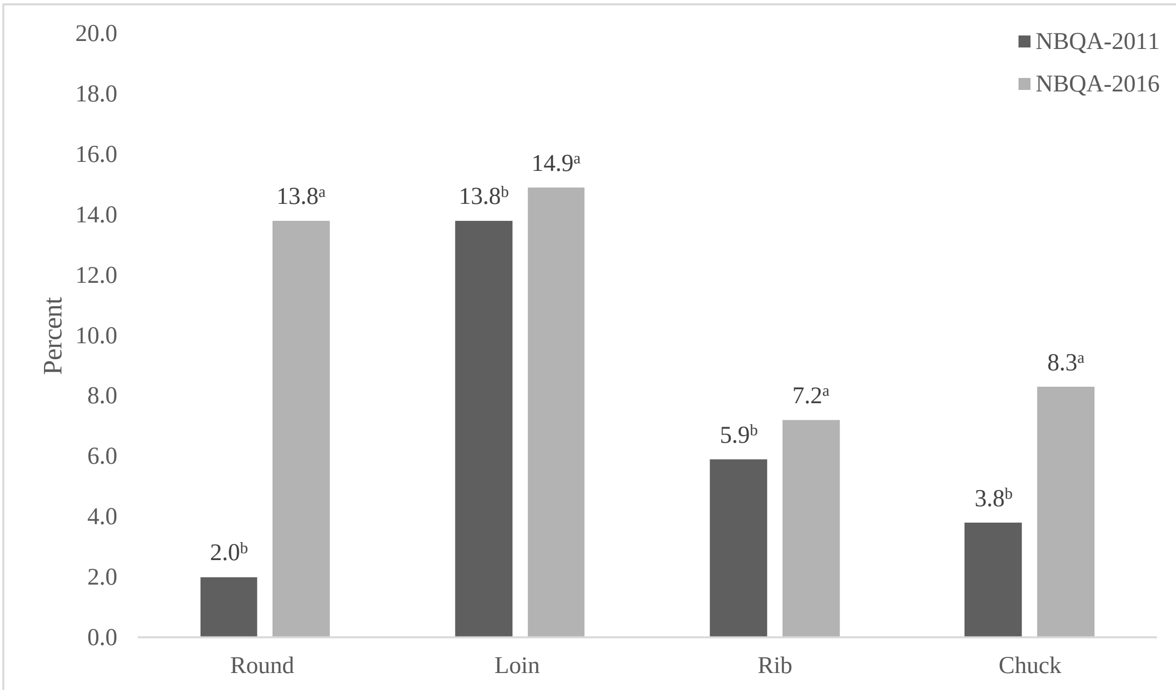


Figure 1-1. National Beef Quality Audit (NBQA): Frequency distributions of bruises in primals from all carcasses sampled in NBQA-2011 and NBQA-2016 (χ^2 for round $P < 0.0001$, loin $P = 0.0022$, rib $P < 0.0001$, and chuck $P < 0.0001$). Means within primals with different superscripts differ ($P < 0.05$). Total number of observations for bruises was 18,159 (NBQA-2011) and 24,366 (NBQA-2016). (McKeith et al., 2012).

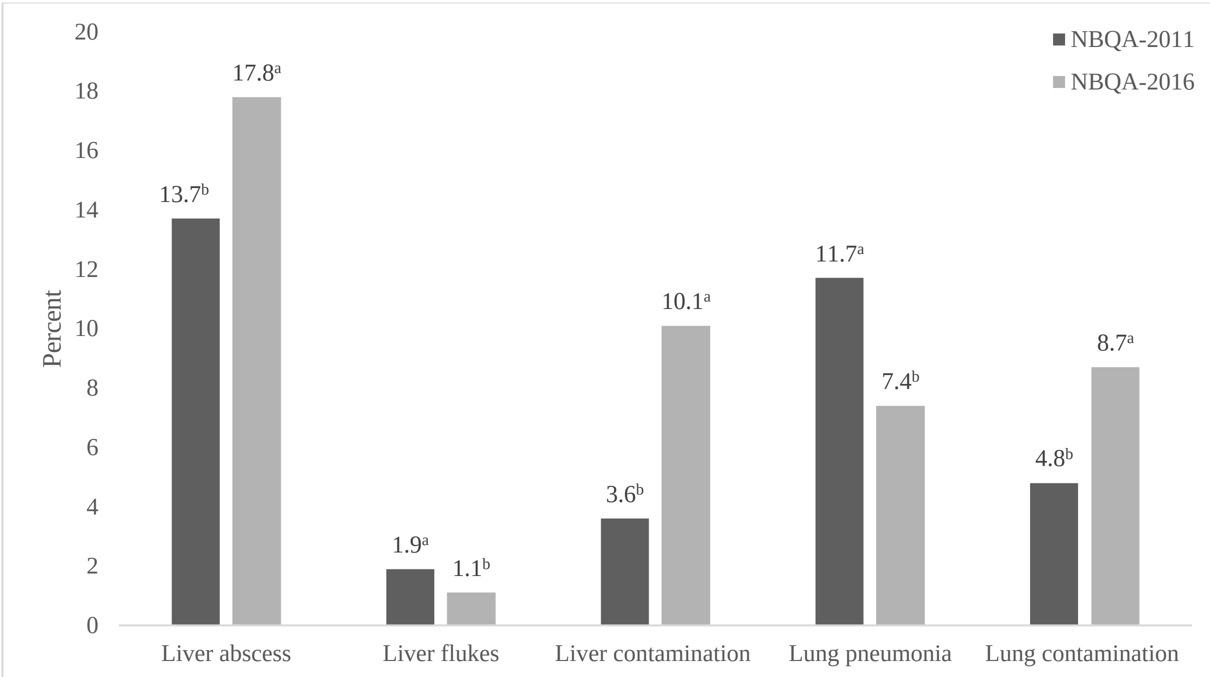


Figure 1-2. National Beef Quality Audit (NBQA): Frequency distributions for specific liver and lung condemnations from all carcasses sampled in NBQA-2011 and NBQA-2016 (χ^2 for liver abscesses $P < 0.0001$, liver flukes $P < 0.0001$, liver contamination $P < 0.0001$, lung pneumonia $P < 0.0001$, and lung contamination $P < 0.0001$). Means within specific condemnation reason with different superscripts differ ($P < 0.05$). Total number of observations for liver and lung condemnations was 17,926 (NBQA-2011) and 24,940 (NBQA-2016). (McKeith et al., 2012).

Table 1-1. National Beef Quality Audit (NBQA): Company and location of harvest floor assessments

Company	Location
American Foods Group – Green Bay Dressed Beef	Green Bay, WI
Cargill Taylor Beef	Wyalusing, PA
Cargill Meat Solutions	Dodge City, KS
Cargill Meat Solutions	Schuyler, NE
Central Valley Meat	Hanford, CA
Creekstone Farms Premium Beef	Arkansas City, KS
Harris Ranch Beef Company	Selma, CA
JBS Swift & Company	Cactus, TX
JBS Swift & Company	Greeley, CO
JBS Swift & Company	Green Bay, WI
JBS Swift & Company	Plainwell, MI
JBS Swift & Company	Souderton, PA
JBS Swift & Company	Tolleson, AZ
National Beef	Liberal, KS
Tyson Fresh Meats	Amarillo, TX
Tyson Fresh Meats	Dakota City, NE
Tyson Fresh Meats	Lexington, NE

Table 1-2. National Beef Quality Audit (NBQA): Mean values for time and distance traveled, number of cattle in the loads, trailer dimensions, and the subsequent area allotted per head for all trailer types surveyed[1]

Transportation characteristics	n^2	Mean	Std. Dev.	Min	Max
Time traveled (h)	220	2.7	2.4	0.25	12.0
Distance traveled (km)	217	218.5	213.2	12.9	1,400.1
Number of cattle in load	220	36.6	4.8	10	47
Number of compartments used	217	3.5	0.9	2	6
Trailer dimensions (m^2)	212	40.85	2.56	17.84	59.09
Area allotted per head (m^2)	212	1.13	0.17	0.85	2.28

[1]Approximately 10% of cattle trucks were sampled within a day's production at each plant.

[2] These are the number of trailers that were surveyed at the plants.

Table 1-3. National Beef Quality Audit (NBQA): Percentages of hide-on carcasses that were identified individually and type of identification used in NBQA-2005, NBQA-2011, and NBQA-2016[1,2,3]

Item	NBQA-2005	NBQA-2011	NBQA-2016 (± SEM)
With identification	90.3	97.5	95.6 ± 0.1
No identification	9.7	2.5	4.4 ± 0.1
Lot visual tags	63.2	85.7	61.5 ± 0.3
Individual visual tags	38.7	50.6	55.0 ± 0.3
Electronic tags	3.5	20.1	16.9 ± 0.2
Metal-clip tags	11.8	15.7	9.2 ± 0.2
Bar-coded tags	0.3	0.0	0.05 ± 0.01
Wattles	0.0	0.5	0.01 ± 0.0
Other	2.5	5.3	2.6 ± 0.1

[1]Numbers exceeded 100% due to animals having multiple forms of identification.

[2]Total number of observations for animal identification were: 49,330 (NBQA-2005); 18,288 (NBQA-2011); 24,615 (NBQA-2016).

[3]NBQA-2005 (Garcia et al., 2008); NBQA-2011 (McKeith et al., 2012).

Table 1-4. National Beef Quality Audit (NBQA): Percentages of hide-on carcasses with predominant hide color or breed type evaluated in NBQA-2000, NBQA-2005, NBQA-2011, and NBQA-2016[1,2]

Item	NBQA-2000	NBQA-2005	NBQA-2011	NBQA-2016 (± SEM)
Black	45.1	56.3	61.1	57.8 ± 0.3
Holstein (black and white)	5.7	7.9	5.5	20.4 ± 0.3
Red	31.0	18.6	12.8	10.5 ± 0.2
Yellow	8.0	4.9	8.7	4.8 ± 0.1
Gray	4.0	6.0	5.0	2.9 ± 0.1
Brown	1.7	3.0	5.0	1.3 ± 0.1
White	3.2	2.3	1.4	1.1 ± 0.1

[1]Total number of observations for hide color were: 43,415 (NBQA-2000); 49,330 (NBQA-2005); 15,143 (NBQA-2011); 24,672 (NBQA-2016).

[2]NBQA-2000 (McKenna et al., 2002); NBQA-2005 (Garcia et al., 2008); NBQA-2011 (McKeith et al., 2012).

Table 1-5. National Beef Quality Audit (NBQA): Percentages of hot-iron brands on hide-on carcasses evaluated in NBQA-1991, NBQA-1995, NBQA-2000, NBQA-2005, NBQA-2011, and NBQA-2016[1,2,3]

Item	NBQA-1991	NBQA-1995	NBQA-2000	NBQA-2005	NBQA-2011	NBQA-2016 (± SEM)
No brands	55.0	47.7	49.3	61.3	55.2	74.3 ± 0.3
Butt brand	29.9	38.7	36.3	26.5	35.2	18.6 ± 0.2
Side brand	13.8	16.8	13.7	7.4	9.0	6.3 ± 0.2
Shoulder brand	0.8	3.0	3.6	1.2	2.5	1.3 ± 0.1
Cattle with multiple brands	2.1	6.2	4.4	3.6	9.9	1.6 ± 0.1

[1]Number exceeded 100% due to animals having multiple brands.

[2]Total number of observations for hide brands were: 32,265 (NBQA-1991); 56,612 (NBQA-1995); 43,415 (NBQA-2000); 49,330 (NBQA-2005); 15,358 (NBQA-2011); 24,685 (NBQA-2016).

[3]NBQA-1991 (Lorenzen et al., 1993); NBQA-1995 (Boleman et al., 1998); NBQA-2000 (McKenna et al., 2002); NBQA-2005 (Garcia et al., 2008); NBQA-2011(McKeith et al., 2012).

Table 1-6. National Beef Quality Audit (NBQA): Percentages of hide-on carcasses evaluated for the presence of horns in NBQA-1991, NBQA-1995, NBQA-2000, NBQA-2005, NBQA-2011, and NBQA-2016[1,2]

Item	NBQA-1991	NBQA-1995	NBQA-2000	NBQA-2005	NBQA-2011	NBQA-2016 (± SEM)
With horns	31.1	32.2	22.7	22.3	23.8	16.7 ± 0.2
No horns	68.9	67.8	77.3	77.7	76.2	83.3 ± 0.2

[1]Total number of observations for presence of horns were: 32,265 (NBQA-1991); 56,612 (NBQA-1995); 43,415 (NBQA-2000); 49,330 (NBQA-2005); 18,199 (NBQA-2011); 24,588 (NBQA-2016).

[2] NBQA-1991 (Lorenzen et al., 1993); NBQA-1995 (Boleman et al., 1998); NBQA-2000 (McKenna et al., 2002); NBQA-2005 (Garcia et al., 2008); NBQA-2011(McKeith et al., 2012).

Table 1-7. National Beef Quality Audit (NBQA): Percentages of bruises and bruise location (cattle that had at least 1 bruise) for carcasses evaluated in NBQA-1991, NBQA-1995, NBQA-2000, NBQA-2005, NBQA-2011, and NBQA-2016[1,2]

Item	NBQA-1991	NBQA-1995	NBQA-2000	NBQA-2005	NBQA-2011	NBQA-2016 (± SEM)
No bruises	60.8	51.6	53.3	64.8	77.0	61.1 ± 0.3
1 bruise	25.0	30.9	30.9	25.8	18.8	28.2 ± 0.3
2 bruises	10.6	12.8	11.4	7.4	3.4	8.2 ± 0.2
3 bruises	3.5	3.7	3.5	1.6	0.6	2.1 ± 0.1
4 bruises	0.2	0.9	0.8	0.4	0.2	0.3 ± 0.04
More than 4 bruises	nd[3]	0.1	0.1	0.0	0.1	0.0 ± 0.0
Location of bruise						
Loin	23.4	41.1	25.9	32.6	50.1	29.7 ± 0.4
Rib	14.4	20.8	19.4	19.5	21.3	14.4 ± 0.3
Chuck	16.7	30.8	28.2	27.0	13.8	16.4 ± 0.3
Brisket/plate/flank	0.3	0.0	11.6	10.3	7.5	11.6 ± 0.3
Round	2.7	7.2	14.9	10.6	7.3	27.8 ± 0.4

[1] Total number of observations for carcass bruises were: 37,002 (NBQA-1991); 42,156 (NBQA-1995); 43,595 (NBQA-2000); 49,330 (NBQA-2005); 18,159 (NBQA-2011); 24,366 (NBQA-2016).

[2] NBQA-1991 (Lorenzen et al., 1993); NBQA-1995 (Boleman et al., 1998); NBQA-2000 (McKenna et al., 2002); NBQA-2005 (Garcia et al., 2008); NBQA-2011(McKeith et al., 2012).

[3] nd = not determined.

Table 1-8. National Beef Quality Audit (NBQA): Percentages of the number of permanent incisors evaluated in NBQA-2005, NBQA-2011, and NBQA-2016[1,2]

No. of permanent incisors	NBQA-2005	NBQA-2011	NBQA-2016
0	82.2	87.3	80.5
1	5.2	1.4	4.1
2	9.9	8.0	12.7
3	0.4	0.9	0.8
4	1.2	1.9	1.4
5	0.1	0.3	0.07
6	0.3	0.2	0.2
7	0.0	0.1	0.02
8	0.7	0.02	0.2

[1]Total number of observations for dentition were: 49,330 (NBQA-2005); 16,051 (NBQA-2011); 24,382 (NBQA-2016).

[2] NBQA-2005 (Garcia et al., 2008); NBQA-2011 (McKeith et al., 2012).

Table 1-9. National Beef Quality Audit (NBQA): Percentages of offal condemnations for carcasses evaluated in NBQA-1991, NBQA-1995, NBQA-2000, NBQA-2005, NBQA-2011, and NBQA-2016[1,2,3]

Item	NBQA-1991	NBQA-1995	NBQA-2000	NBQA-2005	NBQA-2011	NBQA-2016 (± SEM)
Liver condemnations	19.2	22.2	30.3	24.7	20.9	30.8 ± 0.3
Lung condemnations	5.1	5.0	13.8	11.5	17.3	18.2 ± 0.2
Tripe condemnations	3.5	11.0	11.6	11.6	nd[4]	nd
Viscera condemnations	0.1	nd	nd	nd	9.3	16.3 ± 0.2
Head condemnations	1.1	0.9	6.2	6.0	7.2	2.7 ± 0.1
Tongue condemnations	2.7	3.8	7.0	9.7	10.0	1.9 ± 0.1

[1] Total number of observations for viscera condemnations were: 37,925 (NBQA-1991); 50,517 (NBQA-1995); 8,588 (NBQA-2000); 49,330 (NBQA-2005); 17,926 (NBQA-2011); 24,940 (NBQA-2016).

[2] Total number of observations for head and tongue condemnations were: 30,646 (NBQA-1991); 47,581 (NBQA-1995); 8,588 (NBQA-2000); 49,330 (NBQA-2005); 17,926 (NBQA-2011); 26,657 (NBQA-2016).

[3] NBQA-1991 (Lorenzen et al., 1993); NBQA-1995 (Boleman et al., 1998); NBQA-2000 (McKenna et al., 2002); NBQA-2005 (Garcia et al., 2008); NBQA-2011(McKeith et al., 2012).

4 nd = not determined.

2. Cooler Assessment

ABSTRACT

The National Beef Quality Audit (NBQA) - 2016 utilized in-plant cooler assessments to benchmark the current status of the fed steer and heifer beef industry in the United States. In-plant cooler assessments (*n* = 9,106 carcasses) were conducted at 30 facilities where approximately 10% of a single-day's production were evaluated for USDA quality grade (QG) and yield grade (YG) factors. Frequencies of evaluated traits were 66.5% steer and 33.4% heifer sex classes and 82.9% native, 15.9% dairy-type, and 1.2% *Bos indicus* estimated breed types. Mean USDA YG factors were 1.42 cm for adjusted fat thickness, 89.5 cm^2 for LM area, 390.3 kg for HCW, and 1.9% for KPH. Mean USDA YG was 3.1 with a frequency distribution of 9.6% YG 1, 36.7% YG 2, 39.2% YG 3, 12.0% YG 4, and 2.5% YG 5. Mean USDA QG traits were $Small^{70}$ for marbling score, A^{64} for overall maturity, A^{55} for lean maturity, and A^{69} for skeletal maturity. Mean USDA QG was $Select^{96}$ with a frequency distribution of 3.8% Prime, 67.3% Choice, 23.2% Select, and 5.6% lower score. Lower score included dark cutter (1.9%), blood splash (0.1%), and hard bone, which are USDA overall maturity scores of C or older (1.8%). Marbling score distributions were 0.85% Slightly Abundant or greater, 7.63% Moderate, 23.54% Modest, 39.63% Small, 23.62% Slight, and 0.83% Traces or less. Carcasses that were Choice or Select and USDAYG 2 or 3 accounted for 70.7% of the carcasses evaluated. Compared to the previous NBQA, we found a numerical increase in mean USDA YG, USDA QG, adjusted fat thickness, HCW, LM area, and marbling score with an increase in dairy-type carcasses and percentage of carcasses grading USDA Prime and Choice, as well as frequency of USDA YG 4 and 5. The findings from this study will be utilized by all segments of the industry to understand and improve the quality of fed steer and heifer beef that is being produced.

INTRODUCTION

The first National Beef Quality Audit (**NBQA**) was conducted in 1991 to create a nationwide snapshot of the status of the beef industry. Following the completion of NBQA-1991, the Executive Summary called for the NBQA to be repeated within the next 5 years in order to understand what changes had occurred and what areas still required industry focus (National Cattlemen's Association, 1992). Over the last 25 years, 5 NBQAs have been conducted (Lorenzen et al., 1993; Boleman et al., 1998; McKenna et al., 2002; Garcia et al., 2008; Gray et al., 2012; McKeith et al., 2012; Moore et al., 2012). Successive audits to assess the status of the fed steer and heifer industry allow for ongoing improvements in US beef production, along with continued advancements in producer education.

The 2016 NBQA (**NBQA-2016**) continues the trend of documenting and analyzing the quality and consistency of the US fed steer and heifer beef industry. This aspect of the NBQA-2016 focuses on the assessments of carcass characteristics including USDA quality and yield grades from a nationwide sample of beef. Through this effort, quantifying progress that has been made over time and setting strategies allows the beef industry to identify areas for continued improvement.

MATERIALS AND METHODS

Institutional Animal Care and Use Committee approval was not required for this study because no live animals were involved.

General Overview

Before data collection, a correlation meeting was held to emphasize clarity and consistency of data to be collected by collaborating institutions. In-plant cooler assessments were conducted at 30 federally-inspected beef processing facilities, which were selected to represent virtually all the fed steer and heifer beef industry across the United States (Table 2-1). These assessments occurred from January 2016 to December 2016 and were completed by personnel from 6 collaborating institutions. Each facility was surveyed for the entirety of one day's production; data were collected for both shifts in facilities that processed cattle for two shifts a day.

Carcass Assessment

Beef carcasses (n = 9,106) were selected throughout the day's production to represent approximately 10% of each production lot. Trained personnel evaluated each carcass for HCW, LM area (measured by dot grid, video image analysis instrument, or blotting paper), apparent breed type (native, dairy, or *Bos indicus*), sex class, carcass defects (dark cutter, blood splash, calloused eye, yellow fat), any certified or marketing program, and whether the animal was 30 mo or older as determined by dentition. The (USDA, 2016) standards were used for evaluating sex class. Apparent breed type was determined using the procedures defined by (Lorenzen et al., 1993): *Bos indicus* type cattle were those with dorsal thoracic hump (M. rhomboideus, overlying muscles, and subcutaneous fat) with a height greater than 10.2 cm, dairy-type cattle were identified as those with thin muscling in relation to skeletal size, and all other cattle were classified as native. Carcasses that were denoted as qualifying for certified programs were recorded. Lean maturity, skeletal maturity, preliminary yield grade, percentage of KPH, and marbling score were evaluated by United States Department of Agriculture, Agricultural Marketing Service, Quality Assessment Division personnel (USDA, 2016). For beef processors that removed KPH before grading, the estimated KPH value used by the facility was recorded (some establishments calculated KPH based on before and after carcass weights and some used a standard average KPH measurement).

Statistical Analysis

All analyses were performed using JMP Software (JMP, Version 12.0.1 SAS Institute Inc., Cary, NC, 1989-2007) and Microsoft Excel for Mac 2016 (Microsoft Corporation, Redmond, WA). The Fit Y by X function was used for ANOVA, and least squares means comparisons were conducted using Student's t test. Correlations were determined using the multivariate function. Frequency distributions, means, SD, and minimum and maximum values were determined using the distribution function.

RESULTS AND DISCUSSION

Carcass Assessment

The mean USDA yield grade (YG) for this study was 3.1 (Table 2-2). Table 2-3 reports means for USDA YG from past NBQA; 3.2 for NBQA-1991 (Lorenzen et al., 1993), 2.8 for NBQA-1995 (Boleman et al., 1998), 3.0 for NBQA-2000 (McKenna et al., 2002), 2.9 for NBQA-2005 (Garcia et al., 2008), and 2.9 for NBQA-2011 (Moore et al., 2012). Figure 2-1 shows the frequency distribution of carcasses by one-half YG increments. The frequencies were 9.6% YG 1, 36.7% YG 2, 39.2% YG 3, 12.0% YG 4, and 2.5% YG 5. Moore et al. (2012) reported YG frequencies from NBQA-2011 as 12.4% YG 1, 41.0% YG 2, 36.3% YG 3, 8.6% YG 4, and 1.6% YG 5. The mean USDA YG factors were 1.4 cm for adjusted fat thickness (AFT), 390.3 kg for HCW, 89.5 cm^2 for LM area and 1.9% for KPH (Table 2-2). When compared to NBQA-2011, mean AFT, HCW, and LM area all numerically increased. The most notable difference in this study was a 16.3 kg increase in mean HCW from NBQA-2011 (Moore et al., 2012). There are many factors that have affected cattle weights during the period between the last two audits including but not limited to heavier cattle entering the feedlots, extended periods of cattle on feed, and a larger proportion of steers compared to heifers in the slaughter mix (Mathews and Haley, 2015).

Beginning with NBQA-1995, there has been a continued increase in HCW. Bunting (2015) discussed potential reasons for carcasses continuing to get heavier, with processing facilities' labor costs and cattle availability at the forefront. Heavier carcasses allowed facilities to process the same number of cattle with the same amount of labor, and resulted in a greater amount of salable beef. For this reason, lighter than average carcasses are typically more severely discounted than those carcasses slightly above average. Additionally, a reduction in the fed cattle supply may limit the packers' ability to discount heavy-weight carcasses. As HCW continues to increase, effect on steak thickness and consumer preferences becomes more crucial. Dykstra (2016) evaluated the relationship among USDA YG, HCW, and steak size in which the optimal steak was 2.54 cm thick, and weighed approximately 340.2 g. To achieve these steak parameters from a HCW of approximately 419.5 kg, the carcass must be a YG 4. A YG 2 carcass of the same weight would have a larger LM area, and would not result in the desired steak thickness. Moreover, consumers generally prefer thicker steaks with a smaller surface area (Maples et al., 2016). The correlation constant between HCW and LM area ($r = 0.40$) indicates that while there is a positive relationship between the two traits, a larger HCW does not always result in a larger LM area. Lawrence et al. (2008) reported that LM area is not a linear function of HCW, rather it is quadratic. Because of this relationship, Lawrence et al. (2008) found that the USDA calculated YG equation benefits those carcasses lighter than 363 kg for having above average muscling, but penalizes those carcasses heavier than 363 kg for having below average muscling.

Lambert (1991) identified outlier cattle, such as those with a HCW greater than 409.1 kg, as a lost opportunity and reported approximately 1.5% of carcasses surveyed surpassed this threshold. The current study observed almost half (44.1%) of carcasses surveyed exceeded 409.1 kg (Figure 2-2). (McKenna et al., 2002) addressed concerns regarding discounts for carcasses above 431 kg. The frequency of carcasses exceeding 431 kg were 4.6% in the NBQA-2000 (McKenna et al., 2002), 5.1% in the NBQA-2005 (Garcia et al., 2008), 11.1% in the NBQA-2011 (Moore et al., 2012), and 25.7% in the NBQA-2016. However, Moore et al. (2012) reported in NBQA-2011 that the current heavy-weight carcass price discount was for those that exceeded 454 kg. Moore et al. (2012) reported 3.7% of carcasses greater than 454 kg and the current study shows that 12.4% were above this threshold. In response to the continued increase in HCW, the threshold for heavy-weight discounts is now at 477.3 kg (USDA Market News Service, 2017). Five percent of the carcasses surveyed in NBQA-2016 exceeded this threshold. Kay (2012) stated increased carcass size was a method to combat reduced cattle numbers. Although total number of cattle slaughtered is the lowest in decades, total beef production has increased (Maples et al., 2016). Additionally, increased carcass size and decreased carcass numbers have the potential to increase sustainability by producing a greater amount of beef with the same amount of resources (Bunting, 2015). Finally, Tatum et al. (2006), in a study of the factors that affect value in beef grids, found that the most important driver of carcass value was carcass weight accounting for 70 to 90% of the variation in total revenue when the Choice/Select spread was less than US$10/45.4 kg carcass weight. Without question, the increasing carcass weights observed over the lifetime of these audits are often driven by marketplace conditions.

As USDA YG increased from YG 1 to YG 5, mean AFT and HCW increased ($P < 0.05$) and mean LM area decreased ($P < 0.05$; Table 2-4). This is to be expected, as AFT, HCW, and LM area are all factors in the USDA YG equation. Between USDA YG 4 and 5, no difference ($P > 0.05$) was detected between mean USDA quality grade (QG), marbling score, and KPH percentage. The least squares means of carcass traits by HCW group are reported in Table 2-5. As HCW increases, YG and AFT increase. Mean USDA QG increased as carcass weight increased up to 363.6 kg ($P < 0.05$), thereafter mean USDA quality grade did not improve. Additionally, mean LM area increased as carcass weight increased ($P < 0.05$), with no differences seen in mean LM area at or above 454 kg ($P > 0.05$). Table 2-6 reports the least squares means of carcass traits by AFT groups. As AFT increases, USDA YG increases ($P < 0.05$). The correlation between AFT and marbling score ($r = 0.24$) indicates that although they are related, having a greater amount of external fat does not always result in a greater amount of marbling. The AFT and marbling correlation from NBQA-2011 was 0.34 (Moore et al., 2012). The decrease in the correlation coefficient could be a result of external fat increasing more rapidly than marbling.

The mean USDA QG in this study was Select^{96}. Previous NBQA means for USDA QG were Select^{86} for NBQA-1991 (Lorenzen et al., 1993), Select^{79} for NBQA-1995 (Boleman et al., 1998), Select^{85} for NBQA-2000 (McKenna et al., 2002), Select^{90} for NBQA-2005 (Garcia et al., 2008), and Select^{93} for NBQA-2011 (Moore et al., 2012). The frequency of USDA QG was 3.8% Prime, 67.3% Choice, 23.2% Select, and 5.6% other. The "other" category included Standard, Commercial, Utility, dark cutter, blood splash, hard bone, and calloused eye. The NBQA-2011 frequency of USDA QG was 2.1% Prime, 58.9% Choice, 32.6% Select, 5.1% Standard, 0.9% Commercial, and 0.3% Utility (Moore et al., 2012). These data show a dramatic increase in the frequency of Prime (+1.7 percentage points) and Choice (+8.4 percentage points) carcasses, and a decrease in the frequency of Select (-9.4 percentage points) carcasses since 2011. This study observed the highest frequency of Choice carcasses (67.3%) since the 1974 Market Consist (Abraham, 1977) reported 74% Choice. The notable increase in HCW also significantly influences the increased marbling scores and QG outcomes. Additionally, the increase in dairy-type carcasses—16.3% versus 9.9% reported by Moore et al. (2012) for the last audit—likely plays a role in the increased mean USDA QG and marbling score. Of the carcasses that graded Prime, 32.0% were classified as dairy-type.

Means for factors contributing to QG in the current audit include Small^{70} for marbling score, A^{55} for lean maturity, A^{69} for skeletal maturity, and A^{64} for overall maturity. Mean marbling score was increased compared with previous audits, continuing the trend that began with NBQA-1995. Marbling score distributions were as follows: Slightly Abundant or greater (0.85%), Moderate (7.63%), Modest (23.54%), Small (39.63%), Slight (23.62%), Traces or less (0.83%). For both Prime and Choice, the greatest proportion of carcasses were within the lowest third of the grade (83.1% low Prime and 55.5% low Choice; Table 2-7). However, the majority of carcasses qualifying for Select were in the top half of the grade (61.2% high Select), which would be expected as Small/Slight+ are the peak of the marbling normal distribution curve. As USDA QG increased from Select to Prime, USDA YG, AFT, and HCW increased ($P < 0.05$; Table 2-8). In contrast, LM area decreased as USDA QG increased from Select to Prime ($P < 0.05$). Throughout the NBQAs, there has been a consistent trend of carcasses with higher USDA QG possessing numerically heavier HCW and smaller LM areas.

The largest numerical percentage of carcasses (29.9%) were Choice YG 3 (Table 2-9). The frequency of carcasses that were Choice or Select and USDA YG 2 or 3 was 70.7%, which is comparable to NBQA-2011 (72.0%) (Moore et al., 2012). Non-conforming carcasses (those grading Standard or below and/or USDA YG 4 and 5) in the current audit accounted for 18.2% of all carcasses, which was similar to that reported by (Garcia et al., 2008) at 18.3% of all carcasses. However, Moore et al. (2012) found 15.6% of the carcasses to be non-conforming, which is numerically lower than was found in this audit. The increased proportion of non-conforming carcasses is consistent with the increased frequency of USDA YG 4 and 5 observed in NBQA-2016, which was noted earlier in the discussion of YG trends.

The overall presence of dark cutting was 1.9%, which is numerically lower than NBQA-2011 (3.2%) (Moore et al., 2012) and was the lowest surveyed in NBQA history. Blood splash (0.1%) also decreased numerically from NBQA-2011 (0.3%) (Moore et al., 2012). Additionally, the frequency of hard bone, or carcasses with an overall USDA maturity score of C or greater, was 1.8%.

The frequencies of estimated breed type were 82.9% native, 15.9% dairy-type, and 1.2% *B. indicus*. When compared to NBQA-2011, there was a 6.0 percentage point increase in dairy-type cattle and a 5.4 percentage point decrease in native cattle. This increase in dairy-type cattle is consistent with the upward trend from NBQA-2000 (6.9%), NBQA-2005 (8.3%), and NBQA-2011 (9.9%) (McKenna et al., 2002; Garcia et al., 2008; Moore et al., 2012). Market conditions such as the U.S. drought of 2012, the reduced beef cow herd, and record beef prices created more competitive markets for Holstein steers (Felix, 2016), and an increase in calf-fed dairy beef programs offered by some packers likely had an influence on the greater proportion of dairy-type cattle (Bunting, 2015). Native carcasses possessed the greatest USDA YG (3.1), AFT (1.5 cm), HCW (390.3 kg), and KPH (2.0%) ($P < 0.05$; Table 2-10). Dairy type carcasses had the greatest QG (Choice^{17}), and marbling score (Small^{86}), and the least AFT (0.9 cm) and smallest LM area

(80.6 cm^2) ($P < 0.05$). Additionally, of the dairy carcasses surveyed, 8.0% graded USDA Prime (data not shown in tabular form). This is consistent with the findings from Albrecht et al. (2006) in which Holstein carcasses possessed a greater amount and finer flecks of marbling.

Of carcasses surveyed, steers and heifers accounted for 66.5% and 33.4%, respectively. The numerical increase in frequency of steers in the current study from NBQA-2011 (63.7%) (Moore et al., 2012) is consistent with the increase in dairy cattle. Steers possessed greater mean USDA QG, HCW, and KPH ($P < 0.05$; Table 2-11). Heifers had increased mean AFT, LM area, marbling score, lean maturity, skeletal maturity, and overall maturity ($P < 0.05$).

In 2016, the USDA requested comments on amending the United States Standards for grades of carcass beef to allow cattle that were classified as under 30 mo by dentition or age records to qualify for A maturity. Carcasses that were classified as under 30 mo by dentition had increased USDA QG and LM area, coupled with decreased AFT, HCW, marbling score, skeletal, and overall maturity compared with those 30 mo or older ($P < 0.05$; Table 2-12). There was no difference between the mean lean maturity between the dental age classes ($P > 0.05$). Research has not reported differences in palatability between ossification groups within dental age classes (Lawrence et al., 2001; Acheson et al., 2014; Semler et al., 2016). Dentition was reported as a better predictor of actual age than USDA maturity score (Lawrence et al., 2001; Raines et al., 2008).

Conclusions

The fed steer and heifer beef industry is constantly evolving and the NBQA allows a current benchmark to be established and progress to be evaluated. Through these assessments of beef carcasses across the United States and compared with the last audit, we found a numerical increase in mean USDA YG, USDA QG, AFT, HCW, LM area, and marbling score. Furthermore, an increase in dairy-type carcasses and percentage of carcasses grading USDA Prime and Choice, as well as frequency of USDA YG 4 and 5 was observed. These data indicate that while the industry is improving the quality of beef being produced, there is also an increase in size and fatness.

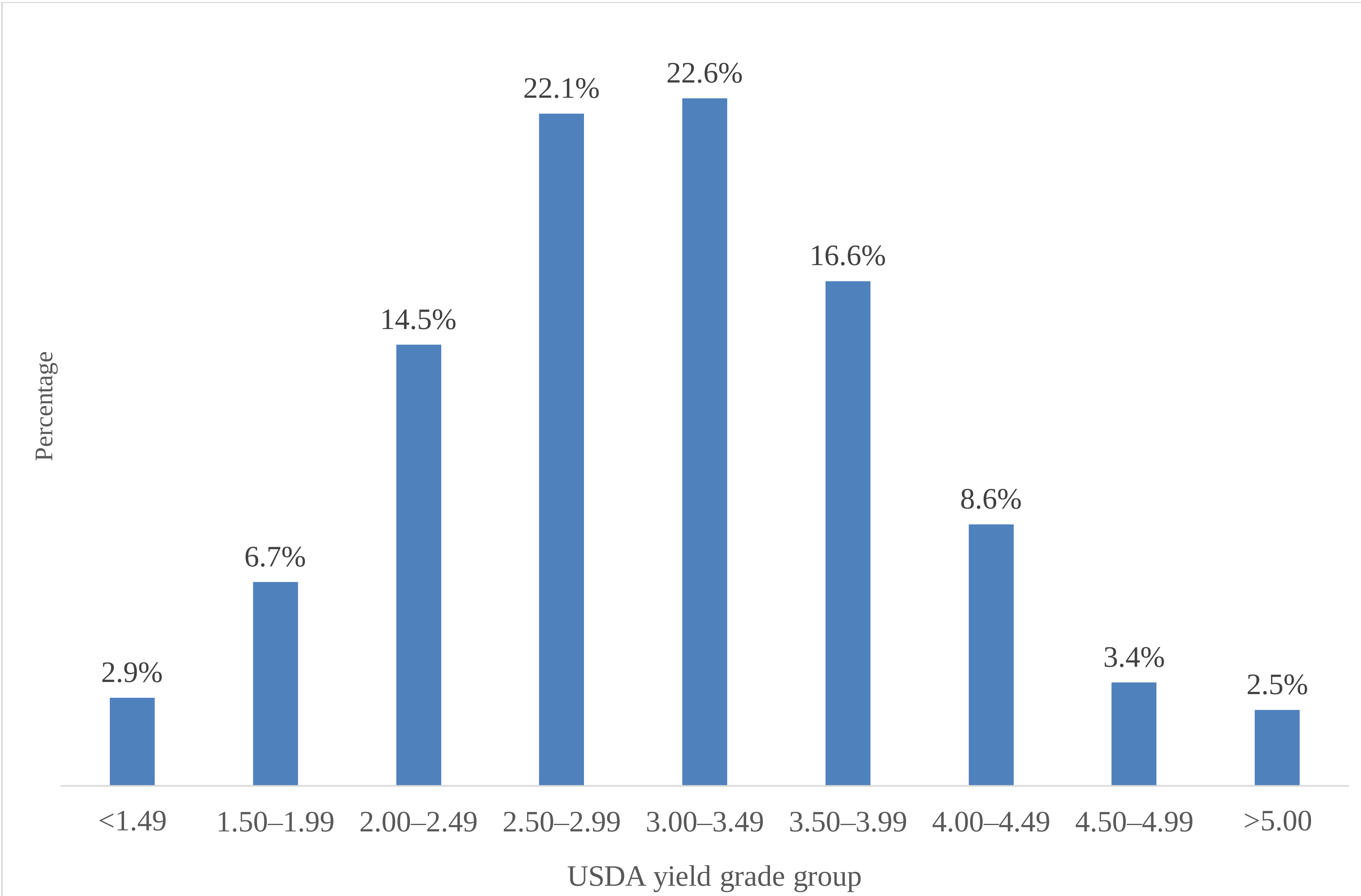


Figure 2-1. National Beef Quality Audit (NBQA)-2016: Frequency distribution of carcasses by one-half yield grade increments.

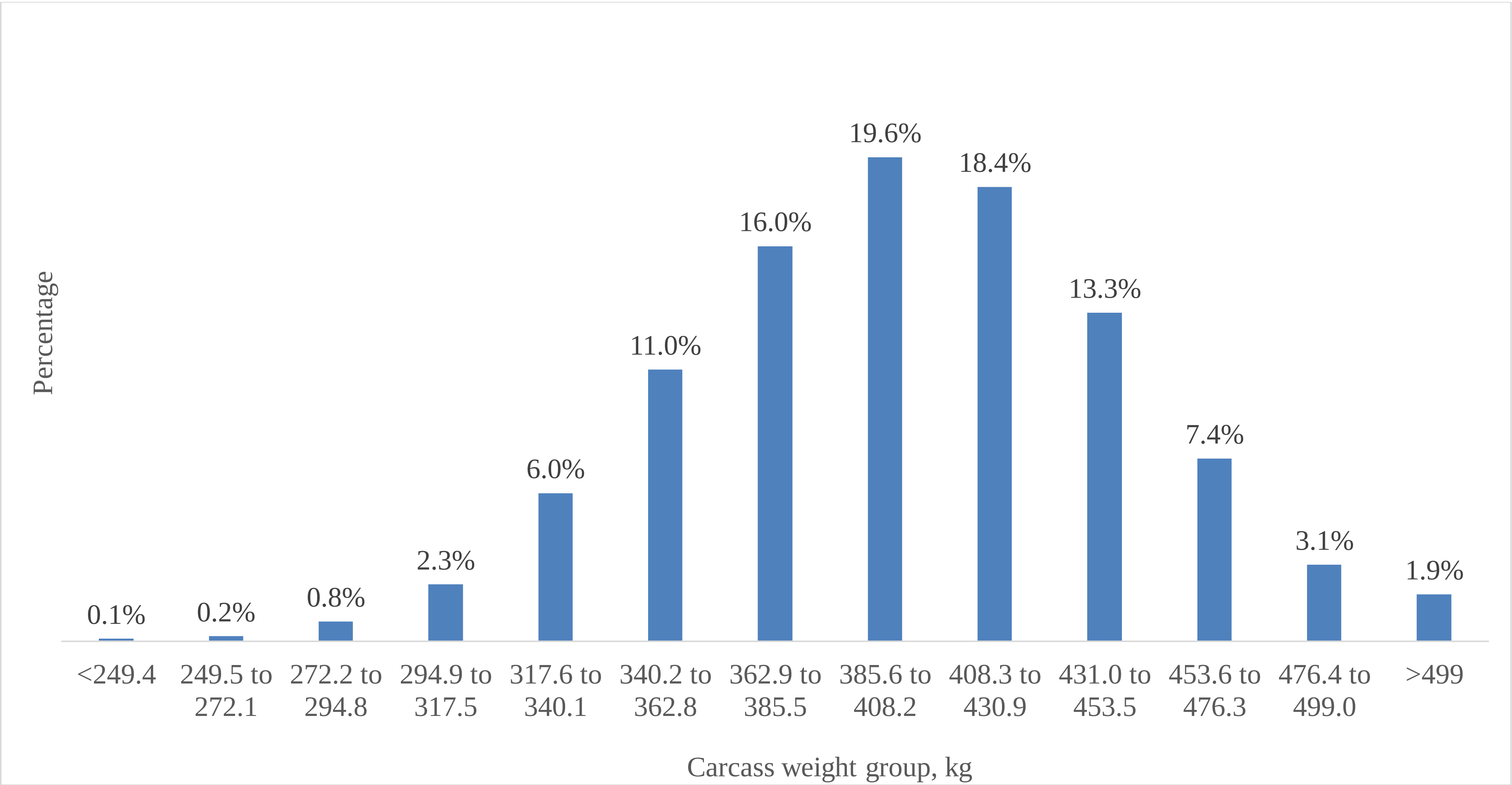


Figure 2-2. National Beef Quality Audit (NBQA)-2016: Frequency distribution by carcass weight groups.

Table 2-1. National Beef Quality Audit (NBQA)-2016: Company and location of surveyed plants

Company	Location
AB Foods Washington Beef	Toppenish, WA
American Foods Group	Green Bay, WI
Cargill Meat Solutions	Dodge City, KS
Cargill Meat Solutions	Fort Morgan, CO
Cargill Meat Solutions	Friona, TX
Cargill Meat Solutions	Schuyler, NE
Cargill Taylor Beef	Wyalusing, PA
Creekstone Farms	Arkansas City, KS
FPL Food	Augusta, GA
Greater Omaha Packing Company	Omaha, NE
Harris Ranch Beef Company	Selma, CA
Iowa Premium Beef	Tama, IA
JBS Green Bay	Green Bay, WI
JBS Plainwell	Plainwell, MI
JBS Souderton	Souderton, PA
JBS Swift Cactus	Cactus, TX
JBS Swift Grand Island	Grand Island, NE
JBS Swift Greeley	Greeley, CO
JBS Swift Hyrum	Hyrum, UT
JBS Tolleson	Tolleson, AZ
Kane Beef	Corpus Christi, TX
National Beef	Dodge City, KS
National Beef	Liberal, KS
Nebraska Beef	Omaha, NE
Tyson Fresh Meats	Amarillo, TX
Tyson Fresh Meats	Dakota City, NE
Tyson Fresh Meats	Finney County, KS
Tyson Fresh Meats	Joslin, IL
Tyson Fresh Meats	Lexington, NE
Tyson Fresh Meats	Pasco, WA

Table 2-2. National Beef Quality Audit (NBQA)-2016: Means, SD, and minimum and maximum values for USDA carcass grade traits

Trait	*n*	Mean	SD	Minimum	Maximum
USDA yield grade	7,379	3.1	1.0	-0.7	9.3
USDA quality grade[1]	8,651	696	110	367	890
Adjusted fat thickness, cm	7,992	1.42	0.71	0.0	6.35
HCW, kg	8,493	390.3	46.5	195.9	616.4
LM area, cm^2	8,681	89.5	11.2	45.8	141.9
KPH, %	8,531	1.9	1.1	0	6.0
Marbling score[2]	8,660	470	104	200	970
Lean maturity[3]	8,741	155	24	110	490
Skeletal maturity[3]	8,061	169	34	110	480
Overall maturity[3]	8,730	164	27	115	445

[1]100 = Canner^{00}, 400 = Commercial^{00}, 600 = Select^{00}, 700 = Choice^{00}, and 800 = Prime^{00} (USDA, 2016).

[2]100 = Practically devoid^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 700 = Slightly Abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

[3]100 = A^{00}, 200 = B^{00}, 300 = C^{00}, 400 = D^{00}, and 500 = E^{00} (USDA, 2016).

Table 2-3. National Beef Quality Audit (NBQA): Means for USDA carcass grade traits from NBQA-1991, NBQA-1995, NBQA-2000, NBQA-2005, NBQA-2011, and NBQA-2016[1]

Trait	NBQA-1991 (*n* = 7,375)	NBQA-1995 (*n* = 11,799)	NBQA-2000 (*n* = 9,396)	NBQA-2005 (*n* = 9,475)	NBQA-2011 (*n* = 9,802)	NBQA-2016 (*n* = 9,106)
USDA yield grade	3.2	2.8	3.0	2.9	2.9	3.1
USDA quality grade[2]	686	679	685	690	693	696
Adjusted fat thickness, cm	1.5	1.2	1.2	1.3	1.3	1.4
HCW, kg	345.0	339.2	356.9	359.9	374.0	390.3
LM area, cm^2	83.4	82.6	84.5	86.4	88.8	89.5
KPH, %	2.2	2.1	2.4	2.3	2.3	1.9
Marbling score[3]	424	406	423	432	440	470
Lean maturity[4]	163	154	165	157	154	155
Skeletal maturity[4]	175	163	167	168	162	169
Overall maturity[4]	169	160	166	164	159	164

[1] NBQA–1991 (Lorenzen et al., 1993); NBQA–1995 (Boleman et al., 1998); NBQA–2000 (McKenna et al., 2002); NBQA–2005 (Garcia et al., 2008); NBQA–2011 (Moore et al., 2012).

[2]100 = Canner^{00}, 400 = Commercial^{00}, 600 = Select^{00}, 700 = Choice^{00}, and 800 = Prime^{00} (USDA, 2016).

[3]100 = Practically devoid^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 700 = Slightly Abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

[4]100 = A^{00}; 200 = B^{00} (USDA, 2016).

Table 2-4. National Beef Quality Audit-2016: Least squares means for carcass traits (SEM) within USDA yield grades

	USDA yield grade				
Trait	1 (*n* = 710)	2 (*n* = 2,705)	3 (*n* = 2,894)	4 (*n* = 884)	5 (*n* = 186)
USDA yield grade	1.6[e]	2.6[d]	3.4[c]	4.4[b]	6.1[a]
	(0.01)	(0.01)	(0.01)	(0.01)	(0.09)
USDA quality grade[1]	675[d]	702[c]	716[b]	725[a]	724[ab]
	(2.3)	(1.2)	(1.2)	(2.6)	(5.1)
Adjusted fat thickness, cm	0.7[e]	1.1[d]	1.5[c]	2.1[b]	3.7[a]
	(0.01)	(0.01)	(0.01)	(0.02)	(0.12)
HCW, kg	359.4[e]	378.2[d]	396.1[c]	412.8[b]	424.5[a]
	(1.70)	(0.82)	(0.77)	(1.51)	(3.87)
LM area, cm^2	100.3[a]	91.7[b]	87.1[c]	83.0[d]	81.1[e]
	(0.42)	(0.20)	(0.18)	(0.32)	(0.77)
KPH, %	1.6[d]	1.9[c]	2.1[b]	2.4[a]	2.4[a]
	(0.03)	(0.02)	(0.02)	(0.04)	(0.08)
Marbling score[2]	401[d]	452[c]	488[b]	517[a]	521[a]
	(3.2)	(1.9)	(1.9)	(3.7)	(8.3)
Lean maturity[3]	156[a]	154[b]	152[c]	149[d]	153[bc]
	(0.6)	(0.3)	(0.3)	(0.5)	(1.7)
Skeletal maturity[3]	165[c]	165[c]	168[b]	169[b]	175[a]
	(0.9)	(0.5)	(0.6)	(1.1)	(2.6)
Overall maturity[3]	161[b]	160[b]	161[b]	161[b]	165[a]
	(0.7)	(0.4)	(0.4)	(0.8)	(1.9)

[a-e]Means within a row with different superscripts differ ($P < 0.05$).

[1]100 = Canner[00], 400 = Commercial[00], 600 = Select[00], 700 = Choice[00], and 800 = Prime[00] (USDA, 2016).

[2]100 = Practically devoid[00], 300 = Slight[00], 400 = Small[00], 500 = Modest[00], 700 = Slightly Abundant[00], and 900 = Abundant[00] (USDA, 2016).

[3]100 = A[00]; 200 = B[00] (USDA, 2016).

Table 2-5. National Beef Quality Audit-2016: Least squares means for carcass traits (SEM) within carcass weight groups

Trait	Carcass weight group, kg						
	<272.6 (*n* = 45)	272.7 to 318.1 (*n* = 379)	318.2 to 363.5 (*n* = 1,715)	363.6 to 409.0 (*n* = 2,864)	409.1 to 454.4 (*n* = 1,852)	454.5 to 500 (*n* = 452)	>500 (*n* = 72)
USDA yield grade	2.2^{g} (0.17)	2.5^{f} (0.04)	2.8^{e} (0.02)	3.1^{d} (0.02)	3.4^{c} (0.02)	3.7^{b} (0.04)	4.3^{a} (0.12)
USDA quality grade[1]	666^{d} (7.5)	688^{c} (3.4)	703^{b} (1.7)	710^{a} (1.1)	708^{a} (1.7)	706^{ab} (4.1)	711^{ab} (9.7)
Adjusted fat thickness, cm	0.9^{f} (0.13)	1.1^{f} (0.03)	1.3^{e} (0.02)	1.4^{d} (0.01)	1.5^{c} (0.02)	1.7^{b} (0.03)	1.9^{a} (0.08)
HCW, kg	255.0^{g} (2.83)	301.7^{f} (0.59)	344.1^{e} (0.29)	386.9^{d} (0.23)	428.4^{c} (0.28)	469.7^{b} (0.49)	518.1^{a} (2.05)
LM area, cm^2	75.6^{f} (1.48)	81.1^{e} (0.44)	85.2^{d} (0.23)	89.2^{c} (0.18)	93.0^{b} (0.23)	97.0^{a} (0.45)	98.6^{a} (1.23)
KPH, %	1.8^{bc} (0.14)	1.9^{c} (0.05)	1.9^{bc} (0.02)	2.0^{b} (0.02)	2.1^{a} (0.02)	2.2^{a} (0.04)	2.1^{ab} (0.12)
Marbling score[2]	379^{f} (12.3)	434^{e} (4.7)	462^{d} (2.4)	473^{c} (1.8)	478^{bc} (2.3)	486^{b} (4.4)	519^{a} (11.9)
Lean maturity[3]	154^{abc} (2.1)	156^{a} (1.0)	154^{b} (0.4)	153^{c} (0.3)	152^{d} (0.3)	151^{d} (0.6)	153^{bcd} (1.8)
Skeletal maturity[3]	159^{e} (2.6)	165^{de} (1.4)	167^{de} (0.6)	167^{d} (0.5)	169^{c} (0.7)	174^{b} (1.6)	188^{a} (5.5)
Overall maturity[3]	157^{c} (2.1)	161^{c} (1.0)	161^{c} (0.5)	161^{c} (0.4)	162^{c} (0.5)	165^{b} (1.2)	174^{a} (3.9)

$^{a-g}$Means within a row with different superscripts differ ($P < 0.05$).

[1] 100 = Canner^{00}, 400 = Commercial^{00}, 600 = Select^{00}, 700 = Choice^{00}, and 800 = Prime^{00} (USDA, 2016).

[2] 100 = Practically devoid^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 700 = Slightly Abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

[3] 100 = A^{00}; 200 = B^{00} (USDA, 2016).

Table 2-6. National Beef Quality Audit-2016: Least squares means for carcass traits (SEM) within fat thickness groups

Trait	Fat thickness, cm											
	<0.51 (*n* = 291)	0.51 to 0.74 (*n* = 832)	0.76 to 0.99 (*n* = 972)	1.02 to 1.25 (*n* = 1,297)	1.27 to 1.50 (*n* = 1,184)	1.52 to 1.75 (*n* = 1,542)	1.78 to 2.01 (*n* = 670)	2.03 to 2.26 (*n* = 517)	2.29 to 2.52 (*n* = 253)	2.54 to 2.77 (*n* = 246)	2.79 to 3.05 (*n* = 58)	>3.05 (*n* = 135)
USDA yield grade	1.9^{l}	2.3^{k}	2.5^{j}	2.8^{i}	3.0^{h}	3.4^{g}	3.7^{f}	4.0^{e}	4.2^{d}	4.6^{c}	4.8^{b}	6.6^{a}
	(0.05)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.04)	(0.04)	(0.08)	(0.14)
USDA quality grade[1]	675^{f}	691^{e}	699^{d}	704^{cd}	709^{c}	716^{b}	718^{b}	721^{b}	719^{b}	734^{a}	746^{a}	710^{bcd}
	(3.8)	(1.9)	(2.0)	(1.9)	(1.8)	(1.7)	(2.7)	(3.2)	(5.6)	(4.8)	(5.6)	(10.1)
Adjusted fat thickness, cm	0.2^{l}	0.6^{k}	0.9^{j}	1.11^{i}	1.4^{h}	1.6^{g}	1.9^{f}	2.1^{e}	2.4^{d}	2.6^{c}	2.9^{b}	4.4^{a}
	(0.01)	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.004)	(0.003)	(0.01)	(0.01)	(0.12)
HCW, kg	359.0^{a}	371.2^{i}	378.7^{h}	383.7^{g}	393.1^{f}	397.3^{e}	400.2^{de}	404.5^{cd}	404.6^{bcd}	411.7^{b}	426.6^{a}	411.0^{bc}
	(2.90)	(1.50)	(1.37)	(1.27	(1.28)	(1.15)	(1.68)	(2.05)	(2.89)	(3.04)	(5.92)	(4.19)
LM area, cm^{2}	86.1^{e}	87.1^{de}	89.5^{bc}	90.4^{b}	91.3^{a}	90.4^{b}	90.3^{ab}	89.3^{bc}	90.0^{abc}	88.2^{cd}	90.5^{abc}	86.1^{de}
	(0.77)	(0.43)	(0.39)	(0.31)	(0.30)	(0.27)	(0.41)	(0.45)	(0.69)	(0.64)	(1.08)	(1.07)
KPH, %	2.0^{abc}	2.0^{abc}	1.8^{def}	2.0^{ab}	2.0^{bc}	1.9^{cde}	1.8^{ef}	2.1^{a}	1.8^{fg}	2.0^{abc}	1.7^{bcdefg}	1.6^{g}
	(0.07)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.05)	(0.08)	(0.08)	(0.18)	(0.11)
Marbling score[2]	407^{i}	429^{h}	446^{g}	458^{f}	468^{e}	487^{d}	498^{c}	506^{bc}	511^{bc}	538^{a}	543^{a}	524^{ab}
	(6.1)	(3.4)	(3.3)	(2.8)	(2.8)	(2.6)	(3.9)	(4.5)	(6.7)	(6.6)	(16.2)	(10.5)
Lean maturity[3]	161^{a}	154^{b}	155^{b}	154^{b}	152^{cd}	151de	151de	150^{e}	150^{e}	150de	147^{e}	155^{bc}
	(1.5)	(0.6)	(0.5)	(0.5)	(0.4)	(0.4)	(0.5)	(0.6)	(0.8)	(1.0)	(1.3)	(2.1)
Skeletal maturity[3]	164^{ef}	162^{f}	164^{ef}	165^{e}	166^{e}	169^{cd}	171^{bcd}	172^{b}	172^{bcd}	173^{bc}	164^{def}	180^{a}
	(1.5)	(0.8)	(0.8)	(0.7)	(0.8)	(0.8)	(1.4)	(1.5)	(2.0)	(2.1)	(2.5)	(3.6)
Overall maturity[3]	163^{b}	158^{f}	160^{cdef}	160^{cde}	160^{def}	161^{bcde}	162^{b}	163^{b}	162^{bcd}	163^{bc}	156^{ef}	169^{a}
	(1.2)	(0.6)	(0.6)	(0.5)	(0.6)	(0.6)	(1.0)	(1.1)	(1.5)	(1.5)	(1.6)	(2.3)

[a-l]Means within a row with different superscripts differ ($P < 0.05$).

[1]100 = Canner^{00}, 400 = Commercial^{00}, 600 = Select^{00}, 700 = Choice^{00}, and 800 = Prime^{00} (USDA, 2016).

[2]100 = Practically devoid^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 700 = Slightly Abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

[3]100 = A^{00}; 200 = B^{00} (USDA, 2016).

Table 2-7. National Beef Quality Audit-2016: Occurrence (%)[1] of marbling scores within USDA quality grades[2]

Marbling score	Overall[3]	Prime	Choice	Select	Other[4]
Abundant	0.13	2.46			0.28
Moderately Abundant	0.57	14.46			0.57
Slightly Abundant	3.25	83.08			2.27
Moderate	7.63		10.88		5.10
Modest	23.54		33.61		15.86
Small	39.63		55.45		42.21
Slight+	15.31			61.18	8.83
Slight-	8.31			38.71	3.99
Traces	0.83				19.26

[1]Rounding error prevents all categories from adding to 100.0%.

[2]USDA quality grade was affected by maturity and dark cutting.

[3]Overall category represents USDA quality grades of Prime, Choice, Select, Standard, Commercial, Utility, and Cutter.

[4] Other includes: No roll, Standard, Commercial, Utility, dark cutter, blood splash, hard bone, and calloused ribeye.

Table 2-8. National Beef Quality Audit-2016: Least squares means for carcass traits (SEM) within USDA quality grades

	USDA quality grade			
Trait	Prime (n = 288)	Choice (n = 4,979)	Select (n = 1,710)	Other[1] (n = 262)
USDA yield grade	3.6[a] (0.05)	3.3[b] (0.01)	2.7[d] (0.02)	3.1[c] (0.07)
USDA quality grade[2]	819[a] (0.9)	732[b] (0.3)	656[c] (0.5)	357[d] (10.8)
Adjusted fat thickness, cm	1.6[a] (0.04)	1.5[b] (0.01)	1.2[c] (0.02)	1.4[b] (0.05)
HCW, kg	399.4[a] (2.47)	393.1[b] (0.60)	381.7[c] (1.07)	391.0[b] (2.91)
LM area, cm^2	84.5[c] (0.63)	88.9[b] (0.14)	91.5[a] (0.27)	91.2[a] (0.63)
KPH, %	1.8[b] (0.07)	2.0[b] (0.01)	1.9[b] (0.02)	2.1[a] (0.06)
Marbling score[3]	756[a] (2.8)	497[b] (0.9)	356[d] (0.5)	429[c] (6.1)
Lean maturity[4]	149[c] (0.8)	151[c] (0.2)	155[b] (0.3)	171[a] (2.1)
Skeletal maturity[4]	163[bc] (1.3)	166[b] (0.3)	161[c] (0.4)	230[a] (3.6)
Overall maturity[4]	157[b] (0.9)	159[b] (0.2)	158[b] (0.3)	211[a] (2.7)

[a-d]Means within a row with different superscripts differ ($P < 0.05$).

[1] Other includes: Standard, Commercial, Utility, dark cutter, blood splash, hard bone, and calloused ribeye.

[2]100 = Canner^{00}, 400 = Commercial^{00}, 600 = Select^{00}, 700 = Choice^{00}, and 800 = Prime^{00} (USDA, 2016).

[3]100 = Practically devoid^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 700 = Slightly Abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

[4]100 = A^{00}; 200 = B^{00}; 300 = C^{00} (USDA, 2016).

Table 2-9. National Beef Quality Audit-2016: Percentage distribution[1] of carcasses stratified by USDA quality and yield grades

USDA yield grade	USDA quality grade, %			
	Prime	Choice	Select	Other[2]
1	0.07	4.06	4.79	0.55
2	0.94	23.61	10.90	1.05
3	1.78	29.94	6.20	1.49
4	0.97	9.31	1.40	0.40
5	0.22	1.86	0.33	0.12

[1]Carcasses with missing values for USDA quality or yield grades are not included.

[2]Other includes: Standard, Commercial, Utility, dark cutter, blood splash, hard bone, and calloused ribeye.

Table 2-10. National Beef Quality Audit-2016: Least squares means for carcass traits (SEM) within estimated breed types

	Estimated breed type		
Trait	Native (n = 7,106)	Dairy (n = 1,342)	*Bos indicus* (n = 106)
USDA yield grade	3.1[a]	3.0[b]	2.6[c]
	(0.01)	(0.03)	(0.18)
USDA quality grade[1]	705[b]	717[a]	667[c]
	(0.9)	(1.7)	(4.7)
Adjusted fat thickness, cm	1.5[a]	0.9[c]	1.2[b]
	(0.01)	(0.02)	(0.08)
HCW, kg	390.2[a]	383.6[b]	389.9[ab]
	(0.57)	(1.06)	(4.20)
LM area, cm^2	90.9[a]	80.5[b]	91.6[a]
	(0.13)	(0.26)	(1.06)
KPH, %	2.0[a]	1.9[b]	1.0[c]
	(0.01)	(0.04)	(0.12)
Marbling score[2]	469[b]	486[a]	382[c]
	(1.2)	(3.2)	(7.0)
Lean maturity[3]	153[b]	156[b]	149[a]
	(0.2)	(0.5)	(1.1)
Skeletal maturity[3]	169[a]	165[b]	159[b]
	(0.4)	(0.6)	(1.9)
Overall maturity[3]	162[a]	161[a]	155[b]
	(0.3)	(0.5)	(1.3)

[a-c]Means within a row with different superscripts differ ($P < 0.05$).

[1]100 = Canner[00], 400 = Commercial[00], 600 = Select[00], 700 = Choice[00], and 800 = Prime[00] (USDA, 2016).

[2]100 = Practically devoid[00], 300 = Slight[00], 400 = Small[00], 500 = Modest[00], 700 = Slightly Abundant[00], and 900 = Abundant[00] (USDA, 2016).

[3]100 = A[00]; 200 = B[00] (USDA, 2016).

Table 2-11. National Beef Quality Audit-2016: Least squares means for carcass traits (SEM) within sex class

Trait	Sex class: Steer (n = 4,850)	Sex class: Heifer (n = 2,467)
USDA yield grade	3.1[a] (0.01)	3.1[a] (0.02)
USDA quality grade[1]	708[a] (0.9)	704[b] (1.5)
Adjusted fat thickness, cm	1.3[b] (0.01)	1.6[a] (0.01)
HCW, kg	398.2[a] (0.61)	374.7[b] (0.83)
LM area, cm^2	88.9[b] (0.15)	90.6[a] (0.20)
KPH, %	2.0[a] (0.01)	1.9[b] (0.02)
Marbling score[2]	467[b] (1.4)	477[a] (1.9)
Lean maturity[3]	152[b] (0.2)	154[a] (0.3)
Skeletal maturity[3]	164[b] (0.4)	176[a] (0.6)
Overall maturity[3]	159[b] (0.3)	167[a] (0.5)

[a-b]Means within a row with different superscripts differ ($P < 0.05$).

[1]100 = Canner^{00}, 400 = Commercial^{00}, 600 = Select^{00}, 700 = Choice^{00}, and 800 = Prime^{00} (USDA, 2016).

[2]100 = Practically devoid^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 700 = Slightly Abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

[3]100 = A^{00}; 200 = B^{00} (USDA, 2016).

Table 2-12. National Beef Quality Audit-2016: Least squares means for carcass traits (SEM) of carcasses by dental age classification

Trait	< 30 mo (n = 7,293)	≥ 30 mo (n = 86)
USDA yield grade	3.1[a] (0.01)	3.1[a] (0.10)
USDA quality grade[1]	697[a] (1.2)	612[b] (23.7)
Adjusted fat thickness, cm	1.4[a] (0.01)	1.1[b] (0.06)
HCW, kg	389.2[a] (0.51)	397.6[a] (6.60)
LM area, cm^2	89.5[a] (0.12)	86.1[b] (1.27)
KPH, %	2.0[a] (0.01)	2.0[a] (0.13)
Marbling score[2]	470[b] (1.1)	518[a] (13.3)
Lean maturity[3]	153[a] (0.1)	230[a] (8.0)
Skeletal maturity[3]	168[b] (0.3)	269[a] (8.2)
Overall maturity[3]	161[b] (0.2)	247[a] (7.3)

[a-b]Means within a row with different superscripts differ (P < 0.05).

[1]100 = Canner[00], 400 = Commercial[00], 600 = Select[00], 700 = Chocie[00], and 800 = Prime[00] (USDA, 2016).

[2]100 = Practically devoid[00], 300 = Slight[00], 400 = Small[00], 500 = Modest[00], 700 = Slightly Abundant[00], and 900 = Abundant[00] (USDA, 2016).

[3]100 = A[00]; 200 = B[00]; 300 = C[00] (USDA, 2016).

3. Instrument Grading Assessment

ABSTRACT

The instrument grading assessment portion of the National Beef Quality Audit (NBQA)–2016 allows the unique opportunity to evaluate beef carcass traits over the course of a year. One week of instrument grading data was collected each month from 5 beef processing corporations encompassing 18 facilities from January 2016 through December 2016 (n = 4,544,635 carcasses). Mean USDA yield grade (YG) was 3.1 with 1.37 cm fat thickness (FT), 88.9 cm^2 LM area, 393.6 kg HCW, and 2.1% KPH. Frequency distribution of USDA YG was 9.5% YG 1, 34.6% YG 2, 38.8% YG 3, 14.6% YG 4, and 2.5%YG 5. Increases in HCW and FT since the NBQA-2011 were major contributors to differences in mean YG and the (numerically) increased frequency of YG 3, 4, and 5 carcasses found in the current audit. Mean marbling score was Small^{75}, and the distribution of USDA quality grades were 4.2% Prime, 71.4% Choice, 21.7% Select, and 2.7% other. Frequency of carcasses grading Prime on Monday (6.43%) was numerically higher than the average frequency of carcasses grading Prime overall (4.2%). Monthly HCW means were 397.6 kg in January, 397.2 kg in February, 396.5 kg in March, 389.3 kg in April, 384.8 kg in May, 385.0 kg in June, 386.1 kg in July, 394.1 kg in August, 399.1 kg in September, 403.9 kg in October, 406.5 kg in November, and 401.9 kg in December. Monthly mean marbling scores were Small^{73}in January, Small^{80} in February, Small^{81} in March, Small^{77} in April, Small^{70} in May, Small^{67} in June, Small^{70} in July, Small^{75} in August, Small^{74} in September, Small^{76} in October, Small^{80} in November, and Small^{79} in December. Both mean HCW and mean marbling score declined in the months of May and June. The month with the greatest numerical frequency of dark cutters was October (0.74%). Comparison of overall data from in-plant carcass and instrument grading assessments revealed close alignment of information, especially for YG (3.1 for in-plant assessment versus 3.1 for instrument grading) and marbling (Small^{70} for in-plant assessment versus Small^{75} for instrument grading). These findings allow the beef industry access to the greatest volume of beef value-determining characteristics for the U.S. fed steer and heifer population than ever reported, resulting in potentially more precise targeting of future quality and consistency efforts.

INTRODUCTION

The first National Beef Quality Audit (**NBQA**) was conducted in 1991 to target areas of improvement as well as establish a baseline for future studies. Following the first NBQA, successive audits were conducted every 5 to 6 years to provide the industry with a current representation of the fed steer and heifer beef supply, as well as continue to evaluate progress on targeted areas of improvement.

One of the key messages from the NBQA-2005 was the need to implement instrument grading in the industry. With the increasing number of plants that had implemented instrument grading, the NBQA-2011 was the first to include the instrument grading assessments (Gray et al., 2012), which for the first time allowed seasonal trends in beef carcass traits to be evaluated. Instrument grading was approved for official United States Department of Agriculture (USDA) measurement of LM area in 2001, as well as yield grade **(YG)** and marbling score in 2007 (Mafi et al., 2014). Accuracy, precision, and producer confidence of USDA YG and quality grade

(QG) were found to be greatly improved due to the transition to instrument grading (Belk et al., 1998; Cannell et al., 1999; Steiner et al., 2003a; Steiner et al., 2003b; Emerson et al., 2013).

For the NBQA-2016, beef carcass characteristics were obtained using traditional in-plant assessments (Boykin et al., 2017) and with instrument grading information. With more widespread adoption of instrument grading in the U.S. beef industry, collecting such information complements the historic data gathered through in-plant assessments. These data provide a unique opportunity to evaluate the value and quantity determining characteristics of the fed steer and heifer beef industry in a magnitude unparalleled.

MATERIALS AND METHODS

Institutional Animal Care and Use Committee approval was not required for this study because no live animals were involved.

General Overview

Representatives who manage instrument grading programs from 5 beef processing corporations were contacted to obtain carcass data from their plants. These representatives agreed to share these data with us so long as all information was merged and it would not be revealed by individual plants or corporations. The corporations represented 18 federally inspected beef processing facilities, and information was collected from 1 week of production over a 12-mo period (January 2016 through December 2016). There were 4,544,635 beef carcasses represented in the overall dataset.

Information obtained included harvest date, grade date, sex class (steer, heifer, and other), apparent breed type (native [predominately British/Continental European breeding without dairy influence] and dairy [predominately Holstein breeding]), marbling score, defects (hard bone, blood splash, dark cutter), certified programs, fat thickness **(FT)**, LM area, HCW, and KPH percentage. The value obtained for KPH value was that utilized by each facility. Once data were received, USDA QG and YG were calculated from these factors (USDA, 2016).

Data were received in Microsoft Excel (Microsoft Corporation, Redmond, WA) spreadsheets from all 5 corporations. All corporate identities were removed, and the spreadsheets were compiled.

Statistical Analyses

All analyses were performed using JMP Software (JMP, Version 12.0.1 SAS Institute Inc., Cary, NC, 1989-2007) and Microsoft Excel for Mac 2016 (Microsoft Corporation, Redmond, WA). The Fit Y by X function was used for ANOVA, and least squares means comparisons were conducted using Student’s *t* test. Correlations were determined using the multivariate functions. Frequency distributions, means, standard deviations, and minimum and maximum values were determined using the distribution function.

RESULTS AND DISCUSSION

In-plant Carcass Assessment and Instrument Grading Comparison

The in-plant assessment (Boykin et al., 2017) included 9,106 carcasses, whereas the instrument grading included 4,544,635 carcasses (Table 3-1). Although the two assessments were not statistically analyzed, it is surprising how close some of the QG and YG factors were to each other. This is especially evident where the marbling scores were only 5/100's of a unit apart.

Collecting carcass information through both methods allowed comparison between the two, and gives credibility to previous NBQAs that solely utilized in-plant carcass assessments. The comparison of frequencies for various carcass traits between the in-plant and instrument grading (data not reported in tabular form) showed a similar percentage of carcasses that exceeded 477.3 kg (5%), percentage of carcasses that were Choice or Select, YG 2 or 3 (70.7% and 69.7%, respectively), and percentage of non-conforming carcasses (18.2% and 18.6%, respectively). Similar sex class frequencies were observed in both assessments. The instrument grading results reported a higher correlation between FT and marbling score ($r = 0.36$) than the in-plant assessment ($r = 0.24$; Boykin et al., 2017). Additionally, the in-plant results identified a greater frequency of dark cutters (1.9%) than the instrument grading dataset (0.5%). Additionally, instrument grading data were not collected from all facilities surveyed in the in-plant assessment.

The instrument grading assessment reported a slightly decreased frequency of YG 2 (-2.1% points), and an increased frequency of YG 4 (+2.6% points) when compared to the in-plant dataset (Figure 3-1). When comparing the in-plant and instrument QG frequencies (Figure 3-2), the in-plant assessment detected a slightly lower frequency of Choice carcasses (-4.1% points) and a slightly higher frequency of Select carcasses (+1.5% points). The similarity of results between the in-plant carcass and instrument grading assessments gives confidence to either method of determining a nationwide overview of beef carcass characteristics, which has been one of the primary features of the NBQA.

Instrument Grading Information; NBQA-2016 versus NBQA-2011

Instrument carcass grading means for NBQA-2016 are presented in Table 3-2. The mean USDA YG was 3.1 with a distribution of 9.5% YG 1, 34.6% YG 2, 38.8% YG 3, 14.6% YG 4, 2.5% YG 5 (Figure 3-1). In comparison, the YG distribution from NBQA-2011 (Gray et al., 2012) was 15.7% YG 1, 41.0% YG 2, 33.8% YG 3, 8.5% YG 4, and 0.9% YG 5. For the present study, mean YG factors (Table 3-2) were 1.37 cm FT, 88.9 cm^2 LM area, 393.6 kg HCW, and 2.1% KPH. For the NBQA-2011 (Gray et al., 2012), mean YG factors were as follows: 1.20 cm FT, 88.45 cm^2 LM area, and 371.28 kg HCW (Table 3-3). Similar to the in-plant carcass assessment results (Boykin et al., 2017), the increases in HCW and FT from NBQA-2011 were the major contributors to differences in mean YG and the (numerically) increased frequency of YG 3, 4, and 5 carcasses found in the current audit. Mathews and Haley (2015) attributed several factors to the increased weights including heavier cattle entering the feedlots, extended days on feed, and the greater proportion of steers versus heifers in the slaughter mix.

Since the NBQA-2011, some USDA Certified Programs have updated their specifications to account for increased carcass size and weights (Certified Angus Beef LLC, 2014). The current acceptable HCW range is 272.2 kg to 477.3 kg (USDA Market News Service, 2017). The present study recorded 95.0% of carcasses within this HCW range. Gray et al. (2012) reported 95.1% of carcasses within the HCW then-current range common to USDA certified programs (272.2 to 453.6 kg), as compared to the 88.4% in the current study. This 6.7% point decrease in carcasses within the acceptable HCW range is consistent with the increase in mean HCW.

Instrument Grading Assessment by Month

Mean FT was at its minimum in May of 2016 (1.26 cm; Figure 3-3) and its maximum in November 2016 (1.47 cm). Native heifer carcasses possessed the greatest FT ($P < 0.05$) through the entire year, whereas dairy steer and dairy heifer carcasses consistently had the least FT ($P < 0.05$). Gray et al. (2012) also reported native heifer carcasses to have the greatest FT.

Numerical comparisons (not statistically analyzed) for mean LM area and mean HCW are shown in Figures 3-4 and 3-5. Mean LM area was the smallest (86.69 cm^2; Figure 3-4) in June 2016, and reached its peak (91.38 cm^2) in October 2016. Native steer carcasses possessed the largest LM area throughout the year, reaching the greatest point (93.99 cm^2) in October 2016. Gray et al. (2012) also reported that native steer carcasses possessed the largest LM area, with a peak (93.0 cm^2) in November 2010. Monthly HCW means were: January (397.6 kg), February (397.2 kg), March (396.5 kg), April (389.3 kg), May (384.8 kg), June (385.0 kg), July (386.1 kg), August (394.1 kg), September (399.1 kg), October (403.9 kg), November (406.5 kg), and December (401.9 kg). Mean HCW reached its lightest point in May 2016, and its heaviest point in November 2016 (Figure 3-5). The highest mean HCW (381.3 kg) from NBQA-2011 was recorded in November 2010, and the lowest (357.9 kg) in May 2011 (Gray et al., 2012). The lowest mean HCW from NBQA-2016 (384.8 kg) is greater than the highest mean HCW from NBQA-2011 (381.3 kg).

Native steer carcasses consistently had the heaviest HCW ($P < 0.05$) over all months, and reached their heaviest (422.3 kg) in November 2016 (Figure 3-5). Gray et al. (2012) also reported in NBQA-2011 that native steer carcasses had the heaviest HCW with the highest weight (395.4 kg) in November 2010. Dairy heifer carcasses possessed the lightest HCW and reached their lightest weight (345.1 kg) in September 2016.

The lowest numerical percentage of YG 4 (11.6%) was observed in May 2016, whereas the lowest numerical percentages of YG 5 (1.5%) were observed in June and July 2016 (Figure 3-6). The greatest percentage of YG 4 (17.0%) and YG 5 (4.3%) occurred in January of 2016 (Figure 3-6). When comparing the current frequency of YG 4 and YG 5 to NBQA-2011 (Gray et al., 2012), YG 4 carcasses were up 6.1% points and YG 5 carcasses were up 1.6% points. Although not as numerically great, these findings mirror those for YG 4 (up 3.4% points) and

YG 5 (up 0.9% points) carcasses for the in-plant assessments in NBQA-2016 (Boykin et al., 2017) versus NBQA-2011 (Moore et al., 2012).

The mean marbling score was Small^{75} (Table 3-2). This is numerically increased from the mean marbling score of Small^{49} from NBQA-2011 (Gray et al., 2012). One opportunity with this dataset was to sort carcasses by the day of the week that they were graded (Table 3-4). Historically, for the in-plant carcass assessment portions of the NBQA, there was an attempt to not over- or under-sample carcasses that would have been chilled over the weekend and offered for grading on Mondays (McKenna et al., 2002). This was based on the findings of Calkins et al. (1980) in which carcasses that were chilled for additional time influenced USDA quality grading factors. Cattle slaughtered on Fridays and Saturdays and graded on Mondays have an increased chilling time compared with those slaughtered and graded in the same week (e.g., slaughtered on Tuesday; graded on Wednesday). Frequency of carcasses grading Prime on Monday (6.43%) was higher numerically than the average frequency of carcasses grading Prime overall (4.2%; Figure 3-2). Additional chilling time alone may not explain this phenomenon, but it is interesting to note this occurrence.

Steers accounted for 65.9% and heifers 34.1% of all carcasses assessed, and the frequency of estimated breed types was 91.9%, 7.8%, and 0.3% for native, dairy, and other, respectively (data not reported in tabular form). The frequency of native steer, native heifer, dairy steer, and dairy heifer carcasses by month are presented in Figure 3-7. Native steer carcasses were consistently the most prevalent followed by native heifers.

Figure 3-8 shows the frequency distribution of QG over the course of the year. Prime reached its highest frequency (5.0%) in November 2016, and lowest (3.0%) in August 2016. Choice was highest (72.6%) in February 2016, and lowest (68.7%) in August 2016. June 2016 had the highest frequency (24.1%) of Select, while August 2016 had the lowest (16.3%). Seasonal changes in mean marbling score are presented in Figure 3-9. Monthly mean marbling scores were January (Small^{73}), February (Small^{80}), March (Small^{81}), April (Small^{77}), May (Small^{70}), June (Small^{67}), July (Small^{70}), August (Small^{75}), September (Small^{74}), October (Small^{76}), November (Small^{80}), and December (Small^{79}). There were 2 groups of months (January, February, March and October, November, December) when mean marbling scores were the highest numerically, and 1 group of months (May, June, and July) when the mean marbling scores were the lowest numerically (Figure 3-9). In NBQA-2011, Gray et al. (2012) reported the highest mean marbling score (Small^{60}) in March 2011. Dairy heifer carcasses possessed the highest marbling score ($P < 0.05$) throughout the year, with the highest mean marbling score (Modest^{40}) in September 2016.

The highest incidence of dark cutters (0.74%) occurred in October 2016, and the lowest (0.33%) in January 2016 (Figure 3-10). Gray et al. (2012) reported the highest frequency (1.94%) in September 2011, and the lowest (0.38%) in March 2011. These data are supported by Kreikemeier et al. (1998), who reported that the highest frequency of dark cutters was in August, September, and October. Scanga et al. (1998) reported that temperature changes 1 to 3 d before slaughter create stress and increase the occurrence of dark cutters.

As in the in-plant assessment (Boykin et al., 2017), the greatest proportion of carcasses were Choice YG 3 (30.37%; Table 3-5). The frequency of carcasses that were Choice or Select and YG 2 or 3 was 69.31% as compared to the 70.5% reported in NBQA-2011 (Gray et al., 2012). Non-conforming carcasses are those that are Standard or below and/or YG 4 or 5. Of the instrumentally assessed carcasses, 18.6% were non-conforming (data not reported in tabular form), as compared to 18.2% for the in-plant surveyed carcasses (Boykin et al., 2017).

Conclusions

The instrument grading portion of the NBQA permitted the unique opportunity to evaluate trends in carcass traits over the course of a year. Mean FT and HCW decreased to reach the lowest point in May 2016, and continued to increase through November 2016. Similarly, mean marbling scores were at their highest at the beginning and end of the year and were at their lowest in May, June, and July. These trends are remarkably similar to those observed in NBQA-2011. Findings allow the beef industry access to the greatest volume of beef value-determining characteristics for the U.S. fed steer and heifer population ever reported.

Table 3-1. National Beef Quality Audit-2016: Means for USDA carcass grade traits between the in-plant survey and instrument data

Trait	In-Plant Survey[1] (*n* = 9,106)	Instrument Data (*n* = 4,544,635)
USDA yield grade	3.1	3.1
Fat thickness, cm	1.4	1.37
HCW, kg	390.3	393.6
LM area, cm^2	89.5	88.9
KPH, %	1.9	2.1
Marbling score[2]	470	475

[1]Boykin et al. (2017)

[2]100 = Practically devoid[00], 300 = Slight[00], 400 = Small[00], 500 = Modest[00], 700 = Slightly Abundant[00], and 900 = Abundant[00] (USDA, 2016).

Table 3-2. National Beef Quality Audit-2016: Instrument grading means, SD, and minimum and maximum values for USDA carcass grade traits

Trait	*n*	Mean	SD	Minimum	Maximum
USDA yield grade	4,391,142	3.1	0.90	-2.0	9.3
Fat thickness, cm	4,532,166	1.37	0.55	0.0	6.35
HCW, kg	4,516,858	393.6	57.56	136.1	719.1
LM area, cm^2	4,508,422	88.9	12.74	19.69	219.3
KPH, %	3,877,100	2.1	0.40	0.0	8.5
Marbling score[1]	4,544,634	475	110.73	100	1099

[1]100 = Practically devoid^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 700 = Slightly Abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

Table 3-3. National Beef Quality Audit (NBQA): Instrument grading means for USDA carcass grade traits from NBQA-2011 and NBQA-2016

Trait	NBQA-2011 (*n* = 2,427,074)	NBQA-2016 (*n* = 4,544,635)
USDA yield grade	2.86	3.10
Fat thickness, cm	1.20	1.37
HCW, kg	371.28	393.6
LM area, cm^2	88.45	88.9
Marbling score[1]	449	475

[1]100 = Practically devoid^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 700 = Slightly Abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

Table 3-4. National Beef Quality Audit-2016: Frequency of USDA quality grade by day of week graded

Day of week graded	USDA quality grade, %			
	Prime	Choice	Select	Other[1]
Monday	6.43	68.90	20.97	3.70
Tuesday	4.10	67.25	25.00	3.65
Wednesday	3.67	66.08	26.67	3.58
Thursday	3.78	66.35	26.10	3.77
Friday	4.08	66.63	25.39	3.91
Saturday	4.83	68.90	22.58	3.70

[1]Other includes: Standard, Commercial, Utility, dark cutter, blood splash, hard bone, and calloused ribeye.

Table 3-5. National Beef Quality Audit-2016: Instrument grading percentage distribution[1] of carcasses stratified by USDA quality and yield grades

USDA yield grade	USDA quality grade, %			
	Prime	Choice	Select	Other[2]
1	0.03	4.42	4.61	0.45
2	0.58	23.22	9.82	0.93
3	1.88	30.37	5.90	0.64
4	1.37	11.79	1.27	0.18
5	0.37	1.98	0.14	0.03

[1]Carcasses with missing values for USDA quality or yield grades are not included.

[2]Other includes: Standard, Commercial, Utility, dark cutter, blood splash, hard bone, and calloused ribeye.

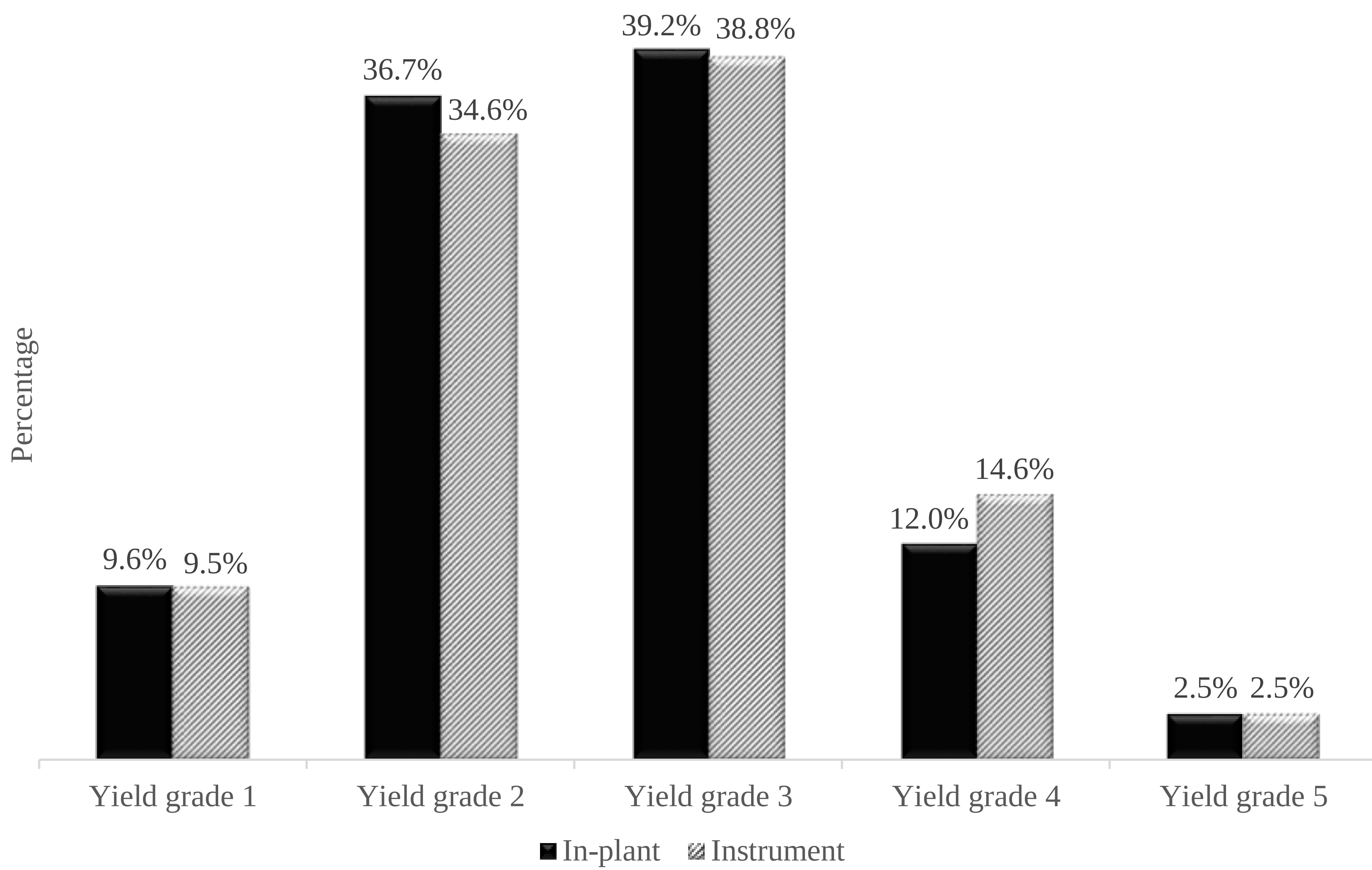
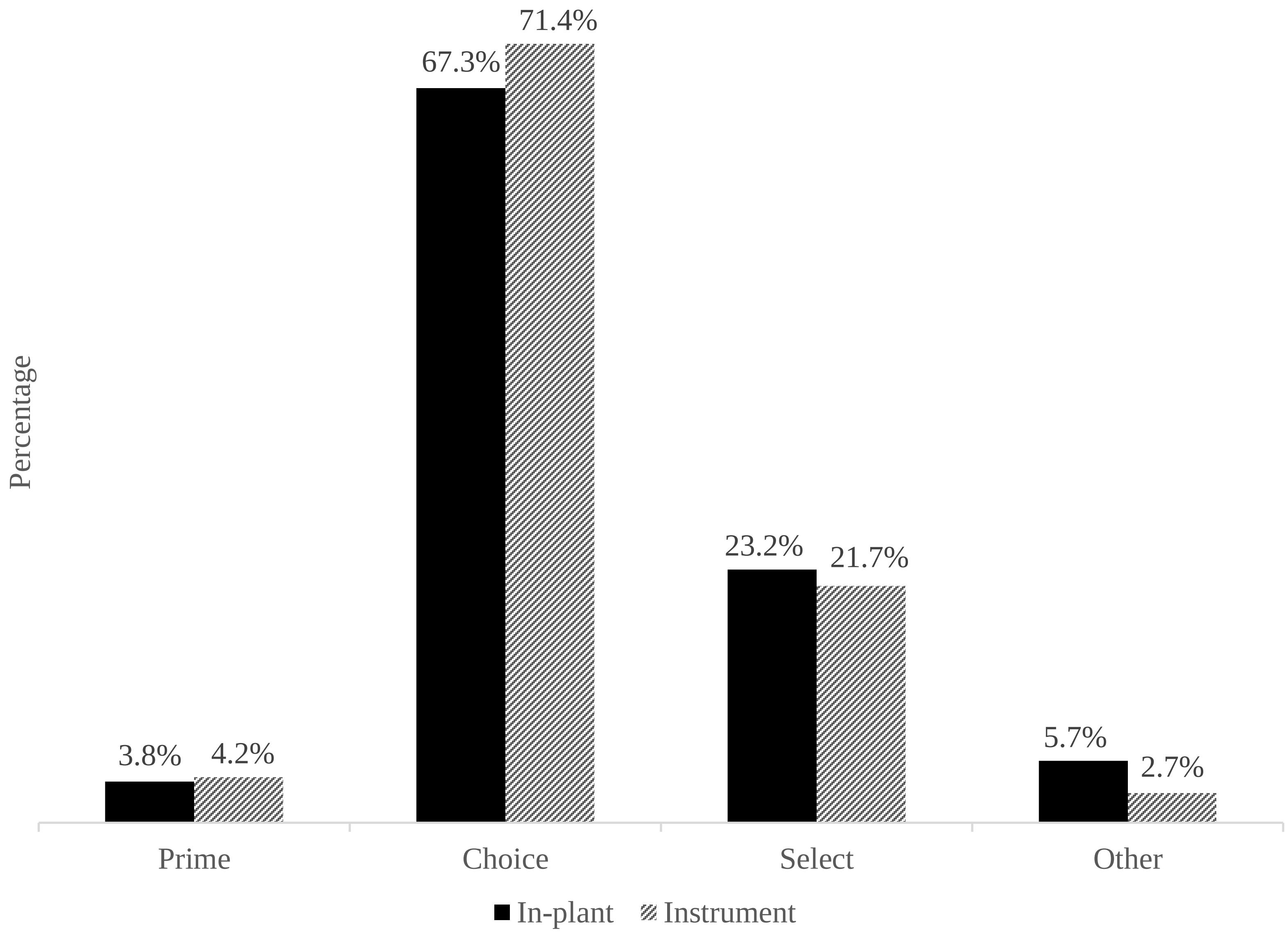

Percentage
9.6%
9.5%
36.7%
34.6%
39.2%
38.8%
12.0%
14.6%
2.5%
2.5%
Yield grade 1
Yield grade 2
Yield grade 3
Yield grade 4
Yield grade 5
In-plant
Instrument

Figure 3-1. National Beef Quality Audit – 2016: Instrument and in-plant comparison of frequency of USDA yield grades



Percentage
3.8%
4.2%
67.3%
71.4%
23.2%
21.7%
5.7%
2.7%
Prime
Choice
Select
Other
In-plant
Instrument

Figure 3-2. National Beef Quality Audit – 2016: Instrument and in-plant comparison of frequency of USDA quality grades

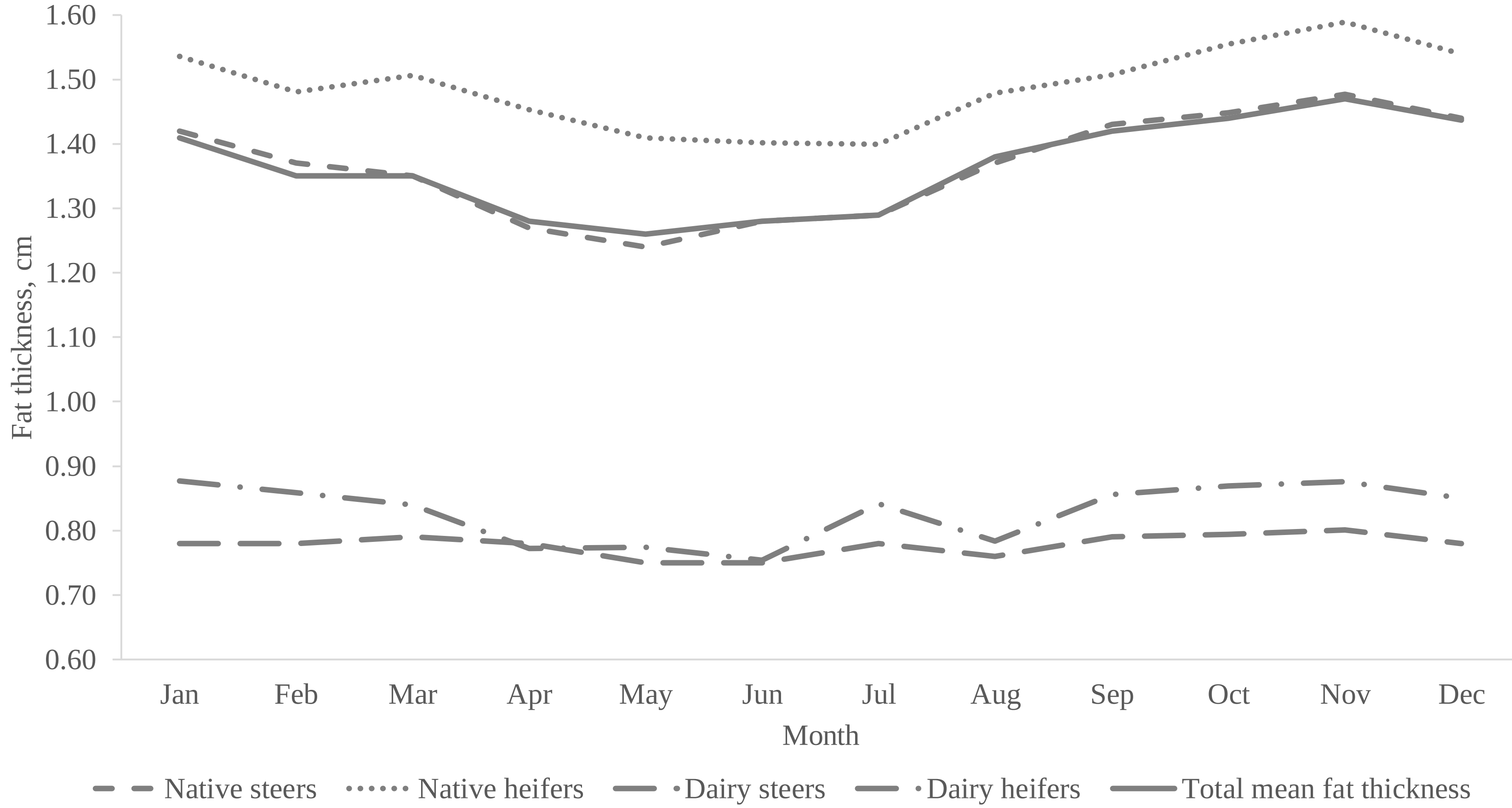

1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
Fat thickness, cm
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Native steers
Native heifers
Dairy steers
Dairy heifers
Total mean fat thickness

Figure 3-3. National Beef Quality Audit – 2016: Seasonal changes in mean fat thickness by month. Mean fat thickness is the mean for all observations.

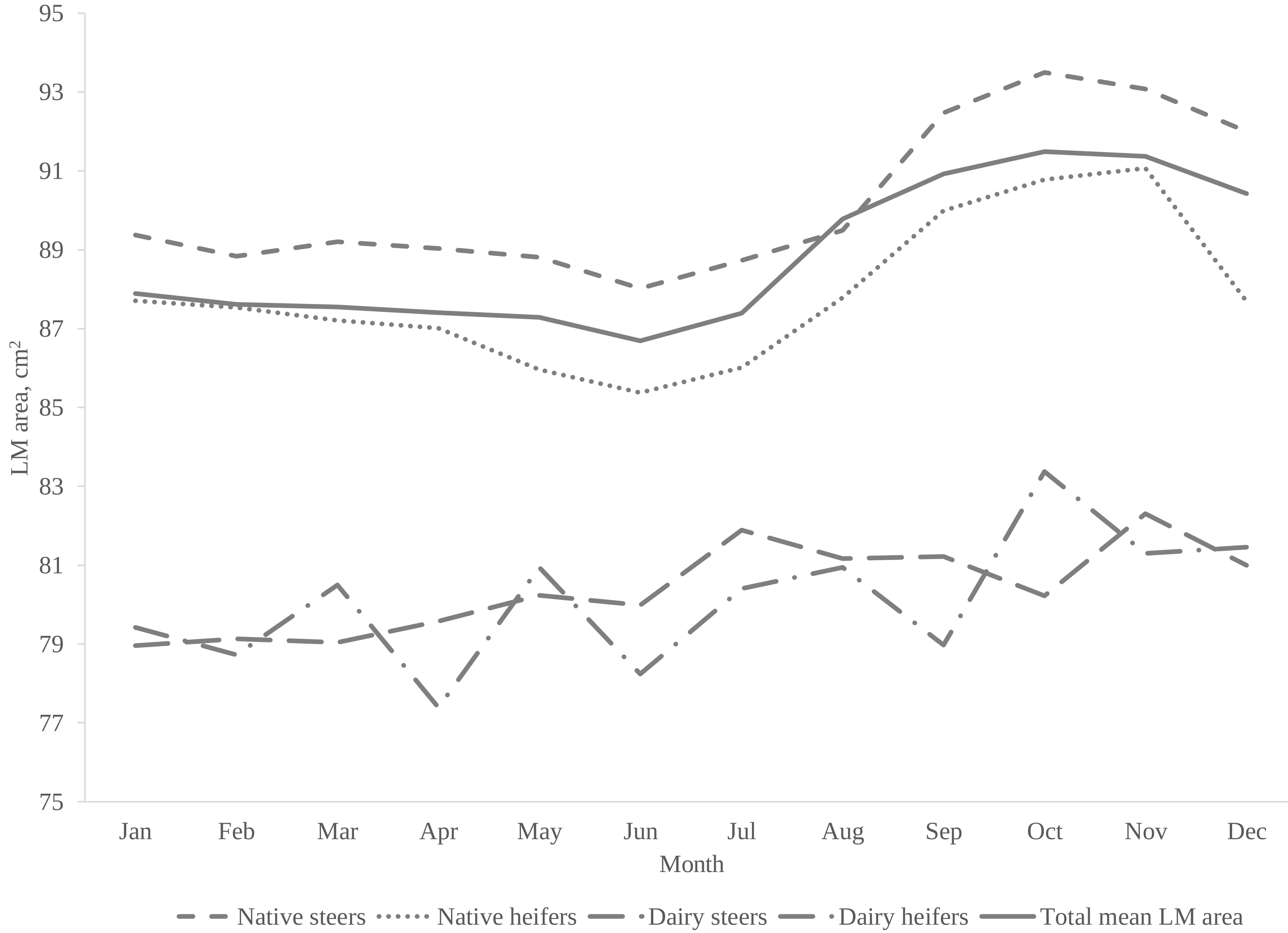

95
93
91
89
87
85
83
81
79
77
75
LM area, cm²
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Native steers
Native heifers
Dairy steers
Dairy heifers
Total mean LM area

Figure 3-4. National Beef Quality Audit – 2016: Seasonal changes in mean LM area by month.

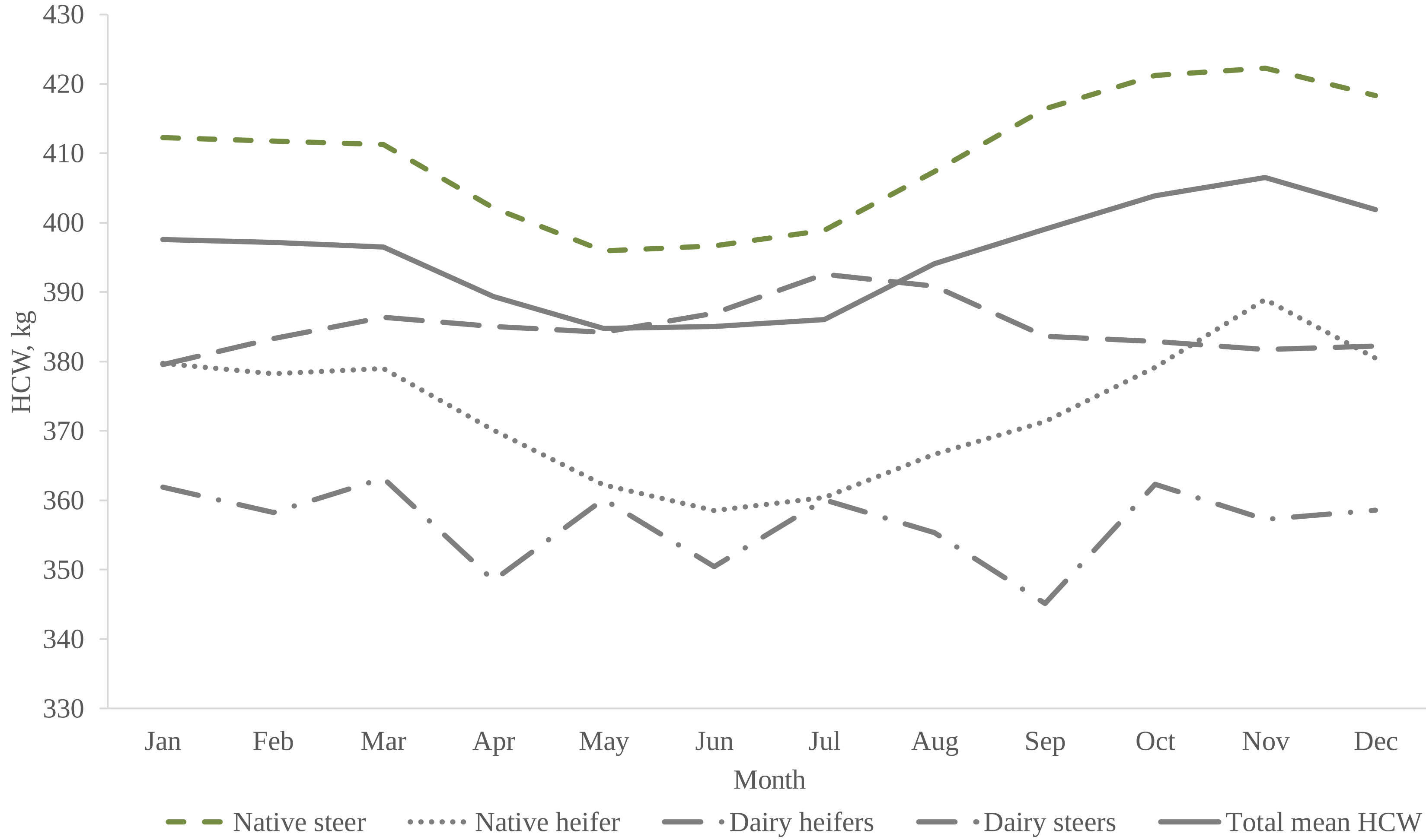

430
420
410
400
390
380
370
360
350
340
330
HCW, kg
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Native steer
Native heifer
Dairy heifers
Dairy steers
Total mean HCW

Figure 3-5. National Beef Quality Audit – 2016: Seasonal changes in mean HCW by month.

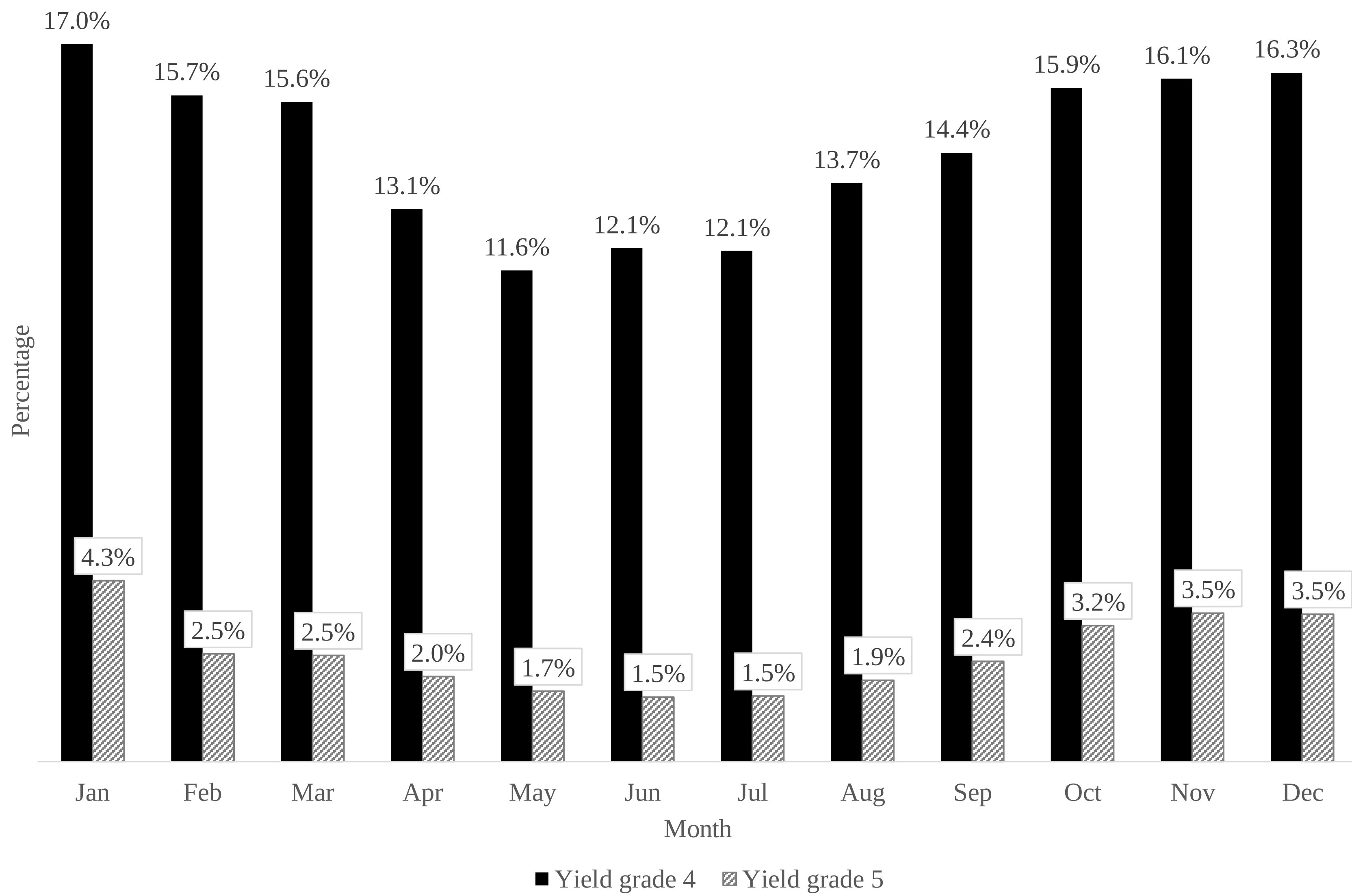

17.0%
15.7%
15.6%
13.1%
11.6%
12.1%
12.1%
13.7%
14.4%
15.9%
16.1%
16.3%
4.3%
2.5%
2.5%
2.0%
1.7%
1.5%
1.5%
1.9%
2.4%
3.2%
3.5%
3.5%
Percentage
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Yield grade 4
Yield grade 5

Figure 3-6. National Beef Quality Audit – 2016: Frequency distribution of yield grade 4 and 5 carcasses by month.

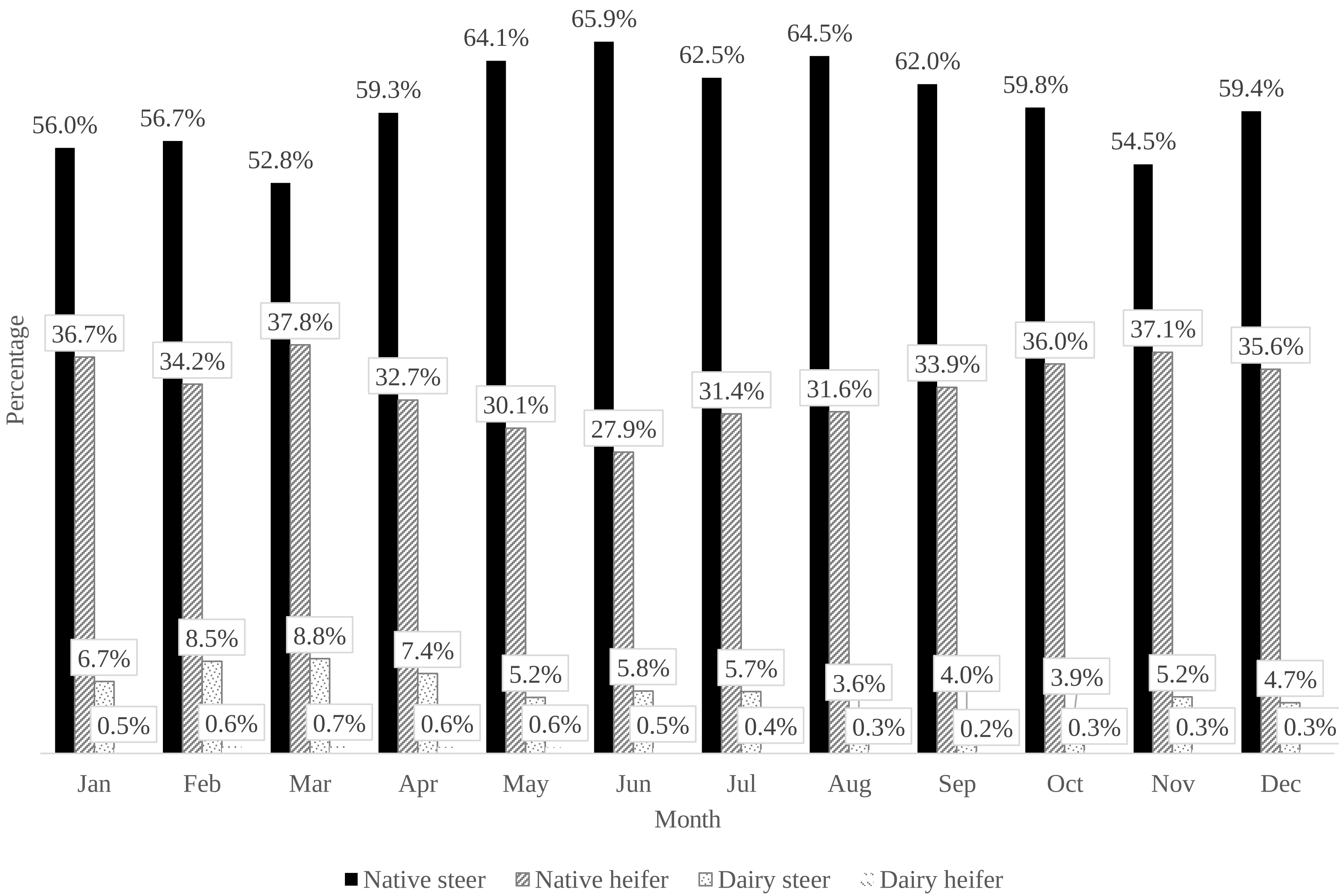

56.0%
56.7%
52.8%
59.3%
64.1%
65.9%
62.5%
64.5%
62.0%
59.8%
54.5%
59.4%
36.7%
34.2%
37.8%
32.7%
30.1%
27.9%
31.4%
31.6%
33.9%
36.0%
37.1%
35.6%
6.7%
8.5%
8.8%
7.4%
5.2%
5.8%
5.7%
3.6%
4.0%
3.9%
5.2%
4.7%
0.5%
0.6%
0.7%
0.6%
0.6%
0.5%
0.4%
0.3%
0.2%
0.3%
0.3%
0.3%
Percentage
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Native steer
Native heifer
Dairy steer
Dairy heifer

Figure 3-7. National Beef Quality Audit – 2016: Frequency distribution of sex class by month.

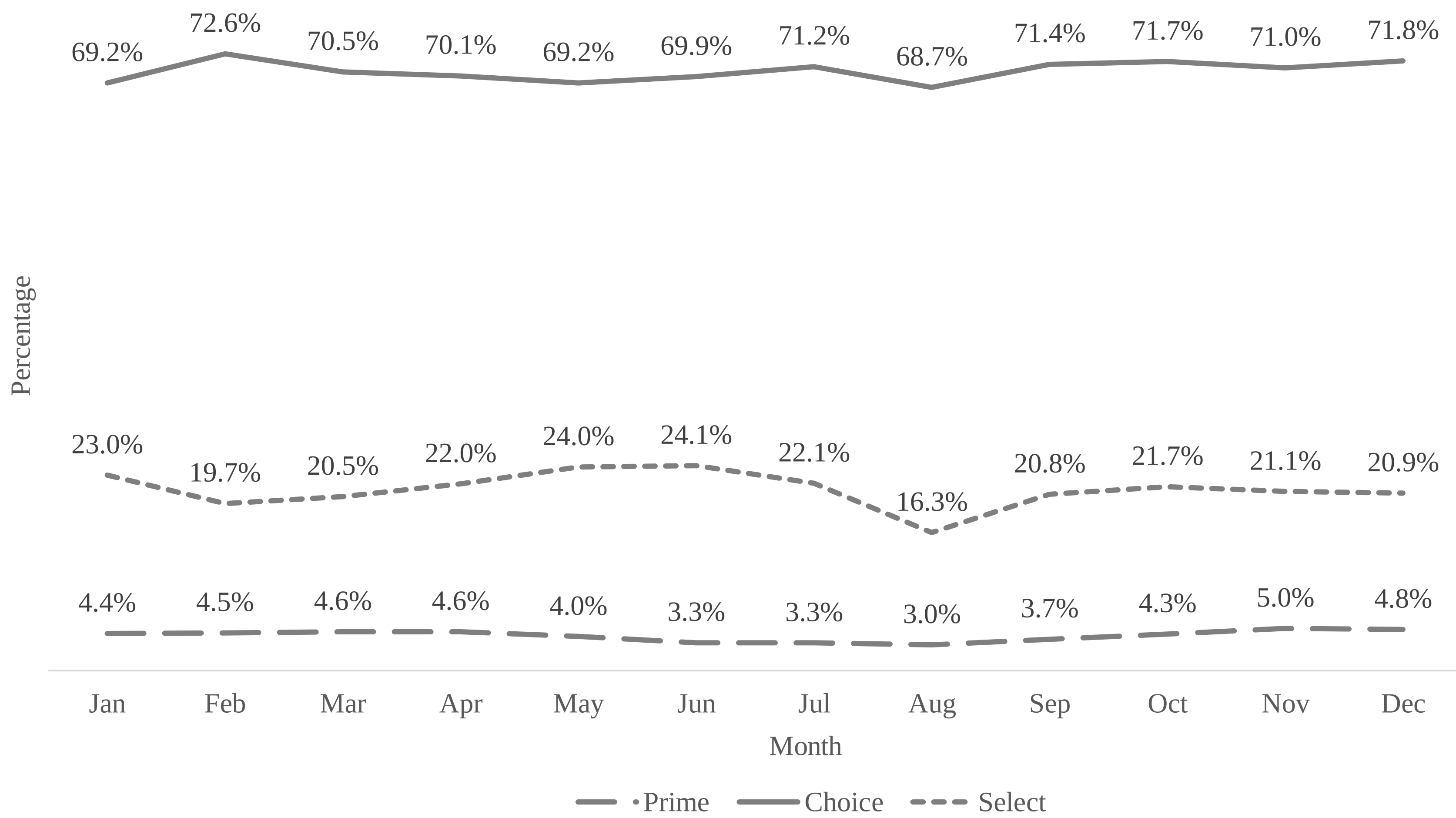

69.2%
72.6%
70.5%
70.1%
69.2%
69.9%
71.2%
68.7%
71.4%
71.7%
71.0%
71.8%
Percentage
23.0%
19.7%
20.5%
22.0%
24.0%
24.1%
22.1%
16.3%
20.8%
21.7%
21.1%
20.9%
4.4%
4.5%
4.6%
4.6%
4.0%
3.3%
3.3%
3.0%
3.7%
4.3%
5.0%
4.8%
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Prime
Choice
Select

Figure 3-8. National Beef Quality Audit – 2016: Frequency distribution of USDA quality grade by month.

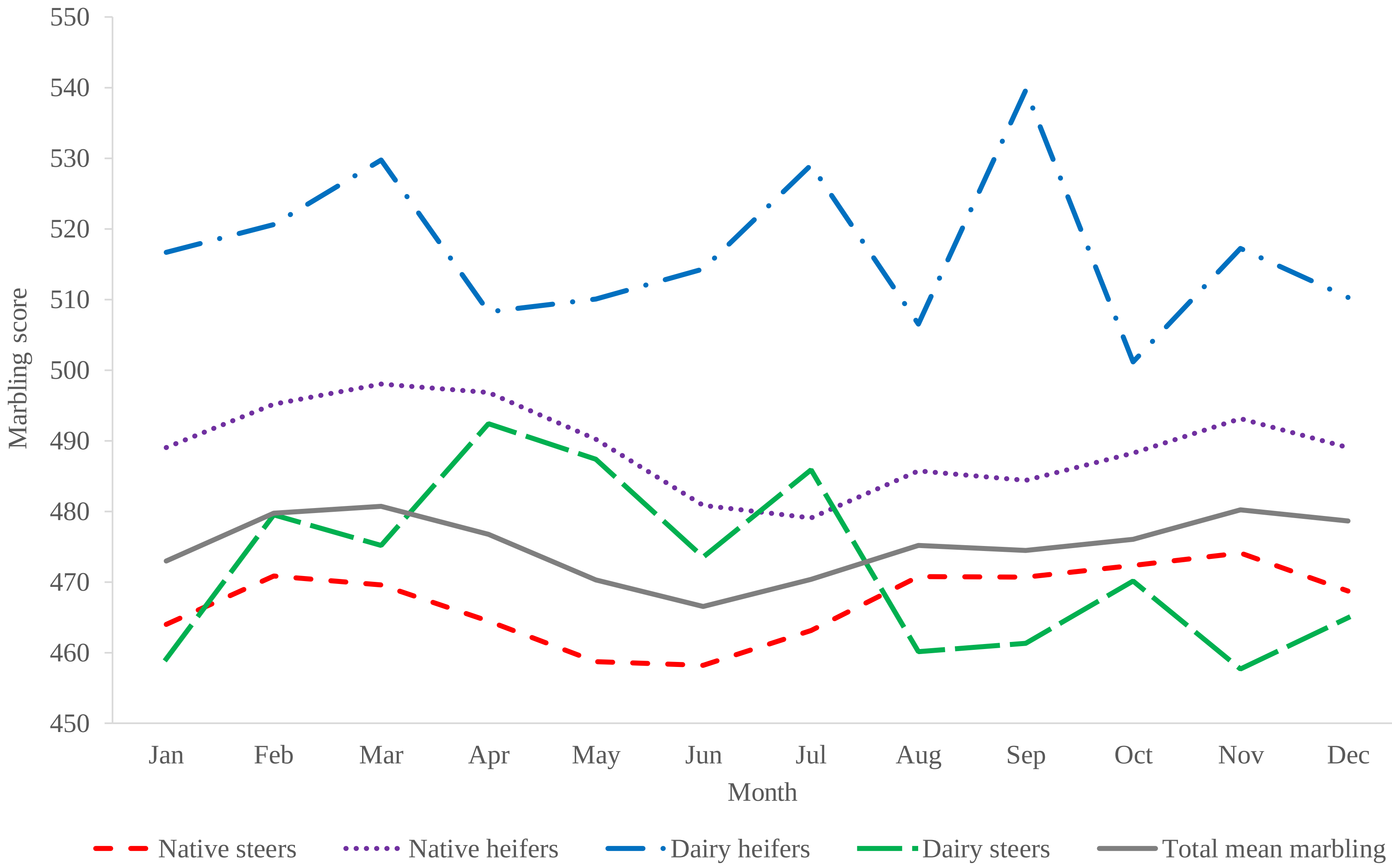

550
540
530
520
510
500
490
480
470
460
450
Marbling score
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Native steers
Native heifers
Dairy heifers
Dairy steers
Total mean marbling

Figure 3-9. National Beef Quality Audit – 2016: Seasonal changes in mean marbling scores by month. 100 = Practically devoid^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 700 = Slightly abundant^{00}, and 900 = Abundant^{00} (USDA, 2016). Mean marbling score is the mean for all observations.

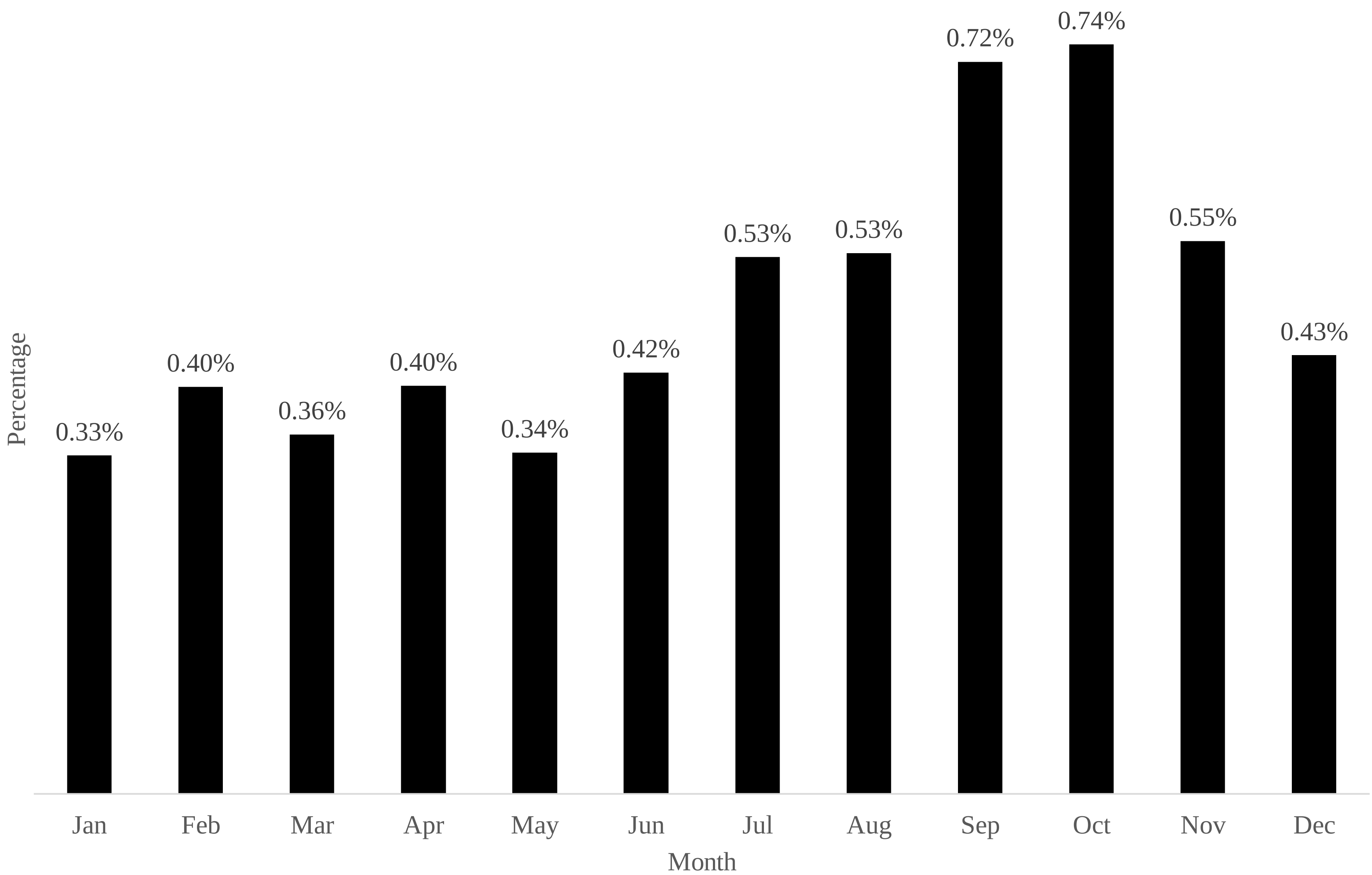

0.33%
0.40%
0.36%
0.40%
0.34%
0.42%
0.53%
0.53%
0.72%
0.74%
0.55%
0.43%
Percentage
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure 3-10. National Beef Quality Audit – 2016: Frequency distribution of dark cutting carcasses by month.

4. Market Cow and Bull Assessment

ABSTRACT

The National Beef Quality Audit–2016 marks the fourth iteration in a series assessing the quality of live beef and dairy cows and bulls and their carcass counterparts. The objective was to determine the incidence of producer-related defects, and report cattle and carcass traits associated with producer management. Conducted from March through December of 2016, trailers (*n* = 154), live animals (*n* = 5,470), hide-on carcasses (*n* = 5,278), hide-off hot carcasses (*n* = 5,510), chilled carcasses (*n* = 4,285), heads (*n* = 5,720), and offal items (*n* = 4,800) were surveyed in 18 commercial packing facilities throughout the United States. Cattle were allowed 2.3 m^2 of trailer space on average during transit indicating some haulers are adhering to industry handling guidelines for trailer space requirements. Of the mixed gender loads arriving at processing facilities, cows and bulls were not segregated on 64.4% of the trailers surveyed. When assessed for mobility, the greatest majority of cattle surveyed were sound. Since the inception of the quality audit series, beef cows have shown substantial improvements in muscle. Today over 90.0% of dairy cows are too light muscled. The mean body condition score for beef animals was 4.7 and for dairy cows and bulls was 2.6 and 3.3, respectively. Dairy cattle were lighter muscled, yet fatter than the dairy cattle surveyed in 2007. Of cattle surveyed, most did not have horns, nor any visible live animal defects. Unbranded hides were observed on 77.3% of cattle. Carcass bruising was seen on 64.1% of cow carcasses and 42.9% of bull carcasses. However, over half of all bruises were identified to only be minor in severity. Nearly all cattle (98.4%) were free of visible injection-site lesions. Beef cattle were predominantly black-hided; 68.0% of beef cows and 67.2% of beef bulls possessed a black hide. Holstein was the predominant type of dairy animal observed. Just over half (56.0%) of the cattle surveyed had no mud contamination on the hide, and when mud was present, 34.1% of cattle only had small amounts. Harvest floor assessments found 44.6% of livers, 23.1% of lungs, 22.3% of hearts, 20.0% of viscera, 8.2% of heads, and 5.9% of tongues were condemned. Liver condemnations were most frequently due to abscess presence. In contrast, contamination was the primary reason for condemnation of all other offal items. Of the cow carcasses surveyed, 17.4% carried a fetus at the time of harvest. As expected, mean carcass weight and loin muscle area (LM area) values observed for bulls were heavier and larger than cows. The marbling scores represented by cull animal carcasses were most frequently slight and traces amounts. Cow carcasses manifested a greater amount of marbling on average than bull carcasses. The predominant fat color score showed all carcasses surveyed had some level of yellow fat. Only 1.3% of carcasses exhibited signs of arthritic joints. Results of the NBQA-2016 indicate there are areas in which the beef and dairy industries have improved and areas that still need attention to prevent value loss in market cows and bulls. Current results suggest improvements have been made in cattle and meat quality in the cow and bull sector. Furthermore, the results provide guidance for continued educational and research efforts for improving market cow and bull beef quality.

INTRODUCTION

The National Market Cow and Bull Beef Quality Audit–2016 (NMCBBQA-2016) marks the fourth iteration in a series destined to quantify the beef quality status in the United States. The first market cow and bull beef quality audit (then called the National Non-Fed Beef Quality Audit–1994), conducted by Colorado State University, followed the completion of the 1991 National Beef Quality Audit for steers and heifers (Lorenzen et al., 1993), and was aimed at understanding and quantifying the producer-related quality defects of cows and bulls and their carcasses (National Cattlemen's Beef Association, 1994; Smith et al., 1994). In determining the initial benchmarks for beef and dairy cow and bull cattle and meat quality, the study concluded cows and bulls were too frequently light muscled and thin, and excessive defects were too often observed. Conclusions urged producers to capitalize on management practices to improve the value of cows and recoup the worth of appropriate on-farm practices.

Five years later, the 1994 benchmarks were used as reference data in the National Market Cow and Bull Beef Quality Audit-1999 (NMCBBQA-1999) (Roeber et al., 2000; Roeber et al., 2001). This study measured the quality improvement and/or decline in live cattle, carcass, and offal traits over the five-year period. Concomitantly, the NMCBBQA-1999 established new beef quality benchmarks utilized in future initiatives, such as the injection-site lesion prevalence in cow primals (Roeber et al., 2002), brought forth by the beef industry.

Eight years later, Texas A&M University led the third NMCBBQA to continue the progression of measuring quality changes and determining the status of the market cow and bull beef industry (Nicholson, 2008; Nicholson et al., 2013). This audit incorporated new information regarding the use of electric prods, animal handling techniques, animal traceability and other data aimed at further quantifying animal welfare and handling practices at processing facilities, a great concern of the beef industry at the time.

Certain characteristics and conditions of cattle may impact harvest practices, as well as the overall value of carcasses and offal. These frequently relate to production practices and can be improved through adjustments in management, thereby increasing the value of carcasses and offal. One such characteristic is hide contamination via mud and manure. Excessive hide contamination necessitates additional resources during harvest to prevent carcass contamination. In addition, hides excessively laden with mud are generally sold at a lower value due to the potential for latent hide damage to occur during the mud removal process (United States Hide Skin and Leather Association, 2014). Additionally, heavy manure and fecal contamination on hides pose an increased risk of pathogen transfer to the carcass and increased risk of food-borne illness to the consumer (Elder et al., 2000). Therefore, producers who understand the importance of hide condition at the time of harvest are more likely to employ management practices to minimize hide contamination.

Individual animal identification has been an important component of cattle operations for many centuries (Stamp, 2013). In its early stages, identification primarily consisted of branding the hide to identify ownership. Identification methods and reasons have evolved. Identifying animals with ear tags, metal clips, ankle tags, etc. allow producers to keep accurate records, while facilitating traceability of cows, bulls, and their offspring in all segments of production. Although not visibly apparent when presented for harvest, conditions that contribute to offal condemnation may be related to producer management (Nagaraja and Chengappa, 1998). The previous National Beef Quality Audit (NBQA) determined the most frequently condemned offal items originating from cows and bulls to be livers, viscera, and hearts (Nicholson, 2008). In the NBQA-2007, 45% of livers were condemned, of which 14% were abscessed, 7% were contaminated, 6% had flukes, and 5% showed signs of telangiectasis (National Cattlemen's Beef Association, 2007). According to USDA’s weekly by-product drop-credit report for September 25, 2017, there was a 30% liver condemnation rate in cows harvested (USDA-AMS, 2017c). Because of the high incidence of liver and other offal condemnations and subsequent high economic losses, it is important to evaluate trends in offal condemnations over time to determine if changes in management practices have impacted incidence rates.

Historically, cows and bulls were thought to primarily be a source of lean trimmings (Woerner, 2010). Overtime, the industry has realized cow and bull carcasses vary in quality, and certain carcasses may receive premiums for increased quality traits, fat cover, and muscle size (Woerner, 2010). Therefore, understanding trends in cow and bull carcass traits such as fat cover, marbling score, and muscle score, allow producers to determine if value improvements in meat quality have been attained.

Previous NBQAs conducted in 1994, 1999, and 2007 assessed and quantified the quality status of the market cow and bull beef industry (Smith et al., 1994; Roeber et al., 2001; Nicholson et al., 2013). Audits surveyed characteristics of live animals, carcasses, and offal that could affect value in the market cow and bull sector. To assess changes since the NBQA-2007, the NBQA-2016 was designed to evaluate live cattle, carcasses and offal throughout 2016. (Harris et al., 2017) reported findings related to cattle mobility, live animal defects, hide branding, and carcass bruising. Hide characteristics, offal condemnations, and carcass traits determined in the NBQA-2016 are reported in this publication.

The objective of the NBQA-2016 was to again quantify the status of the beef industry in regards to the contribution made by mature cows and bulls. The NBQA-2016 provides an updated status report of the market cow and bull sector as it pertains to cattle transportation, mobility, and live cattle and carcass characteristics, as well as offal items and by-products. By comparing these data to the NNFBQA-1994, NMCBBQA-1999, and NMCBBQA-2007, the beef industry can assess changes in the quality of live cattle and carcasses from market cows and bulls. In addition, data from this study can provide direction for future initiatives concerned with improving beef quality.

MATERIALS AND METHODS

General Overview

To ensure consistency, all eight collaborating universities met before data were collected to discuss survey protocols and use of standardized data books. Through the duration of 2016, characterization of transportation, assessment of cattle mobility, and visual assessment of live animals, carcasses and offal, was completed in 18 predetermined federally-inspected beef processing facilities representing 10 states (Table 4-1) representing ten states spanning across the United States. One-third of cattle, carcasses, and offal at each of the 18 surveyed processing facilities were audited over the course of one full production day; if the facility operated two shifts per day, cattle in both shifts were surveyed. When possible, all cattle and carcasses surveyed were classified by breed type (beef or dairy) and sex (cow or bull).

Transportation and Mobility

Truck and trailer information from 10% of all trucks (*n* = 154) to arrive at the 18 processing facilities were evaluated for type, dimension, use of compartments, and use of center gate. The truck driver was interviewed to determine cattle origin, date and time loaded, distance and time traveled, number and type of cattle in the load, if mixed gender loads were segregated, and if cattle were unloaded during transit. If the driver was unsure of the distance traveled, a map was used to estimate the distance from origin to packing facility. Time traveled was considered the duration between time loaded and time unloaded.

As they were moved from the truck to the holding pen, cattle (*n* = 4,066) were assessed for mobility using the North American Meat Institute's 4-point scale (North American Meat Institute, 2015). Animals who fell to the ground and could not rise were classified as non-ambulatory.

Live Animal Evaluation

Cattle (*n* = 5,470) were surveyed for live animal characteristics that could drive producer's culling decisions. Each animal surveyed was assigned a muscle score (5-point scale: 1 = light muscled, 5 = heavy muscled) and a body condition score (beef animal: 9-pt scale; 1 = extremely thin, 9 = very obese; dairy animal: 5-point scale; 1.0 = thin, 5.0 = over-conditioned) (Elanco Animal Health, 2009; Eversole et al., 2009). With the aim of identifying producer-related defects, the research group assessed cattle for anticipated defects (Table 4-2). For these predetermined defects, researchers used the scales presented in Table 4-2 to quantify their observations. Unanticipated defects (not found in Table 4-2) were noted by researchers when observed.

Hide-on Evaluation

Hide-on carcasses (*n* = 5,278), were evaluated for the incidence of hide branding; location (butt, side, shoulder) and size (cm^2) of brands were recorded. The presence and location (neck, shoulder, top butt, round) of knots was recorded. In addition, researchers observed length of horns. Carcasses also were observed for mud, identification type, and color. If present, location of mud was recorded as being observed on legs, belly, side, top line, tail region, and amount was classified as small, moderate, large, or extreme levels as defined by Savell (2016). The type of identification (ankle tag, barcode, electronic tag, individual tag, metal clip, lot tag, waddle, and "other") also was recorded. Additionally, primary color was recorded as the color representing at least 51% of the hide. Hide patterns were classified as Holstein-patterned, baldy, roan, brindle, and spots.

Hide-off Carcass Evaluation

Carcasses (*n* = 5,510) were assessed for number, location (round, rib, shortloin, sirloin, chuck, the combination of brisket, plate, and flank) and severity (minimal = less than 0.45 kg trim loss; major = 0.46 kg to 4.54 kg trim loss; critical = 4.55 kg to 18.14 kg trim loss; extreme = loss of an entire primal) of bruises. Furthermore, the number and location (round, rib, shortloin, sirloin, chuck, the combination of brisket, plate, and flank) of visible injection-site lesions on the exterior carcass surface were recorded.

Offal Assessments

Condemnation by the United States Department of Agriculture, Food Safety and Inspection Service (USDA-FSIS) of heads (*n* = 5,720), tongues (*n* = 5,720), viscera (*n* = 4,800), livers (*n* = 4,800), kidneys (*n* = 4,800), lungs (*n* = 4,586) and hearts (*n* = 4,586) was recorded, and reasons were documented. The incidence and reason for trimming surveyed heads and tongues also was documented. In addition, surveyed heads were recorded as displaying signs of a broken mouth or were classified as a gummer (an animal that had permanent incisors worn down to the gum line). Pneumonia severity was evaluated with mild being 0% - 15% lung tissue consolidation, moderate being 15% - 50% lung tissue consolidation, and severe being 50% - 100% consolidation of the lung. Surveyed viscera in cow carcasses were assessed for fetal presence. When present, approximate fetal age/size was documented as either “early” (less than 150 d old and 35.56 cm or less in length) or “late” (over 150 d or 35.56 cm long) gestation (Sorensen, 1979).

Carcass Traits

Hot carcass weight (HCW) and loin muscle area (LM area; measured with a dot grid) were recorded for selected carcasses (*n* = 4,285). Lean and skeletal maturity, degree of marbling, preliminary yield grade (PYG), and kidney, pelvic, and heart fat (KPH) were evaluated for each selected carcass based on the United States Standards for Grades of Carcass Beef (USDA, 2016).

Quality grades for cow carcasses were determined using the relationship between maturity and marbling and were reported as outlined in the United States Standards for Grades of Carcass Beef (USDA, 2016). Yield grades for all carcasses were calculated by substituting the values recorded for PYG, HCW, LM area, and KPH into the following equation:

$2.5 + (2.5 \times ((\text{PYG} - 2) \times 0.4)) + (0.2 \times \%\text{KPH}) - (0.32 \times \text{LM area, square inches}) + (0.0038 \times \text{HCW, pounds})$. If any of the variables necessary for calculating a quality or yield grade were not recorded, a grade was not assigned.

Carcass muscle score was evaluated according to the standards outlined by Nicholson (2008) using a 5-point scale with 1 being the lightest muscled and 5 being the heaviest muscled. Fat color was scored using a 6-point scale with 1 being the whitest and 6 being the most yellow, also defined by Nicholson (2008). If present, the number of arthritic joints on each carcass were documented.

Statistical Analysis

Data were analyzed using JMP Software (JMP, Version 10. SAS Institute Inc., Cary, NC, 1989-2207) and Microsoft Excel for Mac. Distributions, frequencies, means, standard deviations, minimums, and maximums were calculated using the Distribution and Summary functions of JMP. To test the hypothesis that the frequency of a quality characteristic in the NBQA-2007 was equal to the frequency of the same quality characteristic in the NBQA-2016, a pooled estimate was calculated with: $(x_1 + x_2)/(n_1 + n_2)$. Then, a pooled standard error was calculated and used to determine the z-statistic. If the z-statistic was greater than or equal to 1.96, the two frequencies were considered different.

RESULTS AND DISCUSSION

Transportation

Transportation data by trailer type are presented in Table 4-3. Across all loads surveyed, cattle were in transit for a mean of 6.7 h and traveled a mean distance of 455.7 km. It is important to note that three loads were hauled for over 24 hours and two loads traveled distances greater than 1,600 km. The Beef Quality Assurance program does not recommend withholding feed and water for longer than 24 hours, therefore, transporters should ensure adequate stops during long hauls to meet these guidelines (Beef Quality Assurance Advisory Board, n.d.). In addition, there is evidence increased transportation distance leads to increased carcass bruising in cows (Yeh et al., 1978). On average, there were 26 cattle per load, although load sizes ranged from 1 to 47 head per trailer. As load size increases, it is important that minimum space requirements for each animal are met. The average area allotted per animal for all loads (2.3 m^2) and pot bellies alone (1.2 m^2) indicate some trailers were hauled at proper (1.0 to 1.8 m^2 for horned cattle weighing 364 to 636 kg; 0.97 to 1.7 m^2 for polled cattle weighing 364 to 636 kg) load densities as outlined in the Animal Handling Guidelines (Grandin, 2013). Stocking densities such as these helps minimize animal welfare concerns and profit losses due to carcass defects. Even so, some trailers were overstocked, crowding animals on the way to harvest. Transporters should work to limit the frequency of hauling too many cattle on a single load to assure animal safety and maintain carcass value.

A wide variation in trailer dimensions was observed as a result of multiple trailer types used to transport cattle to harvest. Pot belly trailers (67.1%) were the primary type of trailer used to transport cows and bulls to market, followed by gooseneck trailers (30.3%). Pot belly trailers offer greater capacity and allow for group separation through use of center gates and compartments. Of the pot bellies surveyed, 65.3% (n = 95) used the center gate to separate cattle (data not in tabular form). On average, 5 compartments were used for cattle separation in pot belly trailers during transit (Table 4-3). Nearly 11 percent (10.8%; n = 93) of pot bellies surveyed utilized the smaller compartment located at the back of the trailer intended for hauling lighter weight, smaller-framed cattle; this is 5.1% points lower than the previous survey (data not in tabular form) (Nicholson, 2008). It is important for transporters to understand the weight and size limitations for hauling cattle in this particular compartment. This decrease in percentage points since the NMCBBQA-2007 suggests that there may be fewer transporters using this small compartment. Use of center gate and compartmental divisions provides evidence that transporters may be separating cattle using other compartments to minimize carcass bruising and animal welfare concerns.

Bulls and young bulls transported to a Columbian harvest facility yielded carcasses with a greater incidence of bruising than cow carcasses evaluated in the same study (Strappini et al., 2009). Weeks et al. (2002) described a lesser frequency of bruises on bull carcasses than heifer and steer carcasses. Jarvis et al. (1995) observed a greater incidence of bruising in mixed (heifer and steer) groups and steer-only groups than heifers and bulls independently transported. Researchers speculated that the disruption of cohesive groups, whether that be groups familiar with each other on the farm or ranch or groups of cows mingled with groups of bulls, contributes to the variation in observed carcass bruising (Jarvis et al., 1995; Weeks et al., 2002; Strappini et al., 2009). In the current study, we observed that 64.4% (n = 48) of mixed-sex loads were not hauling cows and bulls in separate compartments (data not in tabular form). This is only a slight percentage change (-2.3% points) from the 66.7% observed in 2007 (Nicholson, 2008). Therefore, segregating cows and bulls during transit may help minimize carcass bruising.

Mobility

Using the scoring system for cattle mobility and locomotion (North American Meat Institute, 2015), the majority of cattle were assigned a score of 1, walking normal with no apparent lameness (Table 4-4). Dairy animals had the greatest incidence of minor stiffness, shortness of stride and a slight limp (score 2) when coming off the trucks. This is not surprising given the production management system utilized in the dairy industry; 38.9% of all dairies in 17 dairy-producing states housed lactating cows in tie stalls or stanchions which have hard surfaces (USDA-APHIS Veterinary Services National Animal Health Monitoring System, 2016). Cook and Nordlund (2009) found the greatest rates of lameness in dairy herds to occur in intensively managed, zero-grazed free stall systems. Nonetheless, dairy cows have seen the greatest improvement in soundness (Figure 4-1) since 2007, most likely due, in part, to the inception of the National Dairy Farmers Assuring Responsible Management (FARM) Program, which encourages commitment to quality farm management practices and safe, wholesome dairy products (National Milk Producer's Federation, 2017). Compared to the NMCBBQA-2007, percentages of sound animals have changed +24.6%, +14.2%, +3.3%, and -0.8%-points for dairy cows, beef bulls, beef cows, and dairy bulls, respectively (Nicholson, 2008).

Although the majority of cows were determined to be sound in the current audit, it is important to realize the need to cull cows before lameness becomes too advanced; Garbarino et al. (2004) and Hernandez et al. (2005) reported lame cattle to have decreased cyclicity and longer postpartum intervals, respectively. In addition, Green et al. (2002) identified milk yield was reduced in lame cattle. Thus, lame cows should be culled early to reduce profit loss due to decreased reproductive health and milking efficiency.

Live Cattle Evaluation

Figure 4-2 illustrates the representation of muscle scores amongst all cattle types surveyed. Beef cows, beef bulls, and dairy bulls had the greatest frequency of average muscling (muscle score 3). It was determined that 66.6% of dairy cows were given the lowest muscle score

(score 1). Therefore, it is not surprising that a greater percentage of score 1 dairy cows were seen compared to other cattle types. Nonetheless, 66.6% is almost 32% points greater than what was reported in 2007 (Nicholson, 2008). If the cow's condition is sufficient for extended retention and it is economically feasible, producers should attempt to increase muscle score before marketing. This may minimize carcass bruising, increase pounds of lean, and reduce criticisms of animal handling practices for cull cows. Figure 4-3 illustrates the changes in the frequency of inadequately muscled animals being marketed during the four quality audits conducted. The beef cow population over the past 17 years has continued to show drastic improvements in muscle. Fewer inadequately muscled dairy cows were marketed in 2007 than 1999, but in the current audit we saw remission to an increased frequency of inadequately muscled dairy cows being marketed (Nicholson, 2008). Muscle score can be used as a measure of condition and fitness of animals destined for market. Increasing feed for light-muscled cattle should be considered, as feeding concentrate diets prior to sale has been shown to increase muscle and fat in animals (Matulis et al., 1987; Schnell et al., 1997)

In tandem with muscle score, body condition score is one useful tool for determining the market readiness of cows and bulls. The mean body condition score (9-point scale) for both beef cows (n = 1,910) and beef bulls (n = 406) was 4.7 (not in tabular form). The mean body condition score (5-point scale) for dairy cows (n = 2,878) and dairy bulls (n = 121) was 2.6 and 3.3, respectively (not in tabular form). Data show there is a greater frequency of advanced-conditioned beef cows and a lesser frequency of beef cows that are too thin than what was reported in 2007 (not in tabular form) (Nicholson, 2008). The same holds true for dairy cows; body condition scores for dairy cows improved substantially from 36.1 percent with body condition score of 3.0 or above in 2007 to 45.0 percent in 2016 (not in tabular form) (Nicholson, 2008). In addition, the distribution of body condition in dairy cows has transitioned since 2007, as the greatest number of dairy cows in 2016 were assigned a condition score of 3.0 versus the greatest number in 2007 being assigned a condition score of 2.5 (Nicholson, 2008). It should be realized that while dairy cattle that are classified in the upper range of the dairy condition scale are being marketed, this most likely does not give evidence these animals are overly fat for some beef fabrication and retail marketing purposes. Conversely, beef cows and bulls with condition scores in excess of seven contribute to excessive pounds of fat trim at the processor.

Too low of a condition score (beef - score 1 and 2; dairy – score 1.0 and 1.5) may indicate to producers that an animal is unable to maintain condition, which comes with production shortfalls (i.e. raising a calf, breeding cows). Figure 4-4 shows the frequency of cows and bulls identified to be "too thin," therefore, reducing their market potential. Cattle that are too thin may have too little fat creating increased potential for cold shortening upon carcass cooling (Savell et al., 2005). They also are more prone to carcass bruising without the protective fat layer (Weeks et al., 2002). Also, too little fat may cause them to mobilize muscle as a source of energy further reducing their carcass merit.

In contrast, cattle that are too fat (beef – score 8 or 9; dairy – score 4.5 or 5.0) are subject to producing excessive fat trim, which has been identified as a significant lost opportunity for the beef industry (National Cattlemen's Beef Association, 2017). Figure 4-5 shows the percentage of cattle identified to be over-conditioned in 2016. Since 1994, fewer over-conditioned beef cows are being marketed. There was a 1.3% point decrease in the frequency of over-conditioned beef bulls. Just as expected due to the finish traits of dairy cattle, the data show very few over-conditioned dairy cows were marketed.

Physical defects which impair reproductive efficiency or result in economic losses also are important factors in determining market readiness of cows and bulls. A large majority of cattle surveyed had no defects present when evaluated at the processing facilities (Figure 4-6). This may indicate animals were culled for reasons not visible to researchers, including behavior, reproductive inability, or genetic replacement. Nonetheless, researchers did observe the presence of at least one visible defect in 44.1%, 32.1%, 27.9%, and 24.2% of dairy cows, beef bulls, beef cows, and dairy bulls, respectively (not in tabular form). Compared to the 2007 audit, an increased frequency of at least one defect was seen in dairy cows (+7.1% points), beef bulls (+8.2% points) and dairy bulls (+4.5% points) (Nicholson, 2008). Overall, defect frequencies (single versus multiple defects) indicate that producers were more likely to cull animals after observing a single defect rather than holding that animal until other conditions occurred (Figure 4-6), showing most producers are marketing animals in a timely manner.

Bovine ocular neoplasia (cancer eye), which is a concern for both cosmetic and welfare reasons, was not identified in 99.0% of all cattle surveyed (not in tabular form). Non-reproductive defect frequencies are shown in Figure 4-7. Foot abnormalities in beef bulls were more prevalent than cows or dairy bulls, and occurred more frequently in 2016 than in 2007 (+6.4% points) (Nicholson, 2008). Nicholson (2008) reported dairy cows had the greatest frequency of foot abnormalities of all cattle types surveyed in 2007. However, the percentage of dairy cattle characterized with a foot abnormality has fallen 5% points. Only a small percentage of cattle possessed some form of abscess. Of the abscesses observed in beef cows (n = 36), 55.6% were located on the face, 16.7% were located on the hooks or pins, and 8.3% were located on the knee or hock (not in tabular form). Dairy cattle abscesses (n = 85) were most frequently located on the knee or hock (50.6%) and only 20.0%, 17.6%, and 11.8% were located on the hooks and pins, face, or "other" area (i.e. shoulder, brisket, round, withers and rib), respectively. Nearly 82% of the abscesses in beef bulls (n = 11) were on the face. Lumpy jaw was observed in 1.2% of beef cows and 0.5% of beef bulls surveyed.

Reproductive soundness is often compromised in cows that show signs of failed suspensory ligaments, mastitis, udder problems, and retained placentas. These reproductive defects were observed in surveyed cattle at frequencies outlined in Figure 4-8. Dairy cows had the greatest incidence of reproductive defects, with the exception of bottle teats for which beef cows had the greater frequency. Bottle teats were previously reported (Frisch, 1982) to cause higher calf mortality due to inadequate milk production to support the calf. Dairy cows (14.7%) in the current audit had a much greater frequency of failed suspensory ligaments compared to the 3.6% reported in 2007 (Nicholson, 2008). Conversely, dairy cows surveyed in 2016 had a lesser frequency (-6.1% points) of multiple udder defects than in 2007 (Nicholson, 2008). Beef cows had a greater rate of mastitis observance in 2016 than beef cows in 2007 (+1.7 % points) (Nicholson, 2008).

Bulls are often culled for inability to breed cows. This could be caused by sperm infertility, a broken penis, incapacity to travel across range due to structural feet and leg problems, or loss of libido. Observations indicated that 6.7% of beef bulls (n = 402) and 0.0% of dairy bulls (*n* = 120) had broken penises. In 2007, there was higher incidence (+3.8% points) of broken penises in dairy bulls compared to the current audit (Nicholson, 2008).

Horn presence may be a cause of carcass bruising (Shaw et al., 1976; Grandin, 1980). Therefore, the cattle were surveyed for presence and length of horns (Table 4-5). Of the cattle evaluated, horns were not seen on 90.3%, 87.9%, 82.7%, and 69.0% of beef cows, dairy cows, beef bulls, and dairy bulls, respectively. These are higher frequencies than reported for beef cows (80.8%), beef bulls (79.3%), and dairy bulls (54.8%) in 2007 (Nicholson, 2008). The greatest frequency of horned beef cattle (4.5% - cows; 10.1% - bulls) had horn lengths greater than 12.7 cm. In contrast, the greatest frequency of horned dairy cattle (7.0% - cows; 16.7% - bulls) had horn lengths less than 2.54 cm. This may indicate dairy producers are more effectively tipping horned cattle to ensure safety for animals and handlers during the production lifetime of animals. This also inadvertently helps minimize undue carcass bruising.

A knot, generally defined as a swelling resulting from an inappropriate intramuscular or subcutaneous injection of animal health products, poses a potential quality concern in the beef and dairy industries (Roeber et al., 2000). If animal health products are not administered subcutaneously in the neck region and instead administered in more valuable muscles, there can be increased incidence of injection-site lesions visible in high-valued primals and subprimals during fabrication. This causes significant loss in meat yield. Of the cattle surveyed (*n* = 5,160), 97.9% displayed no visible sign of a knot (not in tabular form). Of the knots visible (*n* = 109), 45.0% were observed in the neck, 14.7% in the shoulder, 14.7% in the top butt, 6.4% in the round, and 19.3% elsewhere not specified by recorder (not in tabular form). Knots in the neck do not pose a quality concern, as the Beef Quality Assurance program advocates animal health injections being administered subcutaneously in the neck, the least valuable area in the carcass (Beef Quality Assurance Advisory Board, n.d.). In 2007, 2.6% of all cattle surveyed (*n* = 5,520) had a knot in the neck, 4.6% in the shoulder, 0.2% in the top butt, and 0.5% in the round (Nicholson, 2008). Compared to the 2016 survey results, where 0.9%, 0.3%, 0.3%, and 0.1% of all cattle (*n* = 5,160) had a knot in the neck, shoulder, top butt, and round, respectively, it appears efforts to reduce injection-site lesions through Beef Quality Assurance training and producer education have been effective.

Hide Evaluation

Roeber et al. (2000) identified branding as a management practice that reduces the value of cattle hides. Branding has been a practice that dates back to 2700 B.C. (Stamp, 2013). Although hot-iron branding is the most permanent form of identification, it also provides a means for devaluation of the hide. At $53 USD/hide piece (USDA-AMS, 2017c), cow hides are valued at three times that of other offal by-products making it the most valuable item in the drop credit. In the NMCBBQA-1999, branded hides were identified as being the cause for an industry loss of $6.27 USD per animal (Roeber et al., 2000). The dollar value lost due to hide brands and latent damage in 2016 was determined to be $7.47 USD per animal (National Cattlemen's Beef Association, 2017). Therefore, it is imperative that producers make attempts at preventing hide depreciation.

Of the cattle surveyed, 22.7% had at least one brand visible on the hide (not in tabular form). This is an improvement of 0.9% points from 2007 (Nicholson, 2008). The percentage of brand occurrence on beef cattle hides (35.7%) was greater compared to dairy cattle (10.7%) (not in tabular form). Therefore, branding and the loss of hide value is a greater concern in beef cattle. This is expected because traditional beef cattle management involves the branding of calves following the calving season, a management practice that is not utilized heavily in the dairy industry.

Figure 4-9 shows the percentage of cattle with no brand, one brand, or multiple brands. The overwhelming percentage of cattle had unbranded hides. Nine years ago, 90.1%, 68.7%, and 62.4% of dairy cows, beef cows, and beef bulls, respectively, had unbranded (native) hides (Nicholson, 2008). Interestingly, only 71.9% of dairy bulls in 2007 had native hides, which is numerically fewer than 2016 (Nicholson, 2008).

Even though branding is still a traditional practice in maintaining the heritage of cattle ranching, preserving ownership, and is required in some states, producers can minimize value loss by branding cattle on the butt or shoulder rather than the side. On cattle surveyed, butt brands were present at a greater rate than either side or shoulder brands (Table 4-6). Dairy animals surveyed in 2016 had a lesser frequency of side brands when compared to those reported in the NMCBBQA-2007, whereas beef animals surveyed had a greater frequency of side brands than those reported by Nicholson (2008). The frequency of butt branding decreased in dairy bulls, yet increased in all other cattle types compared to 2007 (Nicholson, 2008). The only incidence of increased shoulder brand frequency from the findings of Nicholson (2008) to the current audit was observed on beef cows. Notably, nine years ago, shoulder brand frequency in dairy bulls was 5.2%, when none were observed in the present study for this cattle type (Nicholson, 2008). Brand location is most important to producers registering a new brand through their state or county brand law program. Existing brands already have specified locations, but new brands being registered should be placed either on the butt or shoulder to help mitigate the value loss to hides.

Not only is location of a brand important for minimizing hide devaluation, but size of the brand also plays an important role. Large brands spanning a significant portion of the hide, especially over the midsection of an animal, lower hide value because of decreased usable surface area (Gugelmeyer, 2010). The greatest mean area occupied by a brand was observed on the sides of beef cows (Table 4-7). There was also a large variation in the size of side brands on beef cows.

Mud was not observed on the hides of 56.0% of all cattle surveyed, and those with visible mud were most commonly scored as having small amounts (Table 4-8). When data are presented by gender and type (Table 4-8), 57.8% of dairy cows, 54.9% of beef cows, 52.8% of beef bulls, and 48.8% of dairy bulls had no visible mud. Legs and bellies were found to have the highest prevalence of mud in cattle surveyed, while mud was least frequently seen on the side, top line, and tail region (Table 4-9). Only 42.7% of all cattle surveyed in the NBQA-2007 (Nicholson, 2008) did not have mud on their hide, a lower frequency than we observed. The reduction in mud is indicative of the industry’s initiatives to prevent mud contamination in transport and lairage environments, and remove mud from hides before dressing begins. Mud presence on cattle hides creates potential for cross-contamination of food products when skinning and hide-removal are performed on the harvest floor, thus mud is a potential vehicle for pathogens of foodborne significance (Reid et al., 2002). As such, producers, transporters, and processors all have a role in reducing the prevalence of mud by way of housing animals in dry lots, cleaning trailers, and removing excess mud from the hide before harvesting.

Over 45% of beef cows, beef bulls, and dairy bulls were tagged with a single form of identification, while more than 65% of dairy cows had multiple forms of identification (Table 4-10). Ear tags specifying individual animal identification were most commonly observed in all cattle surveyed; however, dairy cows had a much higher frequency of electronic tag identification than other cattle (Table 4-10). The Holstein Association USA initiated a national tag registration system in 2015 that required registered dairy Holsteins to be tagged once at birth and once again at six months of age using official USDA identification with an 840 number (USDA-APHIS, 2013; Holstein Association USA, n.d.). The 840 ear tags can be either a visible identification with numbers, or may include a radio frequency identification (RFID) to be used for electronic scanning. The required tagging procedures likely contribute to why dairy cows were more frequently observed to have two forms of identification and were most tagged with an electronic identification tag. Because the 840 ear tags come in both electronic and non-electronic in addition to being shaped like standard-type ear tags, the determination of the frequency of individual identification may have been overestimated, whereas the determination of the frequency of electronic identification may have been underestimated.

Electronic tag utilization in the dairy industry is practical because cows are handled once, if not twice, daily for milking. Tracking a cow for milk yield by way of scanning an electronic tag while she is in the milking parlor each day allows for sophisticated livestock management and increased producer awareness to the productivity of their cow herd (Eradus and Jansen, 1999). This type of sophisticated technology is less pertinent, yet still useful if efficiently implemented, in beef operations. This is most likely another reason for the higher incidence of electronic tags observed in dairy versus beef cows and bulls.

As seen in Table 4-11, 68.0% and 67.2% of beef cows and beef bulls, respectively, had a black-colored hide. Red-hided beef animals were the second most prevalent; 20.8% and 18.7% of beef bulls and beef cows, respectively. Overall, 80.1% of beef bulls and 74.0% of beef cows were solid colored (Table 4-12). Baldy-patterned hides were identified on 18.4% and 12.8% of beef cows and beef bulls, respectively. Predominant hide pattern and color for dairy cows (94.2%) and bulls (91.0%) resembled the Holstein breed.

In 2007, Nicholson (2008) reported 44.2% black-hided beef cows and 52.3% black-hided beef bulls. There has been a dramatic increase in the number of black-hided beef cows and bulls marketed over the last nine years. With the increase in black-hided beef cows and bulls being marketed, it would be logical to conclude there may be a decrease in the number of black-hided steers and heifers being harvested. In the steer and heifer NBQA-2016, there were 3.3% fewer black-hided cattle harvested than the previous NBQA-2011 (Eastwood et al., 2017). Studies have shown that a premium price is awarded to black-hided feeder cattle (Bulut and Lawrence, 2007; Schulz et al., 2010). In addition, black-hided beef cows received a premium of $1.69/45.5 kg body weight compared to their red-hided counterparts (Ahola et al., 2011a). So, whether a producer is utilizing cows that are black to produce premium calves, or he/she is culling black-hided cattle, there is opportunity for increased financial returns. This information should not be the primary reason for making culling decisions, but breeding decisions to increase the percentage of black-hided calves should be considered.

Hide-off Carcass Evaluation

For all cow carcasses evaluated, 35.9% did not have a bruise (Table 4-13). This is similar to the frequency of cow carcasses (36.6%) which did not have a bruise in 2007 (Nicholson, 2008). Although over half of the cow carcasses surveyed in the current year were bruised, the majority (67.3%) possessed a bruise of minimal severity, meaning less than 0.45 kg of surface trim would be removed due to bruise damage. In addition, fewer carcasses had critical bruising compared to 2007 (Nicholson, 2008), indicating a lesser frequency of bruises resulting in 4.99 kg to 18.14 kg of surface trim. Table 4-14 indicates even further that all four classes of carcasses surveyed had the greatest incidence of minimal bruises and the lowest incidence of critical or extreme bruises. Multiple bruises were observed on 41.3% of dairy cow and 24.0% of beef cow carcasses, respectively (not in tabular form). In comparison, 25.2% of dairy bull and 13.5% of beef bull carcasses had multiple bruises (not in tabular form).

Roeber et al. (2000) reported that carcass bruising was the sixth cause of whole carcass condemnation in 1999, and encouraged producers to employ handling practices to minimize bruising. Later in 2007, interviews with packers, producers, and retailers established improvements in carcass bruising had been made (National Cattlemen's Beef Association, 2007). Even so, carcass bruising was still included in the list of top quality challenges in 2007 (National Cattlemen's Beef Association, 2007). Based on the results of the 2016 audit, there is still opportunity to decrease the prevalence of carcass bruising.

Of the bruises reported in cow carcasses, the greatest percentage were located on the round and sirloin. Bull carcasses tended to have a greater frequency of bruises on the brisket, plate, and flank region when compared to cow carcasses. Bruises that occur within 24 h of harvest are often a direct result of handling practices and facility design. As outlined in previous audits, carcass bruising costs the industry each year (Smith et al., 1994; Roeber et al., 2000); according to the National Cattlemen's Beef Association (1994), $11.47 USD was lost per animal in 1994 due to the influence of carcass bruising. Likewise, Boleman et al. (1998) found that carcass bruising costs the steer and heifer beef industry $14,452,000 USD annually. In addition, it was reported that $2.24 USD of value was lost per animal due to bruising in 1999 (National Cattlemen's Beef Association, 2017). Thus, there needs to be a continued emphasis placed on proper cattle handling for the purpose of reducing bruising and associated value loss of beef carcasses.

Nearly all cattle surveyed (98.4%) in the current audit had no visible indication of an injection-site lesion on the carcass surface (data not shown in tabular form). Not only is this an improvement of nearly 5% points compared to 2007 (93.5%), but also only 1.7% of dairy cow carcasses showed signs of injection-site lesions compared to 11.2% reported in the previous audit (Nicholson, 2008).

Offal Condemnations

Offal condemnations were assessed in all previous NBQAs (Smith et al., 1994; Roeber et al., 2000; Roeber et al., 2001; Nicholson, 2008). Frequencies of offal condemnations by USDA-FSIS are reported in Table 4-15. The liver condemnation rate in the present study was similar to the NBQA-2007, and higher than in the 1994 and 1999 NBQAs. Reasons for liver condemnation included abscesses (20.7%), contamination (7.8%), telangiectasis (6.5%), flukes (3.2%), and unspecified reasons (6.5%) (Figure 4-10). There has been an increase ($P < 0.05$) in liver condemnation due to abscesses, telangiectasis, liver contamination, and pericarditis since the NBQA-2007 (Nicholson, 2008), whereas liver condemnations due to flukes and unspecified reasons declined ($P < 0.05$) (Figure 4-10). Rezac et al. (2014) observed liver abscesses in 32.2% of the cull dairy and beef cow population they studied. They concluded liver abscesses in dairy cows in particular, are a result of rapid changes in diet when transitioning from gestation to lactation and the high energy diets that are necessary for maximum milk production (Rezac et al., 2014). A high incidence of liver abscesses may also be seen in cows because of the increased opportunity for the development of "hardware disease" (Rezac et al., 2014). Incidence of liver abscesses may be higher in dairy cows than beef cows, because tylosin phosphate is restricted from use in lactating dairy cows (Elanco Animal Health, n.d.). Producers who elect to feed beef cows prior to harvest to achieve carcass merits eligible for White Fat programs should work with their veterinarian to incorporate tylosin phosphate or other similar products to help mitigate the development of liver abscesses, which in turn will preserve the value of the liver as a by-product.

It is interesting that the frequency of liver abscesses (30.8%) reported in the steer and heifer NBQA-2016 (Eastwood et al., 2017) is lower than that reported in the NBQA-2016 for cows and bulls. Being traditionally managed in a feedyard, it would seem steers and heifers have greater exposure to liver abscess development while consuming a high-energy ration. However, the use of antimicrobial feed additives at feedyards under a Veterinary Feed Directive could contribute to the lower rate of abscesses being observed in the steer and heifer population.

Lung condemnations were evaluated for the first time in the present study. Overall, lungs were condemned from nearly one-quarter of the carcasses surveyed (Table 4-15). Reasons for lung condemnations included: contamination (11.7%), mild pneumonia (4.2%), moderate pneumonia (2.3%), severe pneumonia (1.2%), and other reasons not specified (3.8%) (not in tabular form). There was a 6.2% point increase in the frequency of hearts condemned compared to the previous audit. In the current study, hearts were condemned for contamination (15.5%), pericarditis (5.3%), and other reasons not specified (1.5%). Reasons for viscera condemnations included contamination (10.1%), abscesses (5.1%), ulcers (0.3%), and other unspecified reasons (4.6%) (not in tabular form).

The rate of head and tongue condemnations was determined during all market cow and bull audits, whereas the rate of heads and tongues that were trimmed before passing inspection was not documented as part of the 1994 and 1999 NBQAs (Smith et al., 1994; Roeber et al., 2000; Nicholson, 2008). In the current survey, heads were condemned for contamination (3.3%), lymph node concerns (1.8%), abscesses (0.9%), and other unspecified reasons (2.2%) (not in tabular form). Heads were trimmed for contamination (0.5%), lymph node concerns (0.3%), abscesses (0.0%), and other reasons (0.2%) (not in tabular form). Tongues were condemned for lymph node concerns (1.4%), contamination (0.6%), hair sore (0.2%), cactus tongue (0.2%), and unspecified reasons (1.8%) (not in tabular form). Tongues were trimmed for hair sore (9.0%), lymph node concerns (4.1%), contamination (2.3%), cactus tongue (1.4%), and other reasons not specified (0.6%) (not in tabular form).

Compared to the NBQA-2007, both head and tongue condemnations have numerically declined (Table 4-15). Total tongue condemnations have decreased by 4.1% points, while tongues that were trimmed increased by 8.5% points (Nicholson, 2008). There was a decrease in tongues condemned due to cactus tongue (-2.0% points) and hair sore (-1.6% points) compared to 2007, yet an increase in the tongues trimmed due to cactus tongue (+1.4% points) and hair sore (+4.6% points) (Nicholson, 2008). This may indicate a change in tongue inspection protocol by USDA-FSIS; choosing to trim tongues rather than condemn them for hair sore and cactus tongue appeared to be more common for USDA-FSIS inspectors in 2016.

The frequency of broken mouths and gummers observed was 8.5% and 6.2%, respectively (not reported in tabular form). A broken mouth or complete wear of the incisors are very likely causes for culling breeding animals because these animals no longer have the ability to maintain body condition, subsequently reducing their breeding efficacy and functionality.

In the 1999 NBQA, an economic value ($4.49 per animal using 1999 prices) was assigned to the lost opportunity caused by offal condemnations (Roeber et al., 2000). In 2016, this same lost opportunity was computed to provide evidence for improvement in earned value or larger losses in value for offal condemnations. In 2016, offal condemnations cost the industry $2.56 USD per animal. To make accurate comparisons, the prices used to determine the 2016 value loss were used to refigure the value loss in both NBQA-1994 ($1.75 USD) and -1999 ($1.90 USD) (National Cattlemen's Beef Association, 2017). This shows that market cow and bull beef producers and/or processors are losing more value due to offal condemnations today than in previous audit years. Therefore, producers should identify ways to minimize and control factors contributing to offal condemnations.

To determine the incidence of bred cows being harvested, researchers documented the presence of fetuses. Of the cow carcasses surveyed (n = 4,692), 17.4% carried a fetus at the time of harvest. This has increased numerically from that reported in the NBQA-2007, where only 10.6% of cows were pregnant at the time of harvest (Nicholson, 2008). During the NBQA-2016, researchers identified 47.1% of the fetuses present (n = 815) to be older than 150 d (estimated based on fetal size). By day 38 of pregnancy, the fetus has attached to the uterine wall making pregnancy detection by palpation, ultrasound, or blood test very effective (Carpenter and Sprott, 2008). Pregnancy detection by any means is a useful tool in determining when to keep or cull cows based on reproductive performance (Carpenter and Sprott, 2008). A study conducted by the National Animal Health Monitoring System reported that less than 20% of cattlemen check for pregnancy in their cowherd (Bridges et al., 2008). Beef and dairy producers who regularly confirm pregnancies in their herd may cull cows with confirmed pregnancies when the producer believes a cow’s condition is too severe to hold her over until after calving and weaning. However, producers who are not checking for pregnancy before culling are potentially missing an opportunity to capitalize on increased calf crop dollar returns.

Carcass Traits

Carcasses surveyed in the NBQA-2016 were evaluated for both quality and yield grade factors outlined by the USDA (Table 4-16). Beef cow carcasses tended to be slightly fatter, on average, than their counterparts, which may have contributed to beef cow carcasses earning a higher average numerical USDA yield grade than the other carcass types surveyed. Even so, the average adjusted fat thickness determined for beef cow carcasses was not excessively thick. The first NBQA (1994) determined a carcass was "too fat" if assigned a finish score 4 through 9 on a 9-point scale (National Cattlemen's Beef Association, 1994). Although not a direct comparison, this could be considered the same as identifying any carcass with a PYG over 3.5 (over 1.5 cm of back fat) would be considered "too fat." Data show that while the average fat thickness for all carcass types is not excessively fat, 17.7% of beef cows, 4.3% of beef bulls, 3.2% of dairy cows, and 1.7% of dairy bulls are "too fat" based on the NBQA-1994 standards (not in tabular form). The criteria outlined in the NBQA-1994 was likely determined because cow and bull carcasses were most often fabricated for use as the lean trimmings source in ground beef mixing (Speer et al., n.d.). Because cow carcasses that meet specific fat type and muscle size specifications are more frequently fabricated into whole muscle primals and subprimals today (Nicholson, 2008; Woerner, 2010), utilization of the NBQA-1994 standards for determining carcasses that are "too fat" may not be appropriate.

Bull carcasses had heavier mean carcass weights and larger mean LM area as compared to cow carcasses (Table 4-16). This is expected as bulls are generally larger than their cow counterparts. Also as expected, due in part to their inherent lack of muscling, dairy cow carcasses were the lightest weight on average. Because of the tendency for dairy cows to be lighter muscled than beef cows, one may expect the average dairy cow carcass LM area to be lower than the average beef cow carcass LM area. However, data show comparable mean LM areas for the two cow carcass types (Table 4-16).

Cow carcasses had a greater average amount of marbling than bull carcasses (Table 4-16). The distribution of marbling scores (Table 4-17) in both beef cow and dairy bull carcasses indicate that there was an upward shift in marbling compared to 2007. Specifically, the greatest number of carcasses in the NBQA-2016 were assigned a slight marbling score, whereas in the NBQA-2007, the greatest number of carcasses possessed traces marbling (Nicholson, 2008). Dairy cow carcasses and beef bull carcasses had the highest frequency of slight and traces marbling, respectively, which is not different than what was reported by Nicholson (2008). Possibly due to the greater number of cow carcasses surveyed, yet still appropriate to consider, cow carcasses represented all marbling scores — meaning some possessed abundant amounts of marbling, while others had only practically devoid amounts of marbling in the loin muscle. In contrast, bulls only were found to possess practically devoid, traces, slight and small amounts of marbling.

Marbling is important because it indicates the palatability of beef and generally has a positive influence on a consumer's eating experience (Aberle et al., 2012). Because the amount of marbling can increase, lean color can improve, fat can become whiter, and LM areas can become larger as a result of the level of feeding prior to harvest, Woerner (2010) stated, "market cow beef will have an increased influence on beef-eating experiences in the U.S. for years to come.” In a study evaluating the effect of pre-slaughter feeding on carcass characteristics, Allen et al. (2009) reported increased carcass weight, dressing percentage, fat thickness, and marbling scores in dairy cows fed a high concentrate ration for 90 d. Similarly, Schnell et al. (1997) found carcass weight, dressing percentage, and fat thickness to increase when beef and dairy cows were fed for 28 d, while marbling score did not differ between fed and non-fed cows. These studies indicate that exposing market cows to feeding regimes prior to harvest has potential to improve carcass traits that are important for earning producers a premium.

A comparison of USDA carcass traits from the NBQA-2007 (Nicholson, 2008) to the NBQA-2016 is provided in Table 4-18. Average back fat increased numerically in beef cow and bull carcasses, as well as in dairy bull carcasses. Although back fat in dairy cow carcasses decreased numerically compared to 2007, average LM area increased, which may have contributed to the increased average carcass weight. A numerical increase in average LM area was seen for both dairy bull and beef cow carcasses, whereas average carcass weight increased numerically for beef cows but decreased for dairy bulls. Beef bull carcass weight stayed very consistent in the two audit years, but a drastic numerical decrease (over 12 cm^2) in average LM area was seen for beef bull carcasses in the NBQA-2016 compared to the NBQA-2007. The beef carcass population earned a higher average marbling score, whereas the dairy carcass population did the opposite since the NBQA-2007.

The mean carcass muscle scores for beef cow (2.4), dairy cow (1.8), beef bull (3.0), and dairy bull carcasses (2.7) indicate carcass muscling varies between beef and dairy breed-type; lower numerical mean muscle scores are reported for dairy cow and bull carcasses than beef cow and bull carcasses (data not in tabular form). Nonetheless, the expectation that dairy cow carcasses yield the least amount of lean muscle is confirmed. The comparison of muscle score frequencies between the NBQA-2007 and the NBQA-2016 is shown in Table 4-19. Beef cows in both NBQAs were assigned a muscle score 2 most frequently, followed closely by muscle score 3. The highest frequency of dairy cow carcasses reported by Nicholson (2008) were assigned the lowest muscle score, but in the NBQA-2016 carcass muscle appeared to increase, as the highest frequency of dairy cow carcasses were assigned a score 2. In 2016, there was a larger percentage of beef bulls identified closer to the light muscle standard (score 1) than the heavy muscle standard (score 5), something not expected of bull carcasses. Finally, the dairy bull carcass population was assigned a muscle score 2 or 3 more frequently than in 2007, but the overall distribution appears not to have shifted. Because the market cow and bull industry has been, and to an extent still is, driven by production of lean trimmings, it is important for carcasses to be adequately, if not excessively, muscled. Producers should consider feeding cows a high-energy ration as it has been shown to improve muscle mass (Schnell et al., 1997). Not only does increased muscle increase the value of cows and bulls, but it may also aid in the reduction of the number of lame animals and non-ambulatory animals; if an animal has enough body weight and muscle mass to be able to walk, it is likely not going to become too weak to walk into the processing facility for harvesting.

The majority of carcasses surveyed in the NBQA-2016 had a fat color score of 2, indicating a slight tint of yellow fat. The mean fat color score for beef cows (3.2) and beef bulls (2.4) was slightly more yellow than dairy cows (2.3) and dairy bulls (2.1). This may be evidence of the difference between beef and dairy cattle management style; beef animals are often raised in range environments consuming primarily roughage-based diets, whereas dairy cattle are managed by feeding greater amounts of concentrate feed. Fat color is an important contributor to the marketability of beef, particularly the middle meats, and thus should be considered to directly affect value of market cows and bulls (Roeber et al., 2000). Fat color scores in excess of 3 have been determined to decrease cull animal value by $2.27 (NBQA-1994), $6.48 (NBQA-1999), and $12.47 (NBQA-2016) USD per carcass (National Cattlemen's Beef Association, 2017). Some suggest feeding cows a concentrate diet prior to harvest may improve fat color (Woerner, 2010), but others have found no difference in fat color for cows fed concentrate rations prior to harvest (Schnell et al., 1997; Sawyer et al., 2004).

Arthritic joints are another cause of value loss when processing market cows and bulls. Arthritic joints were once determined to contribute to a $9.72 USD per carcass value loss in the NBQA-1999; the loss is now only $1.89 USD per carcass (National Cattlemen's Beef Association, 2017). Once being a significant concern to the industry, arthritic joints have decreased to frequency of only 1.3%. This is a great improvement from the 11.4% that was observed in the NBQA-1999 (Roeber et al., 2000) and 6.2% in the NBQA-2007 (Nicholson, 2008).

CONCLUSIONS

Results from the NBQA-2016 show live cattle and carcass quality improvements in the market cow and bull beef sector compared to 2007. The most notable improvements include an increase in the percentage of cattle with normal mobility (particularly dairy cattle), a transition from thinner to more moderate body conditioned dairy cattle, and a decrease in the percentage of critical and extreme bruising on all carcasses. Additionally, results indicate the cattle industry has made improvements in hide contamination and carcass traits leading to increased value recovery for producers and processors. Producers, academics, industry professionals, and government agencies may use the findings from the NBQA-2016 to direct the future of the cow and bull industry. Emphasis for extension education, beef quality assurance programs, and future research should be focused toward appropriate management of cull cows and bulls to increase muscle before harvest, marketing animals before physical defects are too severe and cause animal welfare concerns or carcass condemnations, and ways to further improve carcass bruising on the farm, in transport, and at the packing facility. Improving producers’ and stakeholders’ knowledge of production practices that can minimize profit loss, will allow them to be better equipped to implement management techniques that contribute increased profits and the advancement of the entire beef industry.

Table 4-1. National Beef Quality Audit (NBQA): Company and location of live animal, harvest floor, and cooler assessments

Company	Location
ABF Packing	Stephenville, TX
American Beef Packers	Chino, CA
American Foods Group – Cimpls Inc.	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 Packing	Hereford, TX
Central Valley Meat Company	Hanford, CA
FPL Foods LLC	Augusta, GA
H&B Packing	Waco, TX
JBS Green Bay	Green Bay, WI
JBS Omaha	Omaha, NE
JBS Plainwell	Plainwell, MI
JBS Souderton	Souderton, PA
JBS Tolleson	Tolleson, AZ
Lone Star Beef	San Angelo, TX

Table 4-2. National Beef Quality Audit (NBQA): Comprehensive list of predetermined defects identified to be a cause for marketing cows and bulls

Defect	Scale	Description
Bovine ocular neoplasia (cancer eye)	0 – 5[1]	0 – normal eye 1 – small benign tumor producing finger-like growth, precancerous 2 – small white elevated plaque on the eyeball, precancerous 3 – growth on the third eyelid or a tumor that is vascular in nature, cancerous 4 – tumors that have metastasized to the bony structure around the eye or exhibit lymphatic involvement of the parotid gland, cancerous 5 – eyeball has prolapsed from the orbit and/or exhibits a necrotic condition, cancerous
Prolapse	Presence/absence	Rectal – protrusion of the rectum through the anus Vaginal – protrusion of the vagina to the exterior of the body cavity
Hide damage	Presence/absence	Insect damage Latent damage – any visible blemish that could devalue the hide (brands not included)
Abscess	Presence/absence	Collection of pus in confined tissue spaces Types: facial, knee/hock, hook/pin
Bottle teats	Presence/absence	The development of raised smooth or rough rings at the teat ends[2]
Failed suspensory ligament	Presence/absence	Insufficient attachment of the udder to the body cavity so as the ventral portion of the udder lies below the hock and the teats splay outward[3]
Full bag	Presence/absence	Udder filled with milk
Mastitis	Presence/absence	Inflammation of the mammary gland
Multiple udder problems	Presence/absence	Any combination of udder defects
Retained placenta	Presence/absence	Discolored, malodorous membrane hanging from the vulva[4]
Lumpy jaw	Presence/absence	Localized abscess that involves the mandible or any other bony tissue of the head[5]
Calf in pen	Presence/absence	
Broken penis	Presence/absence	
Foot abnormality	Presence/absence	
Swollen joints	Presence/absence	
Warts	Presence/absence	

[1] Gelatt (2016).
[2] Frisch (1982).
[3] Rasby (nd).
[4] Gilbert (2016).
[5] Smith (2016).

Table 4-3. National Beef Quality Audit (NBQA): Mean values 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	Std. Dev.	Min	Max
All trailers					
Time traveled, h	151	6.7	6.36	0.2	39.5
Distance traveled, km	145	455.7	440.76	3.2	2,273.8
Number of cattle in load	154	26	13.38	1	47
Number of compartments used	152	4	1.71	1	7
Trailer area, m^2	151	33.5	10.24	8.9	43.4
Area allotted per animal, m^2	151	2.3	3.30	0.6	20.2
Pot belly trailers					
Time traveled, h	100	9.3	6.25	0.2	39.5
Distance traveled, km	95	639.8	436.38	3.21	2,273.8
Number of cattle in load	102	35	4.88	23	47
Number of compartments used	101	5	1.08	2	7
Trailer area, m^2	101	40.0	2.89	17.8	43.4
Area allotted per animal, m^2	101	1.2	0.17	0.6	1.7
Mixed-sex loads					
Time traveled, h	51	8.3	5.05	0.2	19.3
Distance traveled, km	45	623.6	412.42	3.2	1,508.0
Number of cattle in load	51	34	8.71	5	47
Number of compartments used	50	5	1.21	2	7
Trailer area, m^2	50	39.5	5.33	15.6	43.4
Area allotted per animal, m^2	50	1.2	0.48	0.9	4.2

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

Table 4-4. National Beef Quality Audit (NBQA): Percentage of mobility scores[1] and downers in all cattle surveyed

		Mobility score				
Type of animal	*n*	1	2	3	4	Downers[2]
Beef cows	1,557	87.1	10.2	2.3	0.1	0.2
Dairy cows	1,743	76.0	18.2	4.7	0.3	0.9
Beef bulls	321	82.9	13.7	3.4	0.0	0.0
Dairy bulls	52	76.9	19.2	3.9	0.0	0.0

[1] Mobility scores were assigned as 1) walks normal with no apparent lameness; 2) exhibits minor stiffness, shortness of stride, slight limp, but still keeps up with normal cattle; 3) exhibits obvious stiffness, difficulty taking steps, walks with an obvious limp and discomfort, and lags behind normal cattle; 4) extremely reluctant to move even when encouraged (North American Meat Institute, 2015).

[2] Cattle unable to rise.

Table 4-5. National Beef Quality Audit (NBQA): Percentage of horn presence and size in surveyed cattle

Horn size	Beef cows (*n* = 2,094)	Dairy cows (*n* = 2,584)	Beef bulls (*n* = 398)	Dairy bulls (*n* = 84)
No horns	90.3	87.9	82.7	69.0
<2.54 cm	1.9	7.0	2.5	16.7
2.54 cm to 12.7 cm	3.4	4.6	4.8	13.1
>12.7 cm	4.5	0.5	10.1	1.2

Table 4-6. National Beef Quality Audit (NBQA): Percentage of cattle with a brand located on the butt, side, and shoulder

Brand location	*n*	Percentage (%)
Butt brands		
Beef cows	2,106	25.5
Dairy cows	2,618	9.5
Beef bulls	42	27.4
Dairy bulls	84	14.3
Side brands		
Beef cows	2,107	11.8
Dairy cows	2,619	0.9
Beef bulls	402	9.7
Dairy bulls	84	0.0
Shoulder brands		
Beef cows	2,107	2.8
Dairy cows	2,619	0.4
Beef bulls	402	0.4
Dairy bulls	84	0.0

[1] Percentages do not add to 100% because *n* also includes cattle that were unbranded.

Table 4-7. National Beef Quality Audit (NBQA): Mean size (cm^2) of brands located on the butt and side of all branded cattle surveyed

Brand location	n[1]	Mean	Std. Dev.	Min	Max
Beef cows					
Butt	534	191.5	216.88	12.9	1548.4
Side	248	623.2	1048.45	19.4	8361.3
Dairy cows					
Butt	231	502.3	342.64	25.8	2090.3
Side	20	303.2	311.50	25.8	1451.6
Beef bulls					
Butt	110	201.8	203.96	25.8	1161.3
Side	39	435.1	403.97	19.4	1858.06
Dairy bulls[2]					
Butt	12	324.2	194.97	64.5	645.2

[1] Sample size is a reflection of branded cattle. Cattle with native hides were excluded.

[2] Dairy bulls had no incidence of side brands.

Table 4-8. National Beef Quality Audit (NBQA): Percentage of mud observed in cattle surveyed

Amount	All cattle (n = 5,239)	Beef cows (n = 2,094)	Dairy cows (n = 2,612)	Beef bulls (n = 400)	Dairy bulls (n = 82)
None	56.0	54.9	57.8	52.8	48.8
Small[1]	34.1	35.0	32.0	39.0	42.7
Moderate[1]	8.1	8.1	8.5	6.8	6.1
Large[1]	1.1	0.8	1.4	0.8	1.2
Extreme[1]	0.7	1.2	0.2	0.8	1.2

[1] Pictorial references for mud scores were used as standards throughout the NBQA-2016 (Savell, 2016).

Table 4-9. National Beef Quality Audit (NBQA): Percentage of cattle with mud on various locations of surveyed cattle[1,2]

Location	All cattle (*n* = 2,304)	Beef cows (*n* = 944)	Dairy cows (*n* = 1,101)	Beef bulls (*n* = 189)	Dairy bulls (*n* = 42)
Legs	82.2	81.9	81.7	83.6	90.5
Belly	54.1	46.1	64.3	36.5	59.5
Side	11.4	10.4	12.9	8.5	9.5
Top line	12.1	9.0	14.7	12.2	14.3
Tail region	7.5	5.8	9.0	8.5	4.8

[1] Sample size is only a representation of cattle with mud present.

[2] Percentages do not add to 100 percent because multiple responses may have been recorded per animal surveyed.

Table 4-10. National Beef Quality Audit (NBQA): Percentage[1] of identification types in surveyed cattle

Identification	All cattle (n = 5,242)	Beef cows (n = 2,088)	Dairy cows (n = 2,621)	Beef bulls (n = 397)	Dairy bulls (n = 84)
No ID	8.3	11.9	3.2	20.2	17.9
Single ID	38.6	48.3	29.0	50.1	56.0
Multiple ID	53.0	39.8	67.9	29.7	26.2
Identification type					
Ankle	0.7	0.0	1.4	0.0	0.0
Barcode	1.5	0.9	2.3	0.5	0.0
Electronic	13.2	4.0	22.1	3.0	9.5
Ear tag	69.0	54.9	82.9	54.9	61.9
Metal clip	30.0	38.1	26.7	16.1	8.3
Lot Tag	23.0	20.3	27.1	16.1	7.1
Waddles	0.2	0.5	0.0	0.3	0.0
Other	26.9	17.8	34.0	23.4	28.6

[1] Percentages exceed 100% due to animals having multiple forms of identification.

Table 4-11. National Beef Quality Audit (NBQA): Percentage[1] of each primary hide color observed in cattle surveyed

Hide Color	All cattle (n = 5,232)	Beef cows (n = 2,086)	Dairy cows (n = 2,621)	Beef bulls (n = 399)	Dairy bulls (n = 82)
Patterned animal[2]	51.7	0.1	99.3	0.0	98.8
Black	32.5	68.0	0.3	67.2	1.2
White	1.7	3.0	0.1	4.5	0.0
Yellow	0.9	1.8	0.1	1.0	0.0
Red	9.5	18.7	0.5	20.8	0.0
Brown	3.8	5.0	2.8	3.5	3.7
Gray	1.1	1.7	0.2	2.8	0.0
Tan	1.1	1.7	0.6	0.8	3.7

[1] Percentages exceed 100% due to animals being classified as both patterned and having a primary color.

[2] Includes: Holstein-patterned cattle and cattle with a hide that did not have a primary color covering 51% or more of the hide.

Table 4-12. National Beef Quality Audit (NBQA): Percentage[1] of each hide pattern observed in cattle surveyed

Pattern	All cattle (n = 5,106)	Beef cows (n = 2,033)	Dairy cows (n = 2,554)	Beef bulls (n = 391)	Dairy bulls (n = 78)
Solid colored	38.6	74.0	5.1	80.1	9.0
Baldy	8.5	18.4	0.0	12.8	0.0
Roan	0.7	0.9	0.1	0.8	0.0
Brindle	1.3	2.7	0.1	1.8	0.0
Spots	2.7	5.5	0.3	4.6	0.0
Holstein	48.8	nd[2]	94.2	nd	91.0
Other	0.4	0.2	0.2	2.3	0.0

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

Table 4-13. National Beef Quality Audit (NBQA): Carcass bruise severity over the past twenty-two years in cows and bulls surveyed[1,2,3]

Bruise severity	1994	1999	2007	2016
Cows				
n	Unknown	4,848	5,092	4,262
No bruise	20.3%	11.8%	36.6%	35.9%
Minimal[4]	51.5%	77.2%	36.7%	67.3%
Major[4]	53.9%	41.7%	30.9%	45.1%
Critical[4]	30.7%	21.6%	12.4%	4.9%
Extreme[4]	nd[5]	2.4%	5.4%	1.4%
Bulls				
n	Unknown	831	477	389
No bruise	63.8%	47.1%	46.8%	57.1%
Minimal	25.3%	44.4%	31.5%	42.4%
Major	19.5%	16.7%	20.1%	21.9%
Critical	7.4%	6.9%	11.5%	1.5%
Extreme	nd	1.0%	7.6%	0.3%

[1] National Non-Fed Beef Quality Audit - 1994 (Smith et al., 1994); National Market Cow and Bull Beef Quality Audit - 1999 (Roeber et al., 2000); National Market Cow and Bull Beef Quality Audit - 2007 (Nicholson, 2008).

[2] Total number of observations for cow carcass bruises were: unknown (NNFBQA – 1994); 4,848 (NMCBBQA – 1999); 5,092 (NMCBBQA – 2007); 4,262 (NBQA – 2016). Total number of observations for bull carcass bruises were: unknown (NNFBQA – 1994); 831 (NMCBBQA – 1999); 477 (NMCBBQA – 2007); 389 (NBQA – 2016).

[3] Percentages do not add to 100% because some animals possessed multiple bruises, some of varying severity.

[4] Minimal (<0.45 kg carcass trim); major (0.45 kg to 4.54 kg carcass trim); critical (5.0 kg to 18.14 kg carcass trim); extreme (entire primal was trimmed).

[5] nd = not determined.

Table 4-14. National Beef Quality Audit (NBQA): Frequency (%) of bruise severity

Severity[1]	Beef cows	Dairy cows	Beef bulls	Dairy bulls
Minimal	53.6	57.5	57.2	74.3
Major	39.7	37.6	38.8	24.8
Critical	5.6	3.7	3.9	0.0
Extreme	1.0	1.2	0.0	1.0

[1] Minimal (<0.45 kg carcass trim); major (0.45 kg to 4.54 kg carcass trim); critical (5.0 kg to 18.14 kg carcass trim); extreme (entire primal was trimmed).

Table 4-15. National Beef Quality Audit (NBQA): Percentages of offal condemnations for carcasses evaluated in NBQA-1994[1], NBQA-1999[2], NBQA-2007[3], and NBQA-2016[4,5,6]

Item	NBQA-1994	NBQA-1999	NBQA-2007	NBQA-2016 (± SEM)
Liver condemnations	30.8	24.1	45.3	44.6 ± 0.007
Lung condemnations	nd[7]	nd	nd	23.1 ± 0.006
Heart condemnations	11.0	7.2	16.1	22.3 ± 0.006
Viscera condemnations	nd	nd	nd	20.0 ± 0.006
Tripe condemnations	44.8	19.2	20.5	nd
Kidney condemnations	nd	nd	nd	10.5 ± 0.004
Head condemnations	11.1	6.7	10.2	8.2 ± 0.004
Tongue condemnations	5.9	9.5	10.0	5.9 ± 0.003

[1] National Beef Quality Audit - 1994 (Smith et al., 1994).

[2] National Beef Quality Audit – 1999 (Roeber et al., 2000; Roeber et al., 2001).

[3] National Beef Quality Audit – 2007 (Nicholson, 2008).

[4] Total number of observations for liver, viscera, and kidney condemnations were: unknown (NBQA-1994); unknown (NBQA-1999); 4,896 (NBQA-2007); 4,800 (NBQA-2016).

[5] Total number of observations for head and tongue condemnations were: unknown (NBQA-1994); unknown (NBQA-1999); 5,260 (NBQA-2007); 5,720 (NMCBBQA-2016).

[6] Total number of observations for heart and lung condemnations were: unknown (NBQA-1994); unknown (NBQA-1999); 4,896 (NBQA-2007); 4,586 (NBQA-2016).

[7] nd = not determined.

Table 4-16. National Beef Quality Audit (NBQA): Means values for USDA carcass grade traits

Trait	*n*	Mean	Std. Dev.	Min	Max
Beef cows					
USDA yield grade	529	3.1	1.04	0.0	7.4
Adjusted fat thickness, cm	1,718	0.7	0.74	0.0	4.6
HCW, kg	1,728	311.1	86.83	25.5	585.0
LM area, cm^2	1,132	64.2	17.96	19.35	123.8
KPH, %	628	1.5	1.06	0.0	4.5
Marbling score[1]	1,060	346	131.24	100	970
Lean maturity[2]	1,109	357	131.32	110	600
Skeletal maturity[2]	1,734	497	126.24	100	600
Overall maturity[2]	1,109	443	109.57	150	600
Dairy cows					
USDA yield grade	633	2.8	0.84	0.2	5.8
Adjusted fat thickness, cm	1,708	0.4	0.43	0.0	3.0
HCW, kg	1,714	303.4	73.93	91.8	549.1
LM area, cm^2	1,133	64.6	15.75	20.0	107.1
KPH, %	696	1.8	1.40	0.0	7.5
Marbling score	1,124	367	142.45	100	950
Lean maturity	1,117	315	127.53	120	600
Skeletal maturity	1,713	413	150.99	110	600
Overall maturity	1,117	387	126.64	145	600
Beef bulls					
USDA yield grade	28	2.4	0.98	0.9	4.8
Adjusted fat thickness, cm	208	0.4	0.49	0.0	3.6
HCW, kg	210	398.4	91.06	115.5	782.3
LM area, cm^2	141	78.8	16.03	28.38	114.2
KPH, %	33	1.1	0.79	0.0	3.0
Marbling score	129	258	82.99	100	490
Lean maturity	137	380	141.86	160	600
Skeletal maturity	213	422	153.68	140	600
Overall maturity	137	399	136.76	160	600
Dairy bulls					
USDA yield grade	14	2.0	0.7	0.6	2.9
Adjusted fat thickness, cm	58	0.3	0.30	0.0	1.9
HCW, kg	59	373.0	101.68	155.5	665.0
LM area, cm^2	26	77.5	18.28	36.1	109.7
KPH, %	16	1.2	0.82	0.0	2.5
Marbling score	26	273	89.99	100	440
Lean maturity	26	360	141.27	140	600
Skeletal maturity	59	319	151.75	120	600
Overall maturity	26	360	129.36	160	600

Table 4-16 continued.

[1]100 = Practically devoid^{00}, 200 = Traces^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 600 = Moderate^{00}, 700 = Slightly Abundant^{00}, 800 = Moderately Abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

[2]100 = A^{00}, 200 = B^{00}, 300 = C^{00}, 400 = D^{00}, 500 = E^{00} (USDA, 2016).

Table 4-17. National Beef Quality Audit (NBQA): Marbling score frequencies (%) observed in cows and bulls surveyed

		Marbling score[1]								
Type of animal	*n*	PD	TR	SL	SM	MT	MD	SLAB	MAB	AB
Beef cows										
2007[2]	1,057	16.8	27.8	26.2	15.1	6.5	3.3	1.4	0.2	nd[3]
2016	1,129	16.0	22.3	33.6	18.2	5.9	2.2	1.0	0.4	0.3
Dairy cows										
2007	538	8.0	17.2	26.5	22.8	12.2	5.8	3.6	1.7	nd
2016	1,129	11.3	16.3	34.7	23.8	7.3	3.7	2.0	0.4	0.4
Beef bulls										
2007	168	19.2	58.1	15.0	1.2	0.6	0.6	0.0	0.0	nd
2016	138	23.9	50.7	20.3	5.1	0.0	0.0	0.0	0.0	0.0
Dairy bulls										
2007	15	13.3	53.3	20.0	0.0	6.7	6.7	0.0	0.0	nd
2016	33	19.2	30.8	46.2	3.8	0.0	0.0	0.0	0.0	0.0

[1] PD = Practically devoid, TR = Traces, SL = Slight, MT = Modest, MD = Moderate, SLAB = Slightly abundant, MAB = Moderately abundant, AB = Abundant.

[2] National Market Cow and Bull Beef Quality Audit – 2007 (Nicholson, 2008).

[3] nd = not determined.

Table 4-18. National Beef Quality Audit (NBQA): Means for USDA carcass grade traits from the most recent two National Beef Quality Audits

Trait	NBQA-2007[1]	NBQA-2016[2]
Beef cows		
USDA yield grade	2.6	3.1
Adjusted fat thickness, cm	0.64	0.74
HCW, kg	288.0	311.1
LM area, cm^2	61.3	64.2
KPH, %	0.3	1.5
Marbling score[3]	314	346
Lean maturity[4]	418	357
Skeletal maturity[4]	525	497
Overall maturity[4]	482	443
Dairy cows		
USDA yield grade	2.8	2.8
Adjusted fat thickness, cm	0.56	0.42
HCW, kg	294.3	303.2
LM area, cm^2	62.6	64.6
KPH, %	1.1	1.8
Marbling score	388	366
Lean maturity	339	315
Skeletal maturity	489	413
Overall maturity	425	387
Beef bulls		
USDA yield grade	1.6	2.4
Adjusted fat thickness, cm	0.30	0.35
HCW, kg	396.0	396.6
LM area, cm^2	91.0	78.8
KPH, %	0.2	1.1
Marbling score	228	258
Lean maturity	378	380
Skeletal maturity	414	422
Overall maturity	394	399
Dairy bulls		
USDA yield grade	1.9	2.0
Adjusted fat thickness, cm	0.18	0.26
HCW, kg	420.9	373.0
LM area, cm^2	75.5	77.5
KPH, %	0.6	1.2
Marbling score	290	273
Lean maturity	354	360
Skeletal maturity	387	319
Overall maturity	367	360

Table 4-18 continued.

[1] National Market Cow and Bull Beef Quality Audit – 2007 (Nicholson, 2008). Total number of observations were: beef cows (*n* = 1,315), dairy cows (*n* = 1,320), beef bulls (*n* = 245), dairy bulls (*n* = 95).

[2] Total number of observations were: beef cows (*n* = 1,735), dairy cows (*n* = 1,714), beef bulls (*n* = 213), dairy bulls (*n* = 59).

[3] 100 = Practically devoid^{00}, 200 = Traces^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 600 = Moderate^{00}, 700 = Slightly Abundant^{00}, 800 = Moderately Abundant^{00}, 900 = Abundant^{00} (USDA, 2016)

[4] 100 = A^{00}, 200 = B^{00}, 300 = C^{00}, 400 = D^{00}, 500 = E^{00} (USDA, 2016).

Table 4-19. National Beef Quality Audit (NBQA): Muscle score[1] frequencies (%) compared across the 2007[2] and 2016[3] surveys

Muscle score	2007	2016
Beef cows		
1	32.0	21.4
2	31.5	33.5
3	25.3	29.5
4	8.3	11.3
5	2.9	4.3
Dairy cows		
1	53.0	35.3
2	36.8	54.0
3	9.4	9.6
4	0.8	0.9
5	0.0	0.2
Beef bulls		
1	4.9	7.0
2	13.1	24.9
3	30.7	36.2
4	23.4	23.0
5	27.9	8.9
Dairy bulls		
1	11.7	6.9
2	27.7	39.7
3	28.7	34.5
4	19.2	10.3
5	12.8	8.6

[1] 1 = light muscled, 5 = heavy muscled

[2] National Market Cow and Bull Beef Quality Audit – 2007 (Nicholson, 2008).Total number of observations were: beef cows (*n* = 1,315), dairy cows (*n* = 1,320), beef bulls (*n* = 245), dairy bulls (*n* = 95).

[3] Total number of observations were: beef cows (*n* = 1,691), dairy cows (*n* = 1,701), beef bulls (*n* = 213), dairy bulls (*n* = 58).

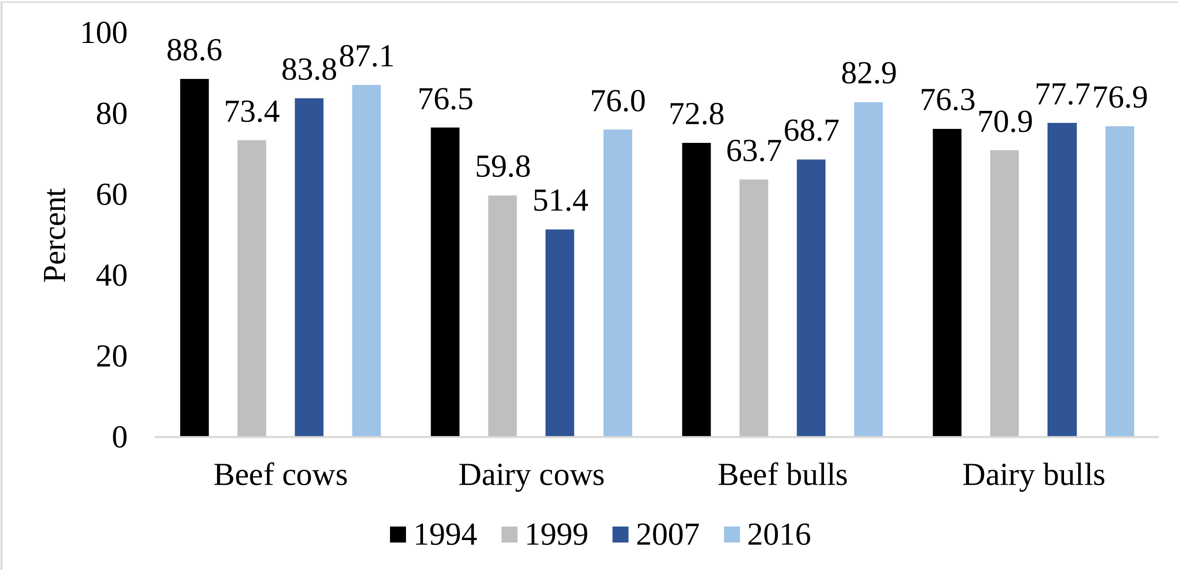

100
80
60
40
20
0
Percent
88.6
73.4
83.8
87.1
76.5
59.8
51.4
76.0
72.8
63.7
68.7
82.9
76.3
70.9
77.7
76.9
Beef cows
Dairy cows
Beef bulls
Dairy bulls
1994
1999
2007
2016

Figure 4-1. National Beef Quality Audit (NBQA): Percentage of sound (normal mobility) cattle observed in each of the National Market Cow and Bull Beef Quality Audits. Total number of observations were National Non-Fed Beef Quality Audit-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: beef cows (*n* = 2,237), dairy cows (*n* = 1,108), beef bulls (*n* = 419), dairy bulls (*n* = 79); NMCBBAQ-2007: beef cows (*n* = 2,807), dairy cows (*n* = 2,112), beef bulls (*n* = 431), dairy bulls (*n* = 130); NBQA-2016: beef cows (*n* = 1,557), dairy cows (*n* = 1,743), beef bulls (*n* = 321), dairy bulls (*n* = 52) (Smith et al., 1994; Roeber et al., 2000; Nicholson, 2008).

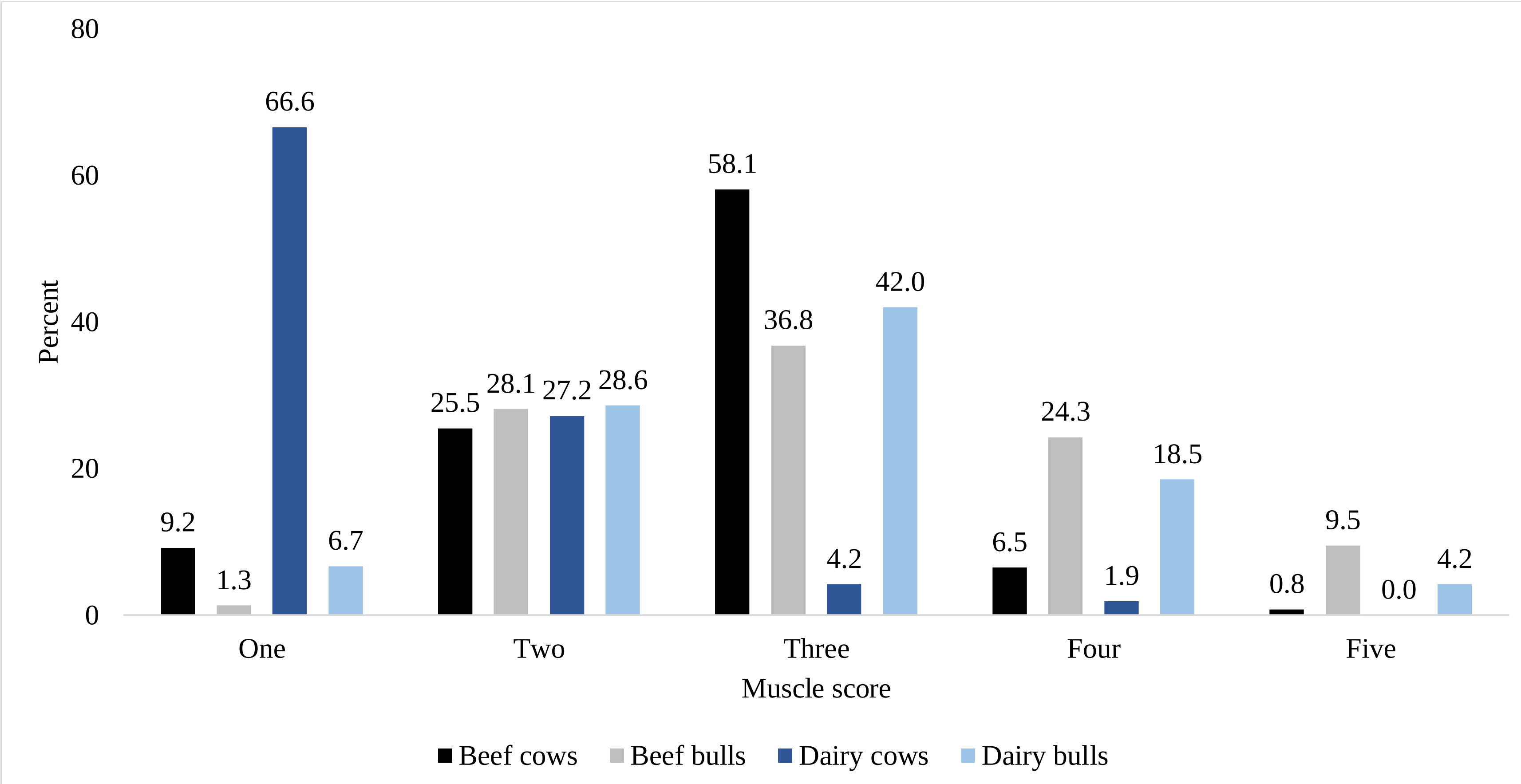
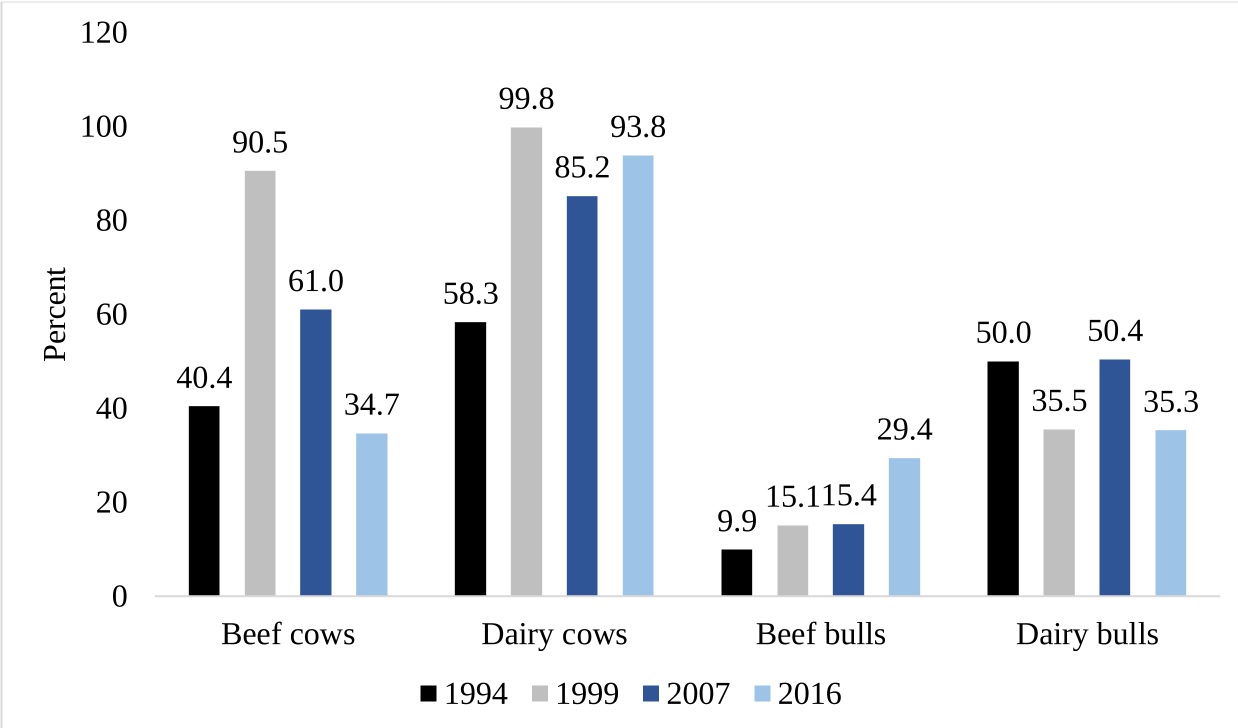
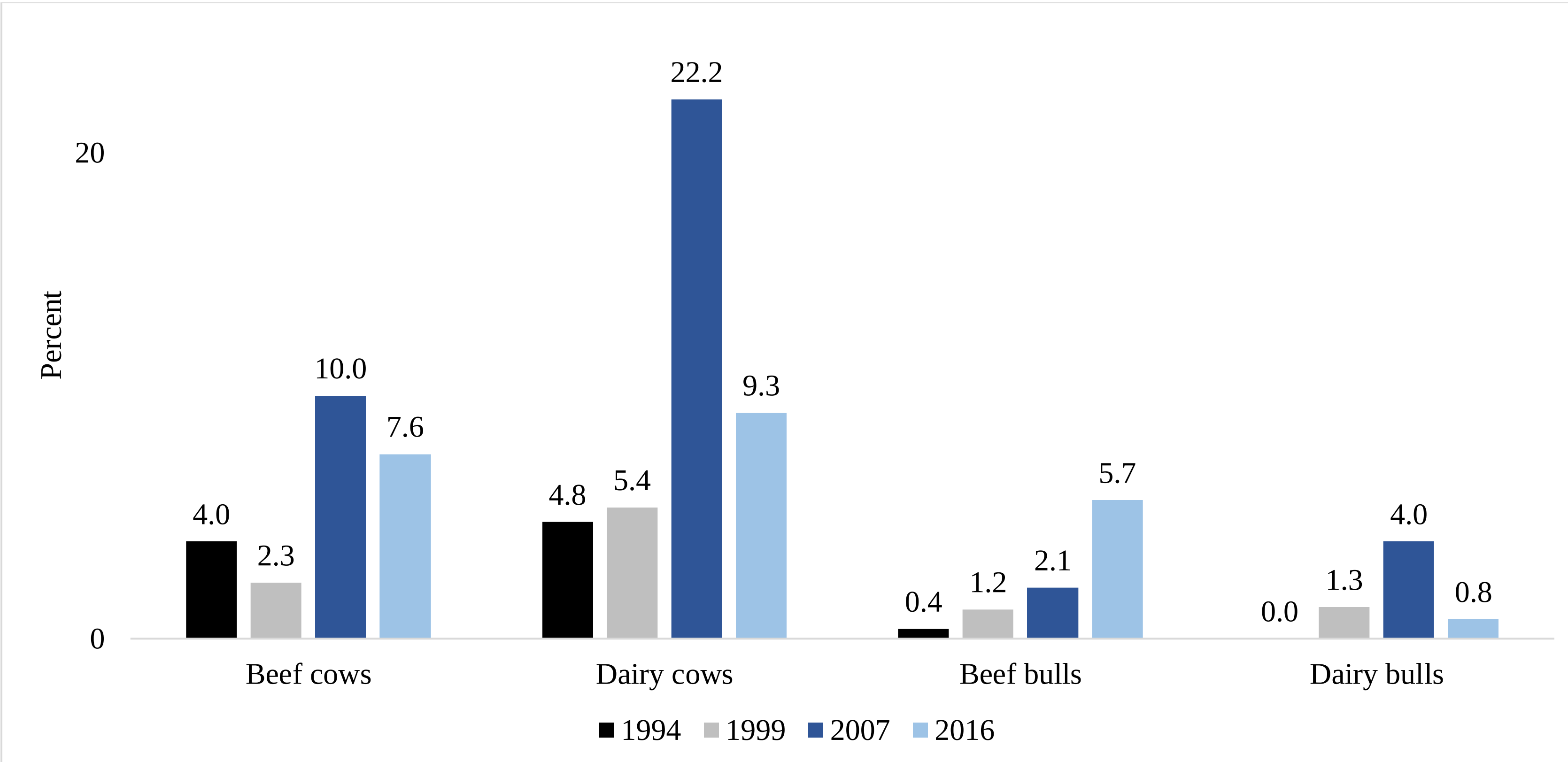

80
60
40
20
0
Percent
66.6
58.1
42.0
36.8
25.5
28.1
27.2
28.6
24.3
18.5
9.2
1.3
6.7
4.2
6.5
1.9
9.5
0.8
0.0
4.2
One
Two
Three
Four
Five
Muscle score
Beef cows
Beef bulls
Dairy cows
Dairy bulls

Figure 4-2. National Beef Quality Audit (NBQA): Frequency of muscle scores observed in surveyed animals. Muscle score was determined based on a 5-point scale: 1 – extremely light muscled, 3 – average muscled, 5 – extremely heavy muscled. Total number of observations were beef cows (*n* = 1,860), dairy cows (*n* = 2,809), beef bulls (*n* = 399), dairy bulls (*n* = 119).



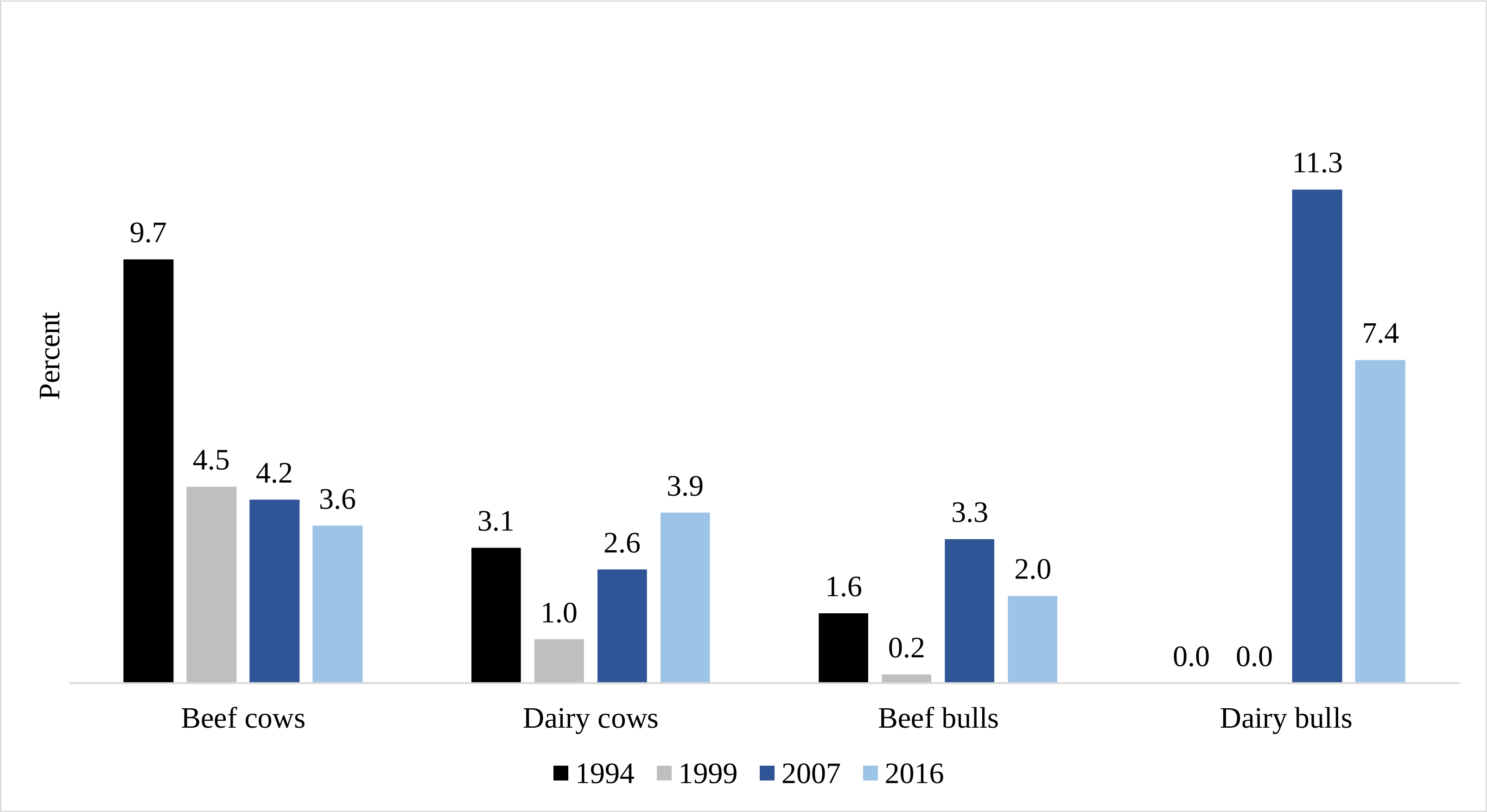
120
100
80
60
40
20
0
Percent
90.5
61.0
40.4
34.7
99.8
93.8
85.2
58.3
9.9
15.1
15.4
29.4
50.0
35.5
50.4
35.3
Beef cows
Dairy cows
Beef bulls
Dairy bulls
1994
1999
2007
2016

Figure 4-3. National Beef Quality Audit (NBQA): A comparison between the percentage of cattle that were inadequately muscled (assigned a muscle score 1 (extremely light muscled) and 2 (light muscled) on a 5-point scale) in 1994, 1999, 2007, and 2016. Total number of observations were National Non-fed Beef Quality Audit -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: beef cows (*n* = 2,237), dairy cows (*n* = 1,108), beef bulls (*n* = 419), dairy bulls (*n* = 79); NMCBBAQ-2007: beef cows (*n* = 2,501), dairy cows (*n* = 1,954), beef bulls (*n* = 385), dairy bulls (*n* = 127); NBQA-2016: beef cows (*n* = 1,860), dairy cows (*n* = 2,809), beef bulls (*n* = 399), dairy bulls (*n* = 119) (Smith et al., 1994; Roeber et al., 2000; Nicholson, 2008).



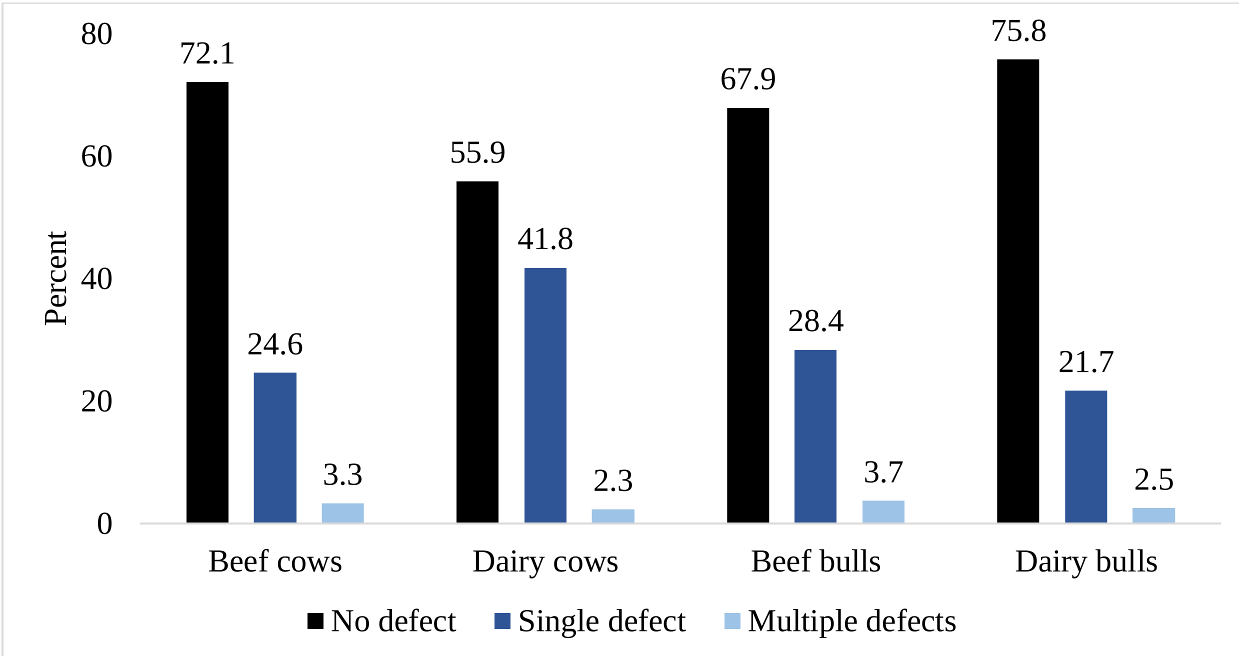
Percent
20
0
22.2
10.0
7.6
4.0
2.3
4.8
5.4
9.3
5.7
0.4
1.2
2.1
0.0
1.3
4.0
0.8
Beef cows
Dairy cows
Beef bulls
Dairy bulls
1994
1999
2007
2016

Figure 4-4. National Beef Quality Audit (NBQA): A comparison between the percentage of cattle that were assigned "too low" of a body condition score (beef – score 1and 2 (extremely thin) on a 9-point scale; dairy – score 1.0 and 1.5 (extremely thin) on a 5-pt scale) in 1994, 1999, 2007, and 2016. Total number of observations were National Non-fed Beef Quality Audit -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: beef cows (*n* = 2,237), dairy cows (*n* = 1,108), beef bulls (*n* = 419), dairy bulls (*n* = 79); NMCBBAQ-2007: beef cows (*n* = 2,800), dairy cows (*n* = 2,103), beef bulls (*n* = 431), dairy bulls (*n* = 124); NBQA-2016: beef cows (*n* = 1,911), dairy cows (*n* = 2,878), beef bulls (*n* = 406), dairy bulls (*n* = 121) (Smith et al., 1994; Roeber et al., 2000; Nicholson, 2008). Dairy cattle in 1994 and 1999 were condition scored based on the same 9-point scale as beef cattle.



Percent
9.7
4.5
4.2
3.6
3.1
1.0
2.6
3.9
1.6
0.2
3.3
2.0
0.0
0.0
11.3
7.4
Beef cows
Dairy cows
Beef bulls
Dairy bulls
1994
1999
2007
2016

Figure 4-5. National Beef Quality Audit (NBQA): A comparison between the percentage of cattle that were over-conditioned (beef – score 8 and 9 (extremely fat) on a 9-point scale; dairy – score 4.5 and 5.0 (extremely fat) on a 5-pt scale) in 1994, 1999, 2007, and 2016. Total number of observations were National Non-fed Beef Quality Audit-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: beef cows (*n* = 2,237), dairy cows (*n* = 1,108), beef bulls (*n* = 419), dairy bulls (*n* = 79); NMCBBQA-2007: beef cows (*n* = 2,800), dairy cows (*n* = 2,103), beef bulls (*n* = 431), dairy bulls (*n* = 124); NBQA-2016: beef cows (*n* = 1,911), dairy cows (*n* = 2,878), beef bulls (*n* = 406), dairy bulls (*n* = 121) (Smith et al., 1994; Roeber et al., 2000; Nicholson, 2008). Dairy cattle in 1994 and 1999 were condition-scored based on the same 9-point scale as beef cattle.22



80
60
40
20
0
Percent
72.1
24.6
3.3
55.9
41.8
2.3
67.9
28.4
3.7
75.8
21.7
2.5
Beef cows
Dairy cows
Beef bulls
Dairy bulls
No defect
Single defect
Multiple defects

Figure 4-6. National Beef Quality Audit (NBQA): Distribution of defects observed on cattle surveyed. Total number of observations were beef cows (*n* = 1,912), dairy cows (*n* = 2,855), beef bulls (*n* = 402), dairy bulls (*n* = 120). Defects included: bottle teats, broken penis, failed suspensory ligament, foot abnormality, full bag, lumpy jaw, mastitis, multiple udder problems, retained placenta, swollen joints, and warts.

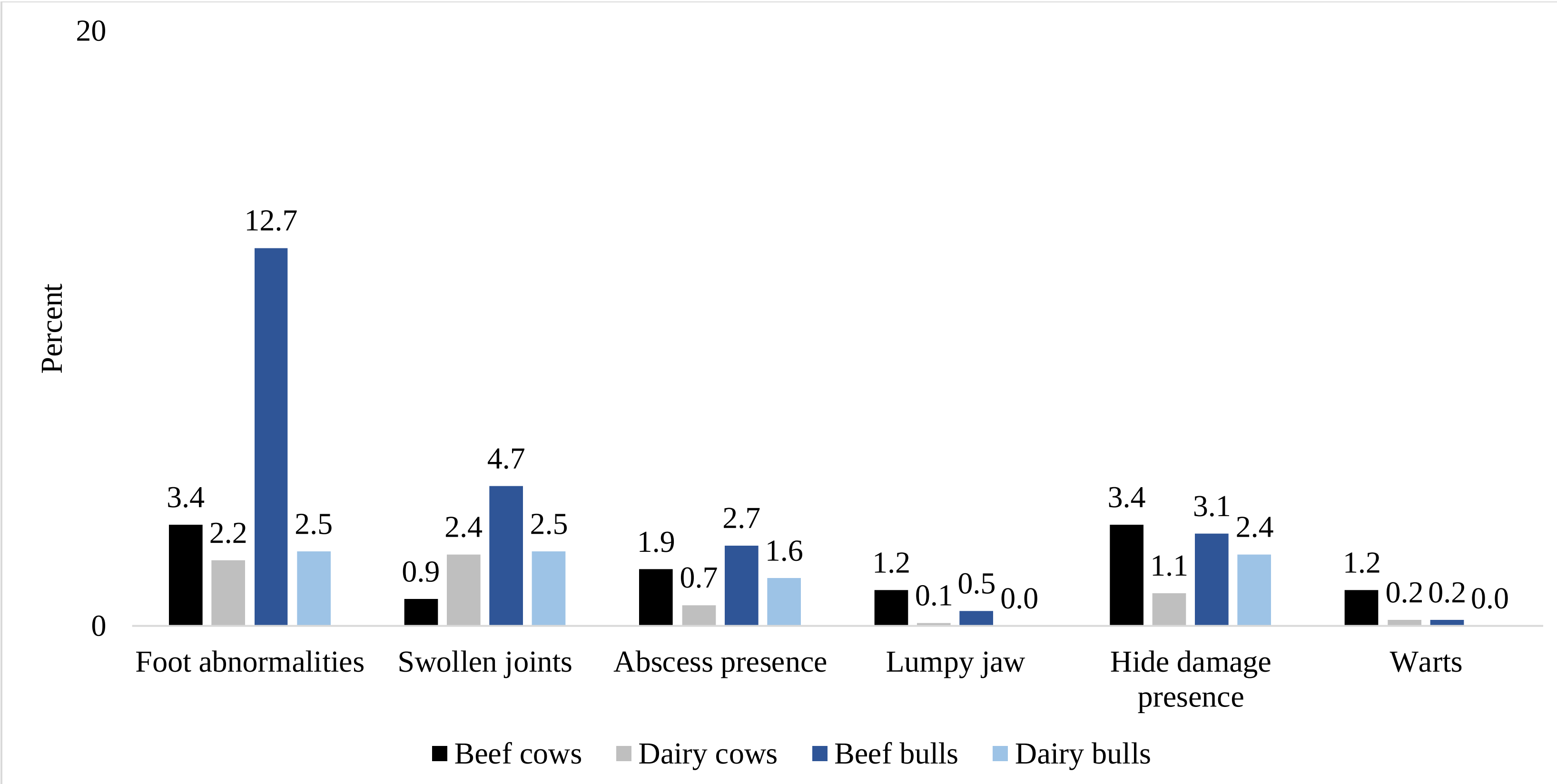

20
0
Percent
12.7
3.4
2.2
2.5
0.9
2.4
4.7
2.5
1.9
0.7
2.7
1.6
1.2
0.1
0.5
0.0
3.4
1.1
3.1
2.4
1.2
0.2
0.2
0.0
Foot abnormalities
Swollen joints
Abscess presence
Lumpy jaw
Hide damage presence
Warts
Beef cows
Dairy cows
Beef bulls
Dairy bulls

Figure 4-7. National Beef Quality Audit (NBQA): Distribution of live animal defects pertinent to all surveyed cattle. Total number of observations were beef cows (*n* = 1,913), dairy cows (*n* = 2,856), beef bulls (*n* = 402), dairy bulls (*n* = 120).

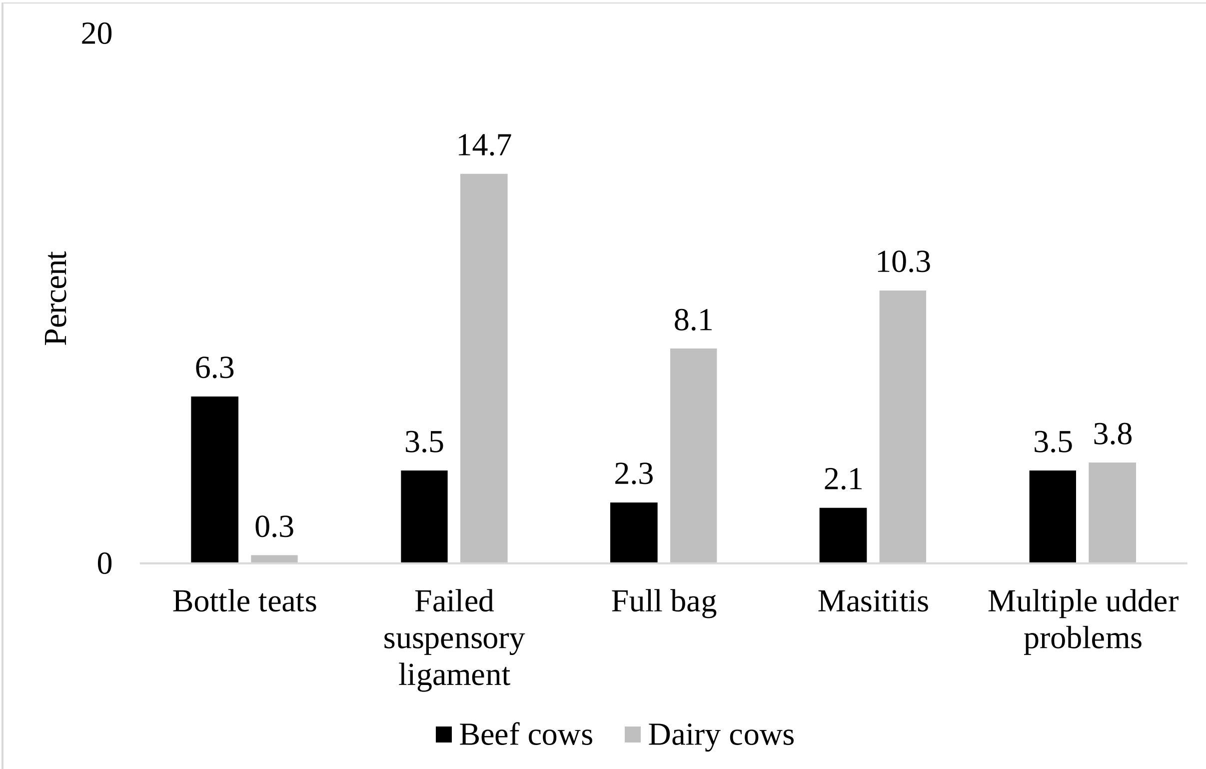

20
0
Percent
6.3
0.3
3.5
14.7
2.3
8.1
2.1
10.3
3.5
3.8
Bottle teats
Failed suspensory ligament
Full bag
Masititis
Multiple udder problems
Beef cows
Dairy cows

Figure 4-8. National Beef Quality Audit (NBQA): Distribution of defects associated with reproductive soundness in cows. Total number of observations were beef cows (n = 1,913) and dairy cows (n = 2,856).

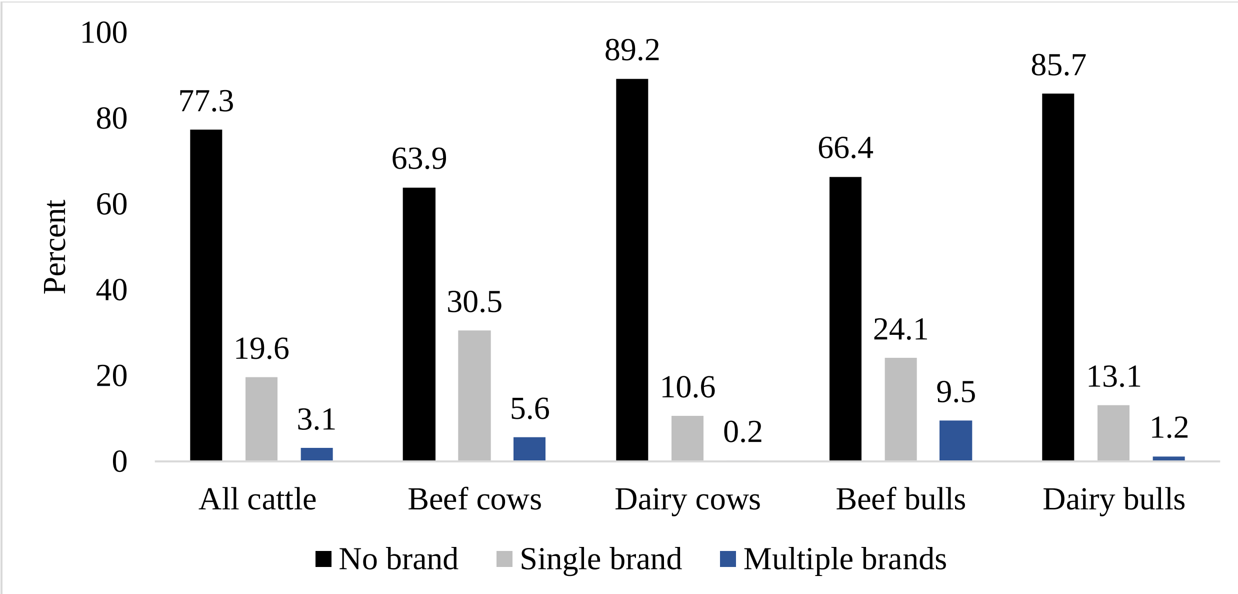


Figure 4-9. National Beef Quality Audit (NBQA): Percentage of cattle with no brands, single brands and multiple brands. Total number of observations were all cattle (n = 5,262), beef cows (n = 2,106), dairy cows (n = 2,618), beef bulls (n = 403), dairy bulls (n = 84).

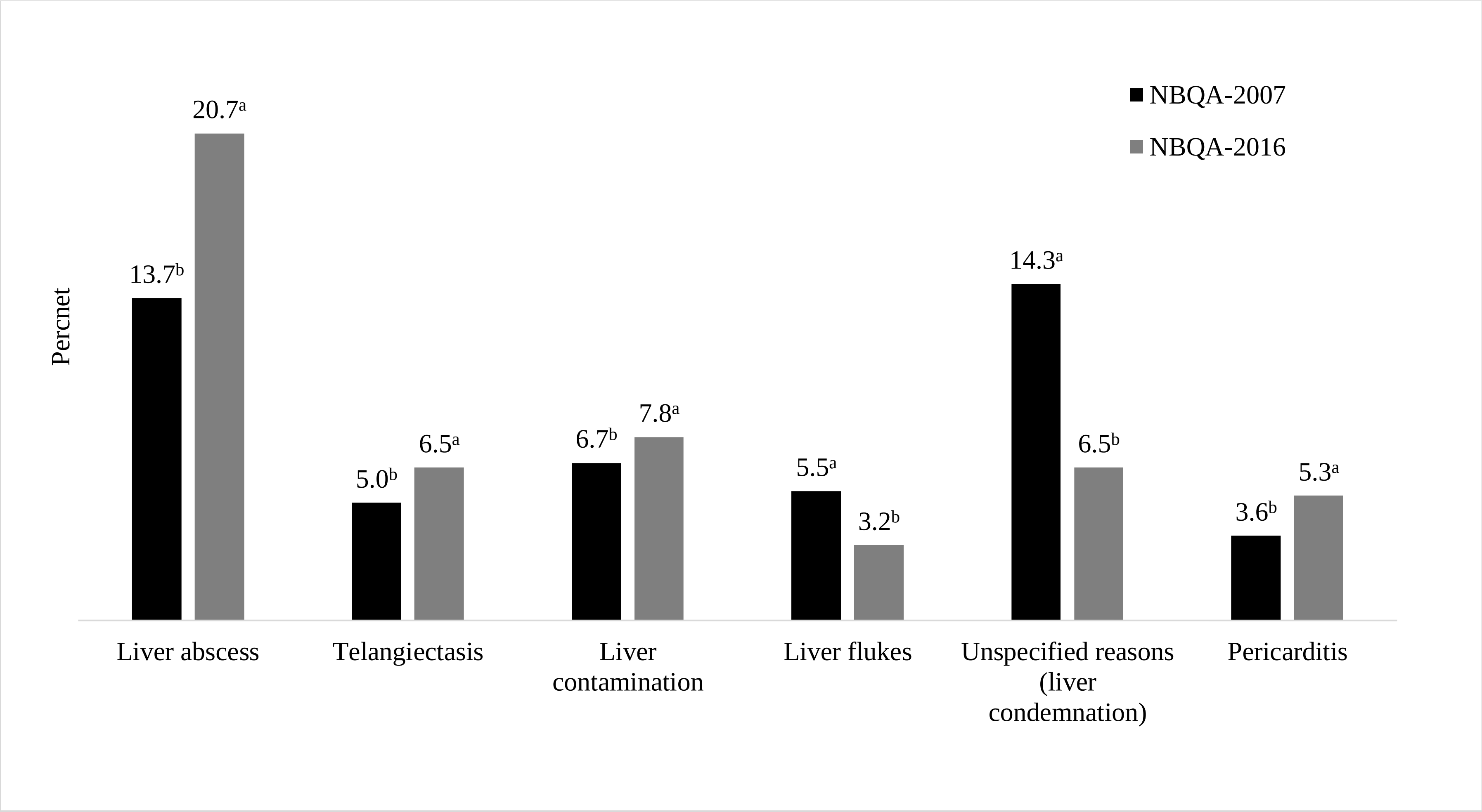

NBQA-2007
NBQA-2016
Percnet
20.7a
13.7b
5.0b
6.5a
6.7b
7.8a
5.5a
3.2b
14.3a
6.5b
3.6b
5.3a
Liver abscess
Telangiectasis
Liver contamination
Liver flukes
Unspecified reasons (liver condemnation)
Pericarditis

Figure 4-10. National Beef Quality Audit (NBQA): Frequency distributions for specific offal condemnations from all carcasses sampled in the NBQA-2007 and NBQA-2016. Means within specific condemnation reason with different superscripts differ ($P < 0.05$). Total number of observations for liver condemnations were 4,896 (NBQA-2007) and 4,800 (NBQA-2016). Total number of observations for hearts condemnations were 4,896 (NBQA-2007) and 4,586 (NBQA-2016) (Nicholson, 2008).

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II. Executive Summary

a. Title, Authors, University or organization, Date of submission
   - National Beef Quality Audit – 2016: In-plant survey phase
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         - Date of submission – October 2017

b. Background

Fed Harvest

The National Beef Quality Audit (NBQA) is conducted about every 5 years to assess and benchmark characteristics associated with producer-related beef quality. Characteristics related to quality and carcass merit are evaluated and relayed back to multiple segments of the beef production industry. Findings of this review are utilized by various segments of the beef industry to set strategic plans for continued improvement. Evaluation of quality traits allows the industry to identify deficiencies in product quality and opportunities for advancement. Previously, this audit has been conducted 5 times: 1991, 1995, 2000, 2005, 2011 (Lorenzen et al., 1993; Boleman et al., 1998; McKenna et al., 2002; Garcia et al., 2008; McKeith et al., 2012). Similar audits have been conducted in Canada to assess quality characteristics of cattle in the Canadian beef supply (Van Donkersgoed et al., 1997; Van Donkersgoed et al., 2001). Over time, the NBQA has been an influential tool to objectively evaluate how cattle producers have improved overall quality and consistency of beef in the U.S.

Fed Cooler

The first National Beef Quality Audit (**NBQA**) was conducted in 1991 to create a nationwide snapshot of the status of the beef industry. Following the completion of NBQA-1991, the Executive Summary called for the NBQA to be repeated within the next 5 years in order to understand what changes had occurred and what areas still required industry focus (National Cattlemen's Association, 1992). Over the last 25 years, 5 NBQAs have been conducted (Lorenzen et al., 1993; Boleman et al., 1998; McKenna et al., 2002; Garcia et al., 2008; Gray et al., 2012; McKeith et al., 2012; Moore et al., 2012). Successive audits to assess the status of the fed steer and heifer industry allow for ongoing improvements in US beef production, along with continued advancements in producer education.

Fed Instrument

The first National Beef Quality Audit (**NBQA**) was conducted in 1991 to target areas of improvement as well as establish a baseline for future studies. Following the first NBQA, successive audits were conducted every 5 to 6 years to provide the industry with a current representation of the fed steer and heifer beef supply, as well as continue to evaluate progress on targeted areas of improvement. One of the key messages from the NBQA-2005 was the need to implement instrument grading in the industry. With the increasing number of plants that had implemented instrument grading, the NBQA-2011 was the first to include the instrument grading assessments (Gray et al., 2012), which for the first time allowed seasonal trends in beef carcass traits to be evaluated. Instrument grading was approved for official United States Department of Agriculture (USDA) measurement of LM area in 2001, as well as yield grade **(YG)** and marbling score in 2007 (Mafi et al., 2014). Accuracy, precision, and producer confidence of USDA YG and quality grade **(QG)** were found to be greatly improved due to the transition to instrument grading (Belk et al., 1998; Cannell et al., 1999; Steiner et al., 2003b; Emerson et al., 2013).

Market Cow and Bull

The National Market Cow and Bull Beef Quality Audit–2016 (NMCBBQA-2016) marks the fourth iteration in a series destined to quantify the beef quality status in the United States. The first market cow and bull beef quality audit (then called the National Non-Fed Beef Quality Audit–1994), conducted by Colorado State University, followed the completion of the 1991 National Beef Quality Audit for steers and heifers (Lorenzen et al., 1993), and was aimed at understanding and quantifying the producer-related quality defects of cows and bulls and their carcasses (National Cattlemen's Beef Association, 1994; Smith et al., 1994). In determining the initial benchmarks for beef and dairy cow and bull cattle and meat quality, the study concluded cows and bulls were too frequently light muscled and thin, and excessive defects were too often observed. Conclusions urged producers to capitalize on management practices to improve the value of cows and recoup the worth of appropriate on-farm practices.

Five years later, the 1994 benchmarks were used as reference data in the National Market Cow and Bull Beef Quality Audit-1999 (NMCBBQA-1999) (Roeber et al., 2000; Roeber et al., 2001). This study measured the quality improvement and/or decline in live cattle, carcass, and offal traits over the five-year period., the NMCBBQA-1999 established new beef quality benchmarks utilized in future initiatives, such as the injection-site lesion prevalence in cow primals (Roeber et al., 2002), brought forth by the beef industry.

Eight years later, Texas A&M University led the third NMCBBQA to continue the progression of measuring quality changes and determining the status of the market cow and bull beef industry (Nicholson, 2008; Nicholson et al., 2013). This audit incorporated new information regarding the use of electric prods, animal handling techniques, animal traceability and other data aimed at further quantifying animal welfare and handling practices at processing facilities, a great concern of the beef industry at the time.

c. Objectives

Fed Harvest

Objectives of NBQA-2016 included measuring specific quality characteristics of cattle and carcasses associated with transportation, mobility, harvest-floor, and carcass characteristics that impact the value of beef and by-products. By measuring and trending lost opportunities, the beef industry will be better able to strategize and manage production practices that impact beef quality and consistency.

Fed Cooler

Objectives of the in-plant cooler assessment focuses on carcass characteristics including USDA quality and yield grades from a nationwide sample of beef. Through this effort, quantifying progress that has been made over time and setting strategies allows the beef industry to identify areas for continued improvement.

Fed Instrument

For the NBQA-2016, beef carcass characteristics were obtained using traditional in-plant assessments (Boykin et al., 2017) and with instrument grading information. With more widespread adoption of instrument grading in the U.S. beef industry, collecting such information complements the historic data gathered through in-plant assessments. These data provide a unique opportunity to evaluate the value and quantity determining characteristics of the fed steer and heifer beef industry in a magnitude unparalleled.

Market Cow/Bull

The objective of the NBQA-2016 was to again quantify the status of the beef industry in regards to the contribution made by mature cows and bulls. The NBQA-2016 provides an updated status report of the market cow and bull sector as it pertains to cattle transportation, mobility, and live cattle and carcass characteristics, as well as offal items and by-products. By comparing these data to the NNFBQA-1994, NMCBBQA-1999, and NMCBBQA-2007, the beef industry can assess changes in the quality of live cattle and carcasses from market cows and bulls. In addition, data from this study can provide direction for future initiatives concerned with improving beef quality.

d. Methods

Fed Harvest

Over the course of this study, all data were collected from March to November 2016. For each in-plant audit, data were collected from the entire day's production. If a beef processor harvested cattle in 2 shifts per day, data were collected during both shifts to capture the entire day of production. Beef processors from which data were obtained were selected to reflect the current fed cattle beef supply in the U.S. All data were analyzed using JMP Software (JMP, Version 12.0.1 SAS Institute Inc., Cary, NC, 1989-2007) and Microsoft Excel for Mac 2016 (Microsoft Corporation, Redmond, WA).

About 10% of trucks arriving at selected beef slaughter facilities within a production day were sampled (*n* = 220). To evaluate mobility, 100% of cattle exiting trucks where transportation data were collected were scored (*n* = 8,051).

About 50% of cattle were sampled per production lot at selected beef processors. For animal identification (*n* = 24,615 cattle), the type of identification was recorded and categorized as: none identified, electronic tag, barcode, individual tag, lot tag, metal clip, wattles, or other. Hide color (*n* = 24,672 cattle) was determined based on primary hide color (> 50% of total hide surface area; black, red, yellow, brown, gray, white, tan) or apparent breed type (i.e., Holstein). Presence of hide brands (*n* = 24,685 cattle) was assessed and categorized by location: butt (round), side, shoulder (chuck). Quantification of brands was determined based upon estimated size (length x width). Presence of mud/manure on the hide was evaluated (*n* = 22,483 cattle) based on location (none visible, legs, belly, side, top line, tail region) and amount using a pictorial reference (none, small, moderate, large, extreme), if present (Savell, 2016). Presence of cattle horns was evaluated (*n* = 24,588 cattle), and if present, approximate length of horns were recorded (< 2.54 cm, 2.54 to 12.7 cm, and > 12.7 cm). This audit also assessed the frequency in which slaughter cattle/carcasses were dragging and unintentionally touching the floor or equipment (*n* = 22,373). This information was captured to assess how beef processors were able to accommodate the ever-increasing size of live animals.

Following hide removal, carcasses were evaluated (*n* = 24,366) for the number (0, 1, 2, 3, or 4) of bruises present, location on the carcass (round, loin, rib, chuck, or brisket/plate/flank), and severity (minimal, major, critical, or extreme). Bruise severity was determined based on a 10-point scale: minimal (1, 2, 3); major (4, 5, 6); critical (7, 8, 9); extreme (10). Trim losses from these bruises would be < 0.45 kg for minimal, 0.45 to 4.54 kg for major, > 4.54 kg for critical, and the loss of the entire subprimal for extreme bruising. Where observed, subcutaneous injection-site lesions were noted. Apparent chronological age of cattle was determined using dentition (*n* = 24,382 heads) by counting the number of permanent incisors present. Offal (*n* = 24,940 carcasses; liver, lung, and viscera) and heads and tongues (*n* = 26,657 heads) were inspected for wholesomeness by USDA Food Safety and Inspection Service personnel, and where applicable, condemnations and reasons for condemnations were recorded. Additionally, females with a fetus presence was recorded at the viscera table.

Fed Cooler

Beef carcasses (n = 9,106) were selected throughout the day's production to represent approximately 10% of each production lot. Trained personnel evaluated each carcass for HCW, LM area (measured by dot grid, video image analysis instrument, or blotting paper), apparent breed type (native, dairy, or *Bos indicus*), sex class, carcass defects (dark cutter, blood splash, calloused eye, yellow fat), any certified or marketing program, and whether the animal was 30 mo or older as determined by dentition. The (USDA, 2016) standards were used for evaluating sex class. Apparent breed type was determined using the procedures defined by (Lorenzen et al., 1993): *Bos indicus* type cattle were those with dorsal thoracic hump (M. rhomboideus, overlying muscles, and subcutaneous fat) with a height greater than 10.2 cm, dairy-type cattle were identified as those with thin muscling in relation to skeletal size, and all other cattle were classified as native. Carcasses that were denoted as qualifying for certified programs were recorded. Lean maturity, skeletal maturity, preliminary yield grade, percentage of KPH, and marbling score were evaluated by United States Department of Agriculture, Agricultural Marketing Service, Quality Assessment Division personnel (USDA, 2016). For beef processors that removed KPH before grading, the estimated KPH value used by the facility was recorded (some establishments calculated KPH based on before and after carcass weights and some used a standard average KPH measurement).

All analyses were performed using JMP Software (JMP, Version 12.0.1 SAS Institute Inc., Cary, NC, 1989-2007) and Microsoft Excel for Mac 2016 (Microsoft Corporation, Redmond, WA). The Fit Y by X function was used for ANOVA, and least squares means comparisons were conducted using Student's *t* test. Correlations were determined using the multivariate function. Frequency distributions, means, SD, and minimum and maximum values were determined using the distribution function.

Fed Instrument

Instrument grading data (n = 4,544,635 carcasses) were collected from 5 beef processing corporations, with a total of 18 federally inspected beef processing facilities over a 12-mo period. Data were collected from one week of production each month. The data collected included: harvest date, grade date, gender, breed type, marbling score, defects (hard bone, blood splash, dark cutter), certified programs, fat thickness, LM area, HCW, and KPH percentage. USDA QG and YG were calculated from these factors (USDA, 2016). Data were received in a Microsoft Excel spreadsheet (Microsoft Corporation, Redmond, WA) from all 5 corporations. All corporate identities were removed and the spreadsheets were harmonized and compiled.

All analyses were performed using JMP Software (JMP, Version 12.0.1 SAS Institute Inc., Cary, NC, 1989-2007) and Microsoft Excel for Mac 2016 (Microsoft Corporation, Redmond, WA). The Fit Y by X function was used for ANOVA, and least squares means comparisons were conducted using Student's *t* test. Correlations were determined using the multivariate functions. Frequency distributions, means, standard deviations, and minimum and maximum values were determined using the distribution function.

Market Cow and Bull

Truck and trailer information from 10% of all trucks (*n* = 154) to arrive at the 18 processing facilities were evaluated for type, dimension, use of compartments, and use of center gate. The truck driver was interviewed to determine cattle origin, date and time loaded, distance and time traveled, number and type of cattle in the load, if mixed gender loads were segregated, and if cattle were unloaded during transit. If the driver was unsure of the distance traveled, a map was used to estimate the distance from origin to packing facility. Time traveled was considered the duration between time loaded and time unloaded. As they were moved from the truck to the holding pen, cattle (*n* = 4,066) were assessed for mobility using the North American Meat Institute's 4-point scale (North American Meat Institute, 2015). Animals who fell to the ground and could not rise were classified as non-ambulatory.

Cattle (*n* = 5,470) were surveyed for live animal characteristics that could drive producer's culling decisions. Each animal surveyed was assigned a muscle score (5-point scale: 1 = light muscled, 5 = heavy muscled) and a body condition score (beef animal: 9-pt scale; 1 = extremely thin, 9 = very obese; dairy animal: 5-point scale; 1.0 = thin, 5.0 = over-conditioned) (Elanco Animal Health, 2009; Eversole et al., 2009). With the aim of identifying producer-related defects, the research group assessed cattle for anticipated defects (Table 4-2). For these predetermined defects, researchers used the scales presented in Table 4-2 to quantify their observations. Unanticipated defects (not found in Table 4-2) were noted by researchers when observed.

Hide-on carcasses (*n* = 5,278), were evaluated for the incidence of hide branding; location (butt, side, shoulder) and size (cm^2) of brands were recorded. The presence and location (neck, shoulder, top butt, round) of knots was recorded. In addition, researchers observed length of horns. Carcasses also were observed for mud, identification type, and color. If present, location of mud was recorded as being observed on legs, belly, side, top line, tail region, and amount was classified as small, moderate, large, or extreme levels as defined by (Savell, 2016). The type of identification (ankle tag, barcode, electronic tag, individual tag, metal clip, lot tag, waddle, and "other") also was recorded. Additionally, primary color was recorded as the color representing at least 51% of the hide. Hide patterns were classified as Holstein-patterned, baldy, roan, brindle, and spots.

Carcasses (*n* = 5,510) were assessed for number, location (round, rib, shortloin, sirloin, chuck, the combination of brisket, plate, and flank) and severity (minimal = less than 0.45 kg trim loss; major = 0.46 kg to 4.54 kg trim loss; critical = 4.55 kg to 18.14 kg trim loss; extreme = loss of an entire primal) of bruises. Furthermore, the number and location (round, rib, shortloin, sirloin, chuck, the combination of brisket, plate, and flank) of visible injection-site lesions on the exterior carcass surface were recorded.

Condemnation by the United States Department of Agriculture, Food Safety and Inspection Service (USDA-FSIS) of heads (n = 5,720), tongues (n = 5,720), viscera (n = 4,800), livers (n = 4,800), kidneys (n = 4,800), lungs (n = 4,586) and hearts (n = 4,586) was recorded, and reasons were documented. The incidence and reason for trimming surveyed heads and tongues also was documented. In addition, surveyed heads were recorded as displaying signs of a broken mouth or were classified as a gummer (an animal that had permanent incisors worn down to the gum line). Pneumonia severity was evaluated with mild being 0% - 15% lung tissue consolidation, moderate being 15% - 50% lung tissue consolidation, and severe being 50% - 100% consolidation of the lung. Surveyed viscera in cow carcasses were assessed for fetal presence. When present, approximate fetal age/size was documented as either “early” (less than 150 d old and 35.56 cm or less in length) or “late” (over 150 d or 35.56 cm long) gestation (Sorensen, 1979).

Hot carcass weight (HCW) and loin muscle area (LM area; measured with a dot grid) were recorded for selected carcasses (n = 4,285). Lean and skeletal maturity, degree of marbling, preliminary yield grade (PYG), and kidney, pelvic, and heart fat (KPH) were evaluated for each selected carcass based on the United States Standards for Grades of Carcass Beef (USDA, 2016).

Quality grades for cow carcasses were determined using the relationship between maturity and marbling and were reported as outlined in the United States Standards for Grades of Carcass Beef (USDA, 2016). Yield grades for all carcasses were calculated by substituting the values recorded for PYG, HCW, LM area, and KPH into the following equation:
2.5 + (2.5 × ((PYG - 2) × 0.4)) + (0.2 × %KPH) - (0.32 × LM area, square inches) + (0.0038 × HCW, pounds). If any of the variables necessary for calculating a quality or yield grade were not recorded, a grade was not assigned.

Carcass muscle score was evaluated according to the standards outlined by Nicholson (2008) using a 5-point scale with 1 being the lightest muscled and 5 being the heaviest muscled. Fat color was scored using a 6-point scale with 1 being the whitest and 6 being the most yellow, also defined by Nicholson (2008). If present, the number of arthritic joints on each carcass were documented.

Data were analyzed using JMP Software (JMP, Version 10. SAS Institute Inc., Cary, NC, 1989-2207) and Microsoft Excel for Mac. Distributions, frequencies, means, standard deviations, minimums, and maximums were calculated using the Distribution and Summary functions of JMP. To test the hypothesis that the frequency of a quality characteristic in the NBQA-2007 was equal to the frequency of the same quality characteristic in the NBQA-2016, a pooled estimate was calculated with: $(x_1 + x_2)/(n_1 + n_2)$. Then, a pooled standard error was calculated and used to determine the z-statistic. If the z-statistic was greater than or equal to 1.96, the two frequencies were considered different.

e. Important Findings

Fed Harvest

Cattle were in transit to the slaughter facility for a mean duration of 2.7 h from a mean distance of 218.5 km using trailers with dimensions ranging from 17.84 m^2 to 59.09 m^2. Area allotted per animal averaged 1.13 m^2 and ranged from 0.85 m^2 to 2.28 m^2. A total of 96.8% of cattle received a mobility score of 1 (walks easily, no apparent lameness). Identification types (35.1% had multiple) were lot visual tags (61.5%), individual tags (55.0%), electronic tags (16.9%), metal-clip tags (9.2%), bar-coded tags (0.05%), wattles (0.01%), and other (2.6%). Cattle were predominately black-hided (57.8%), Holstein (20.4%), red-hided (10.5%), yellow-hided (4.8%), gray-hided (2.9%), brown-hided (1.3%), and white-hided (1.1%). Unbranded hides were observed on 74.3% of cattle; 18.6% had brands located on the butt, 6.3% on the side, and 1.3% on the shoulder (values exceed 100% due to multiple brands). For hide-on carcasses, 37.7% displayed no mud or manure; specific locations for mud or manure were legs (40.8%), belly (33.0%), tail region (15.5%), side (6.8%), and top-line (3.9%). Cattle without horns represented 83.3% of the sample, and cattle that did have horns measured: < 2.54 cm (5.5%), 2.54 to 12.7 cm (8.3%), and > 12.7 cm (2.9%). Carcasses without bruises represented 61.1% of those sampled, whereas 28.2% had 1, 8.2% had 2, 2.1% had 3, and 0.3% had 4 bruises. Of those carcasses with a bruise, the bruise was located on the loin (29.7%), round (27.8%), chuck (16.4%), rib (14.4%), and brisket/plate/flank (11.6%). Frequencies of offal condemnations were livers (30.8%), lungs (18.2%), viscera (16.3%), hearts (11.1%), heads (2.7%), and tongues (2.0%). Compared to NBQA-2011, fewer cattle were identified for traceability, fewer were black-hided, a greater number were Holstein cattle, more with no brand and no horns, fewer without bruises, more liver, lung, and viscera condemnations, and fewer heads and tongues were condemned.

Fed Cooler

Frequencies of evaluated traits were 66.5% steer and 33.4% heifer sex classes and 82.9% native, 15.9% dairy-type, and 1.2% *Bos indicus* estimated breed types. Mean USDA YG factors were 1.42 cm for adjusted fat thickness, 89.5 cm^2 for LM area, 390.3 kg for HCW, and 1.9% for KPH. Mean USDA YG was 3.1 with a frequency distribution of 9.6% YG 1, 36.7% YG 2, 39.2% YG 3, 12.0% YG 4, and 2.5% YG 5. Mean USDA QG traits were Small^{70} for marbling score, A^{64} for overall maturity, A^{55} for lean maturity, and A^{69} for skeletal maturity. Mean USDA QG was Select^{96} with a frequency distribution of 3.8% Prime, 67.3% Choice, 23.2% Select, and 5.6% lower score. Lower score included dark cutter (1.9%), blood splash (0.1%), and hard bone, which are USDA overall maturity scores of C or older (1.8%). Marbling score distributions were 0.85% Slightly Abundant or greater, 7.63% Moderate, 23.54% Modest, 39.63% Small, 23.62% Slight, and 0.83% Traces or less. Carcasses that were Choice or Select and USDA YG 2 or 3 accounted for 70.7% of the carcasses evaluated. Compared to the previous NBQA, we found a numerical increase in mean USDA YG, USDA QG, adjusted fat thickness, HCW, LM area, and marbling score with an increase in dairy-type carcasses and percentage of carcasses grading USDA Prime and Choice, as well as frequency of USDA YG 4 and 5.

Fed Instrument

Mean USDA yield grade (YG) was 3.1 with 1.37 cm fat thickness (FT), 88.9 cm^2 LM area, 393.6 kg HCW, and 2.1% KPH. Frequency distribution of USDA YG was 9.5% YG 1, 34.6% YG 2, 38.8% YG 3, 14.6% YG 4, and 2.5% YG 5. Increases in HCW and FT since the NBQA-2011 were major contributors to differences in mean YG and the (numerically) increased frequency of YG 3, 4, and 5 carcasses found in the current audit. Mean marbling score was Small^{75}, and the distribution of USDA quality grades were 4.2% Prime, 71.4% Choice, 21.7% Select, and 2.7% other. Frequency of carcasses grading Prime on Monday (6.43%) was numerically higher than the average frequency of carcasses grading Prime overall (4.2%). Monthly HCW means were 397.6 kg in January, 397.2 kg in February, 396.5 kg in March, 389.3 kg in April, 384.8 kg in May, 385.0 kg in June, 386.1 kg in July, 394.1 kg in August, 399.1 kg in September, 403.9 kg in October, 406.5 kg in November, and 401.9 kg in December. Monthly mean marbling scores were Small^{73}in January, Small^{80} in February, Small^{81} in March, Small^{77} in April, Small^{70} in May, Small^{67} in June, Small^{70} in July, Small^{75} in August, Small^{74} in September, Small^{76} in October, Small^{80} in November, and Small^{79} in December. Both mean HCW and mean marbling score declined in the months of May and June. The month with the greatest numerical frequency of dark cutters was October (0.74%). Comparison of overall data from in-plant carcass and instrument grading assessments revealed close alignment of information, especially for YG (3.1 for in-plant assessment versus 3.1 for instrument grading) and marbling (Small^{70} for in-plant assessment versus Small^{75} for instrument grading).

Market Cow/Bull

Cattle were allowed 2.3 m^2 of trailer space on average during transit indicating some haulers are adhering to industry handling guidelines for trailer space requirements. Of the mixed gender loads arriving at processing facilities, cows and bulls were not segregated on 64.4% of the trailers surveyed. When assessed for mobility, the greatest majority of cattle surveyed were sound. Since the inception of the quality audit series, beef cows have shown substantial improvements in muscle. Today over 90.0% of dairy cows are too light muscled. The mean body condition score for beef animals was 4.7 and for dairy cows and bulls was 2.6 and 3.3, respectively. Dairy cattle were lighter muscled, yet fatter than the dairy cattle surveyed in 2007. Of cattle surveyed, most did not have horns, nor any visible live animal defects. Unbranded hides were observed on 77.3% of cattle. Carcass bruising was seen on 64.1% of cow carcasses and 42.9% of bull carcasses. However, over half of all bruises were identified to only be minor in severity. Nearly all cattle (98.4%) were free of visible injection-site lesions. Beef cattle were predominantly black-hided; 68.0% of beef cows and 67.2% of beef bulls possessed a black hide. Holstein was the predominant type of dairy animal observed. Just over half (56.0%) of the cattle surveyed had no mud contamination on the hide, and when mud was present, 34.1% of cattle only had small amounts. Harvest floor assessments found 44.6% of livers, 23.1% of lungs, 22.3% of hearts, 20.0% of viscera, 8.2% of heads, and 5.9% of tongues were condemned. Liver condemnations were most frequently due to abscess presence. In contrast, contamination was the primary reason for condemnation of all other offal items.

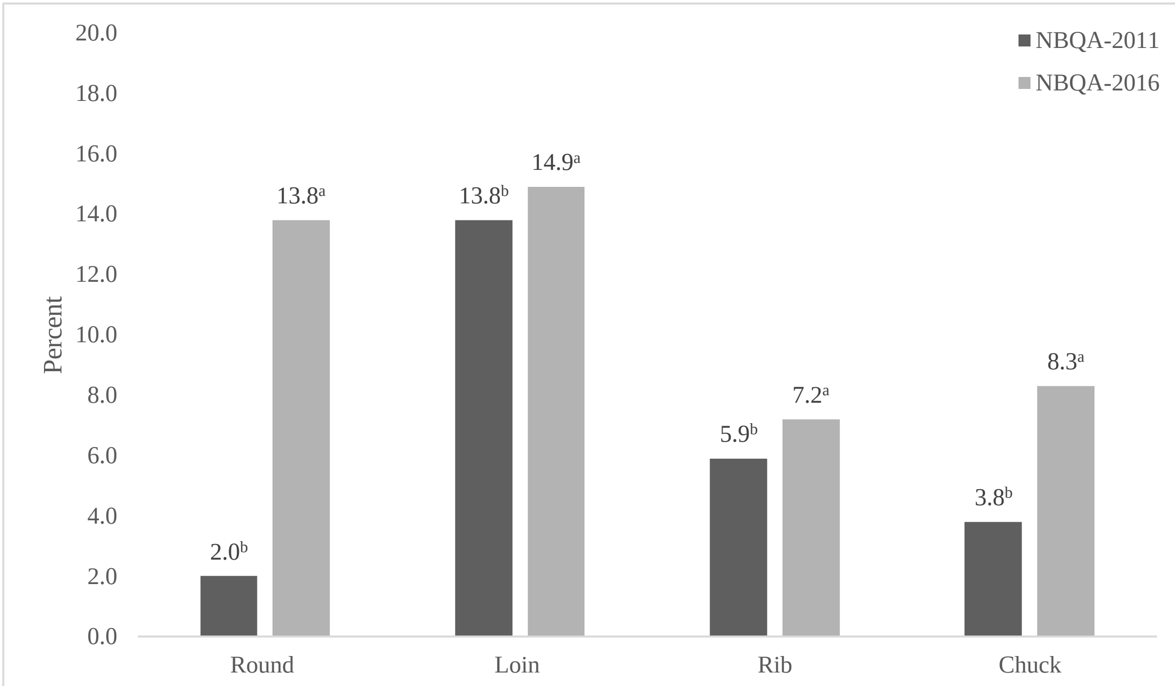
Of the cow carcasses surveyed, 17.4% carried a fetus at the time of harvest. As expected, mean carcass weight and loin muscle area (LM area) values observed for bulls were heavier and larger than cows. The marbling scores represented by cull animal carcasses were most frequently slight and traces amounts. Cow carcasses manifested a greater amount of marbling on average than bull carcasses. The predominant fat color score showed all carcasses surveyed had some level of yellow fat. Only 1.3% of carcasses exhibited signs of arthritic joints.

f. Implications/Industry Impact

The NBQA remains an important measure for the U.S. beef industry as it tries to improve quality and consumer demand. Characteristics evaluated in this audit will be relayed to cattle producers, which can ultimately enhance consistency and quality of cattle and beef products in the U.S. beef supply chain. Data from this survey can be utilized in all segments of beef production to improve upon current management practices and implement innovative techniques to enhance beef quality and consistency in the U.S. supply chain.

g. Graphs/Tables

Fed Harvest



National Beef Quality Audit (NBQA): Frequency distributions of bruises in primals from all carcasses sampled in NBQA-2011 and NBQA-2016 (χ^2 for round $P < 0.0001$, loin $P = 0.0022$, rib $P < 0.0001$, and chuck $P < 0.0001$). Means within primals with different superscripts differ ($P < 0.05$). Total number of observations for bruises was 18,159 (NBQA-2011) and 24,366 (NBQA-2016). (McKeith et al., 2012).

National Beef Quality Audit (NBQA): Mean values for time and distance traveled, number of cattle in the loads, trailer dimensions, and the subsequent area allotted per head for all trailer types surveyed[1]

Transportation characteristics	n^2	Mean	Std. Dev.	Min	Max
Time traveled (h)	220	2.7	2.4	0.25	12.0
Distance traveled (km)	217	218.5	213.2	12.9	1,400.1
Number of cattle in load	220	36.6	4.8	10	47
Number of compartments used	217	3.5	0.9	2	6
Trailer dimensions (m^2)	212	40.85	2.56	17.84	59.09
Area allotted per head (m^2)	212	1.13	0.17	0.85	2.28

[1]Approximately 10% of cattle trucks were sampled within a day's production at each plant.
[2] These are the number of trailers that were surveyed at the plants.

National Beef Quality Audit (NBQA): Percentages of hide-on carcasses with predominant hide color or breed type evaluated in NBQA-2000, NBQA-2005, NBQA-2011, and NBQA-2016[1,2]

Item	NBQA-2000	NBQA-2005	NBQA-2011	NBQA-2016 (± SEM)
Black	45.1	56.3	61.1	57.8 ± 0.3
Holstein (black and white)	5.7	7.9	5.5	20.4 ± 0.3
Red	31.0	18.6	12.8	10.5 ± 0.2
Yellow	8.0	4.9	8.7	4.8 ± 0.1
Gray	4.0	6.0	5.0	2.9 ± 0.1
Brown	1.7	3.0	5.0	1.3 ± 0.1
White	3.2	2.3	1.4	1.1 ± 0.1

[1]Total number of observations for hide color were: 43,415 (NBQA-2000); 49,330 (NBQA-2005); 15,143 (NBQA-2011); 24,672 (NBQA-2016).

[2]NBQA-2000 (McKenna et al., 2002); NBQA-2005 (Garcia et al., 2008); NBQA-2011 (McKeith et al., 2012).

National Beef Quality Audit (NBQA): Percentages of bruises and bruise location (cattle that had at least 1 bruise) for carcasses evaluated in NBQA-1991, NBQA-1995, NBQA-2000, NBQA-2005, NBQA-2011, and NBQA-2016[1,2]

Item	NBQA-1991	NBQA-1995	NBQA-2000	NBQA-2005	NBQA-2011	NBQA-2016 (± SEM)
No bruises	60.8	51.6	53.3	64.8	77.0	61.1 ± 0.3
1 bruise	25.0	30.9	30.9	25.8	18.8	28.2 ± 0.3
2 bruises	10.6	12.8	11.4	7.4	3.4	8.2 ± 0.2
3 bruises	3.5	3.7	3.5	1.6	0.6	2.1 ± 0.1
4 bruises	0.2	0.9	0.8	0.4	0.2	0.3 ± 0.04
More than 4 bruises	nd[3]	0.1	0.1	0.0	0.1	0.0 ± 0.0
Location of bruise						
Loin	23.4	41.1	25.9	32.6	50.1	29.7 ± 0.4
Rib	14.4	20.8	19.4	19.5	21.3	14.4 ± 0.3
Chuck	16.7	30.8	28.2	27.0	13.8	16.4 ± 0.3
Brisket/plate/flank	0.3	0.0	11.6	10.3	7.5	11.6 ± 0.3
Round	2.7	7.2	14.9	10.6	7.3	27.8 ± 0.4

[1] Total number of observations for carcass bruises were: 37,002 (NBQA-1991); 42,156 (NBQA-1995); 43,595 (NBQA-2000); 49,330 (NBQA-2005); 18,159 (NBQA-2011); 24,366 (NBQA-2016).

[2] NBQA-1991 (Lorenzen et al., 1993); NBQA-1995 (Boleman et al., 1998); NBQA-2000 (McKenna et al., 2002); NBQA-2005 (Garcia et al., 2008); NBQA-2011(McKeith et al., 2012).

[3] nd = not determined.

Fed Cooler

National Beef Quality Audit (NBQA)-2016: Means, SD, and minimum and maximum values for USDA carcass grade traits

Trait	*n*	Mean	SD	Minimum	Maximum
USDA yield grade	7,379	3.1	1.0	-0.7	9.3
USDA quality grade[1]	8,651	696	110	367	890
Adjusted fat thickness, cm	7,992	1.42	0.71	0.0	6.35
HCW, kg	8,493	390.3	46.5	195.9	616.4
LM area, cm^2	8,681	89.5	11.2	45.8	141.9
KPH, %	8,531	1.9	1.1	0	6.0
Marbling score[2]	8,660	470	104	200	970
Lean maturity[3]	8,741	155	24	110	490
Skeletal maturity[3]	8,061	169	34	110	480
Overall maturity[3]	8,730	164	27	115	445

[1]100 = Canner^{00}, 400 = Commercial^{00}, 600 = Select^{00}, 700 = Choice^{00}, and 800 = Prime^{00} (USDA, 2016).

[2]100 = Practically devoid^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 700 = Slightly Abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

[3]100 = A^{00}, 200 = B^{00}, 300 = C^{00}, 400 = D^{00}, and 500 = E^{00} (USDA, 2016).

National Beef Quality Audit (NBQA): Means for USDA carcass grade traits from NBQA-1991, NBQA-1995, NBQA-2000, NBQA-2005, NBQA-2011, and NBQA-2016[1]

Trait	NBQA-1991 (*n* = 7,375)	NBQA-1995 (*n* = 11,799)	NBQA-2000 (*n* = 9,396)	NBQA-2005 (*n* = 9,475)	NBQA-2011 (*n* = 9,802)	NBQA-2016 (*n* = 9,106)
USDA yield grade	3.2	2.8	3.0	2.9	2.9	3.1
USDA quality grade[2]	686	679	685	690	693	696
Adjusted fat thickness, cm	1.5	1.2	1.2	1.3	1.3	1.4
HCW, kg	345.0	339.2	356.9	359.9	374.0	390.3
LM area, cm^2	83.4	82.6	84.5	86.4	88.8	89.5
KPH, %	2.2	2.1	2.4	2.3	2.3	1.9
Marbling score[3]	424	406	423	432	440	470
Lean maturity[4]	163	154	165	157	154	155
Skeletal maturity[4]	175	163	167	168	162	169
Overall maturity[4]	169	160	166	164	159	164

[1] NBQA–1991 (Lorenzen et al., 1993); NBQA–1995 (Boleman et al., 1998); NBQA–2000 (McKenna et al., 2002); NBQA–2005 (Garcia et al., 2008); NBQA–2011 (Moore et al., 2012).

[2]100 = Canner^{00}, 400 = Commercial^{00}, 600 = Select^{00}, 700 = Choice^{00}, and 800 = Prime^{00} (USDA, 2016).

[3]100 = Practically devoid^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 700 = Slightly Abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

[4]100 = A^{00}; 200 = B^{00} (USDA, 2016).

National Beef Quality Audit-2016: Occurrence (%)[1] of marbling scores within USDA quality grades[2]

Marbling score	Overall[3]	Prime	Choice	Select	Other[4]
Abundant	0.13	2.46			0.28
Moderately Abundant	0.57	14.46			0.57
Slightly Abundant	3.25	83.08			2.27
Moderate	7.63		10.88		5.10
Modest	23.54		33.61		15.86
Small	39.63		55.45		42.21
Slight+	15.31			61.18	8.83
Slight-	8.31			38.71	3.99
Traces	0.83				19.26

[1]Rounding error prevents all categories from adding to 100.0%.

[2]USDA quality grade was affected by maturity and dark cutting.

[3]Overall category represents USDA quality grades of Prime, Choice, Select, Standard, Commercial, Utility, and Cutter.

[4] Other includes: No roll, Standard, Commercial, Utility, dark cutter, blood splash, hard bone, and calloused ribeye.

National Beef Quality Audit-2016: Least squares means for carcass traits (SEM) within USDA quality grades

Trait	USDA quality grade			
	Prime (*n* = 288)	Choice (*n* = 4,979)	Select (*n* = 1,710)	Other[1] (*n* = 262)
USDA yield grade	3.6^{a} (0.05)	3.3^{b} (0.01)	2.7^{d} (0.02)	3.1^{c} (0.07)
USDA quality grade[2]	819^{a} (0.9)	732^{b} (0.3)	656^{c} (0.5)	357^{d} (10.8)
Adjusted fat thickness, cm	1.6^{a} (0.04)	1.5^{b} (0.01)	1.2^{c} (0.02)	1.4^{b} (0.05)
HCW, kg	399.4^{a} (2.47)	393.1^{b} (0.60)	381.7^{c} (1.07)	391.0^{b} (2.91)
LM area, cm^2	84.5^{c} (0.63)	88.9^{b} (0.14)	91.5^{a} (0.27)	91.2^{a} (0.63)
KPH, %	1.8^{b} (0.07)	2.0^{b} (0.01)	1.9^{b} (0.02)	2.1^{a} (0.06)
Marbling score[3]	756^{a} (2.8)	497^{b} (0.9)	356^{d} (0.5)	429^{c} (6.1)
Lean maturity[4]	149^{c} (0.8)	151^{c} (0.2)	155^{b} (0.3)	171^{a} (2.1)
Skeletal maturity[4]	163^{bc} (1.3)	166^{b} (0.3)	161^{c} (0.4)	230^{a} (3.6)
Overall maturity[4]	157^{b} (0.9)	159^{b} (0.2)	158^{b} (0.3)	211^{a} (2.7)

[a-d]Means within a row with different superscripts differ ($P < 0.05$).

[1] Other includes: Standard, Commercial, Utility, dark cutter, blood splash, hard bone, and calloused ribeye.

[2]100 = $Canner^{00}$, 400 = $Commercial^{00}$, 600 = $Select^{00}$, 700 = $Choice^{00}$, and 800 = $Prime^{00}$ (USDA, 2016).

[3]100 = Practically $devoid^{00}$, 300 = $Slight^{00}$, 400 = $Small^{00}$, 500 = $Modest^{00}$, 700 = Slightly $Abundant^{00}$, and 900 = $Abundant^{00}$ (USDA, 2016).

[4]100 = A^{00}; 200 = B^{00}; 300 = C^{00} (USDA, 2016).

National Beef Quality Audit-2016: Percentage distribution[1] of carcasses stratified by USDA quality and yield grades

USDA yield grade	USDA quality grade, %			
	Prime	Choice	Select	Other[2]
1	0.07	4.06	4.79	0.55
2	0.94	23.61	10.90	1.05
3	1.78	29.94	6.20	1.49
4	0.97	9.31	1.40	0.40
5	0.22	1.86	0.33	0.12

[1]Carcasses with missing values for USDA quality or yield grades are not included.

[2]Other includes: Standard, Commercial, Utility, dark cutter, blood splash, hard bone, and calloused ribeye.

Fed Instrument

National Beef Quality Audit-2016: Means for USDA carcass grade traits between the in-plant survey and instrument data

Trait	In-Plant Survey[1] (*n* = 9,106)	Instrument Data (*n* = 4,544,635)
USDA yield grade	3.1	3.1
Fat thickness, cm	1.4	1.37
HCW, kg	390.3	393.6
LM area, cm^2	89.5	88.9
KPH, %	1.9	2.1
Marbling score[2]	470	475

[1]Boykin et al. (2017)

[2]100 = Practically devoid^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 700 = Slightly Abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

National Beef Quality Audit-2016: Instrument grading means, SD, and minimum and maximum values for USDA carcass grade traits

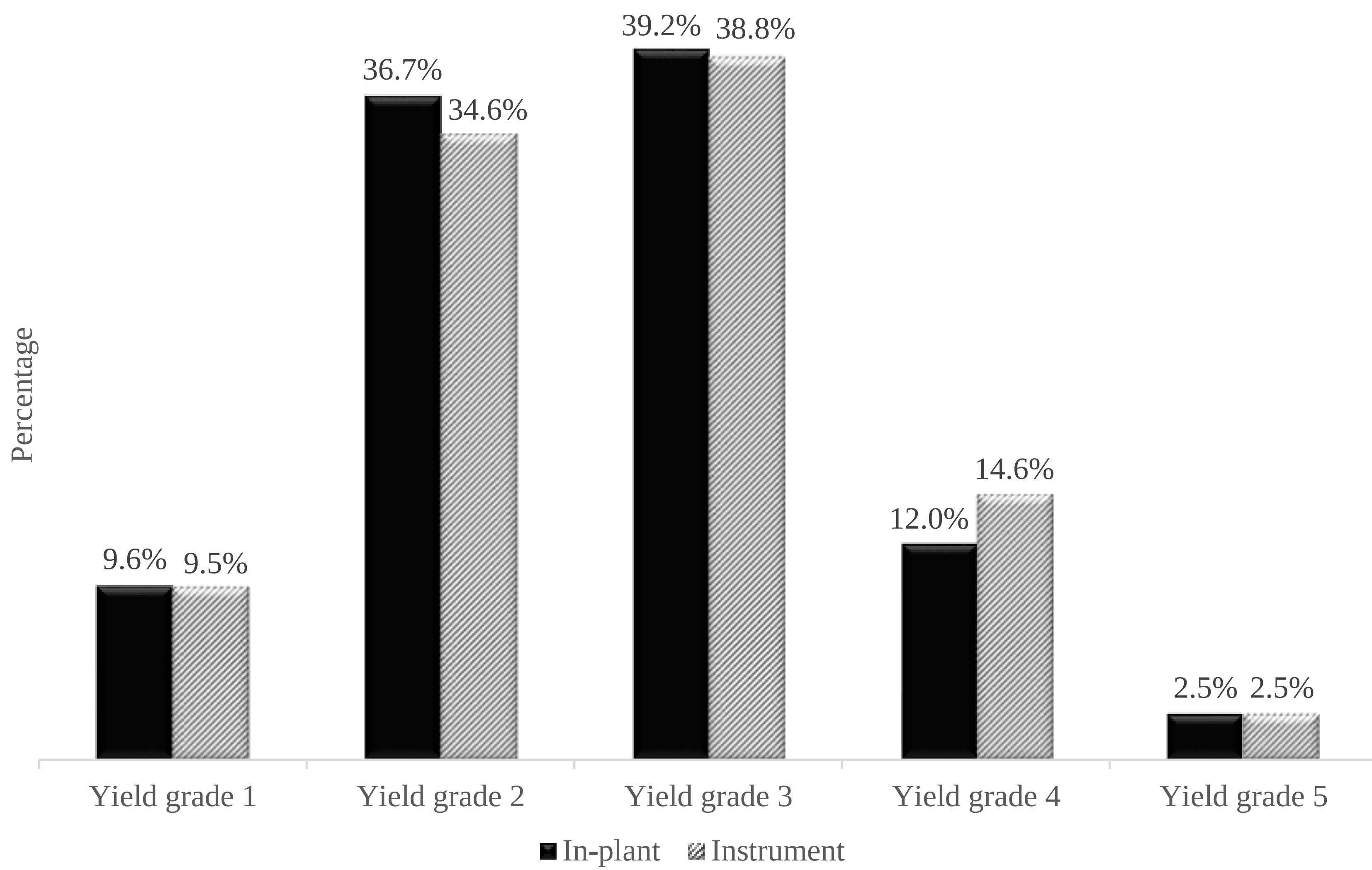
Trait	*n*	Mean	SD	Minimum	Maximum
USDA yield grade	4,391,142	3.1	0.90	-2.0	9.3
Fat thickness, cm	4,532,166	1.37	0.55	0.0	6.35
HCW, kg	4,516,858	393.6	57.56	136.1	719.1
LM area, cm^2	4,508,422	88.9	12.74	19.69	219.3
KPH, %	3,877,100	2.1	0.40	0.0	8.5
Marbling score[1]	4,544,634	475	110.73	100	1099

[1]100 = Practically devoid^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 700 = Slightly Abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

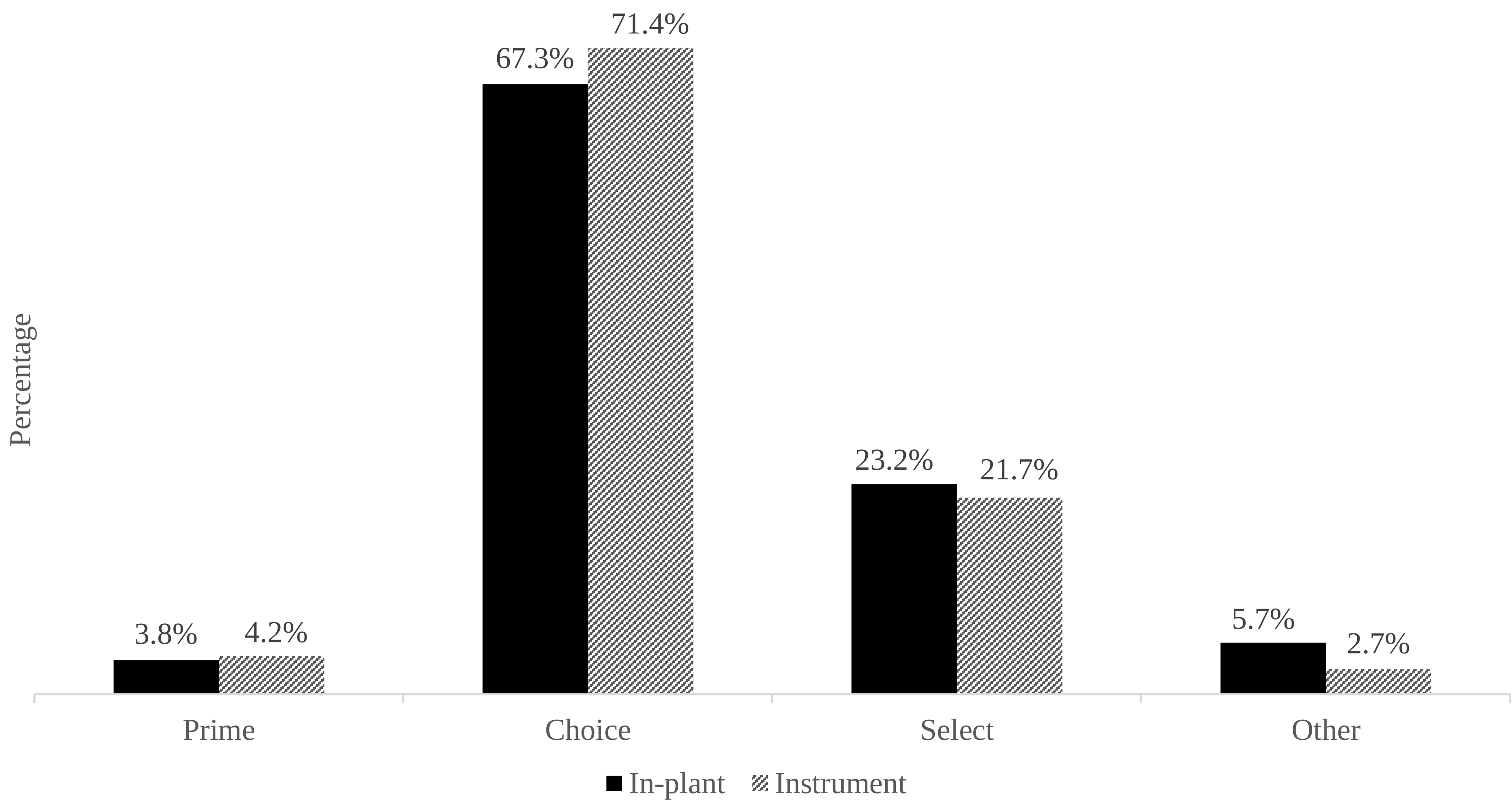
National Beef Quality Audit (NBQA): Instrument grading means for USDA carcass grade traits from NBQA-2011 and NBQA-2016

Trait	NBQA-2011 (*n* = 2,427,074)	NBQA-2016 (*n* = 4,544,635)
USDA yield grade	2.86	3.10
Fat thickness, cm	1.20	1.37
HCW, kg	371.28	393.6
LM area, cm^2	88.45	88.9
Marbling score[1]	449	475

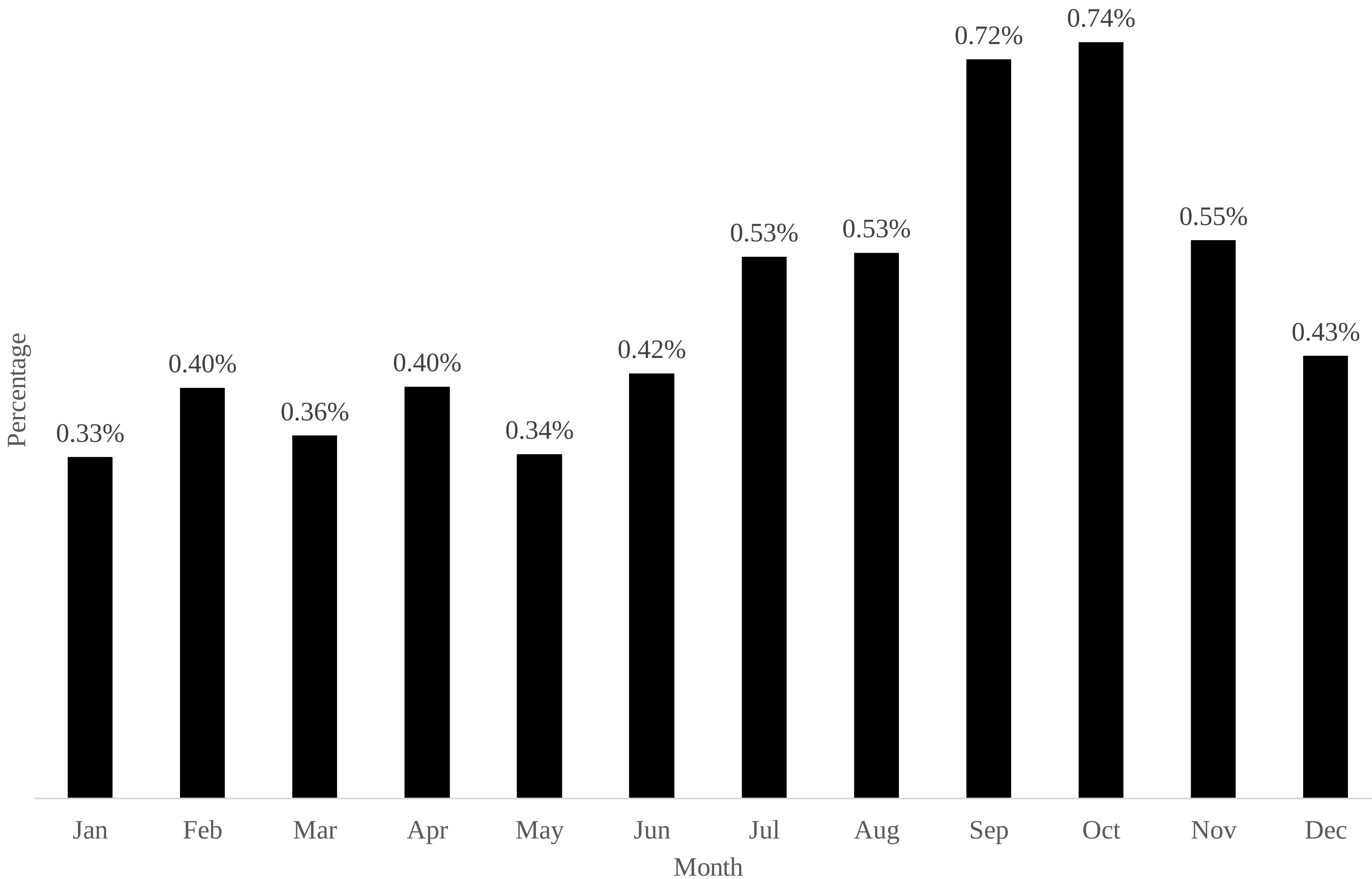
[1]100 = Practically devoid^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 700 = Slightly Abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).



National Beef Quality Audit – 2016: Instrument and in-plant comparison of frequency of USDA yield grades

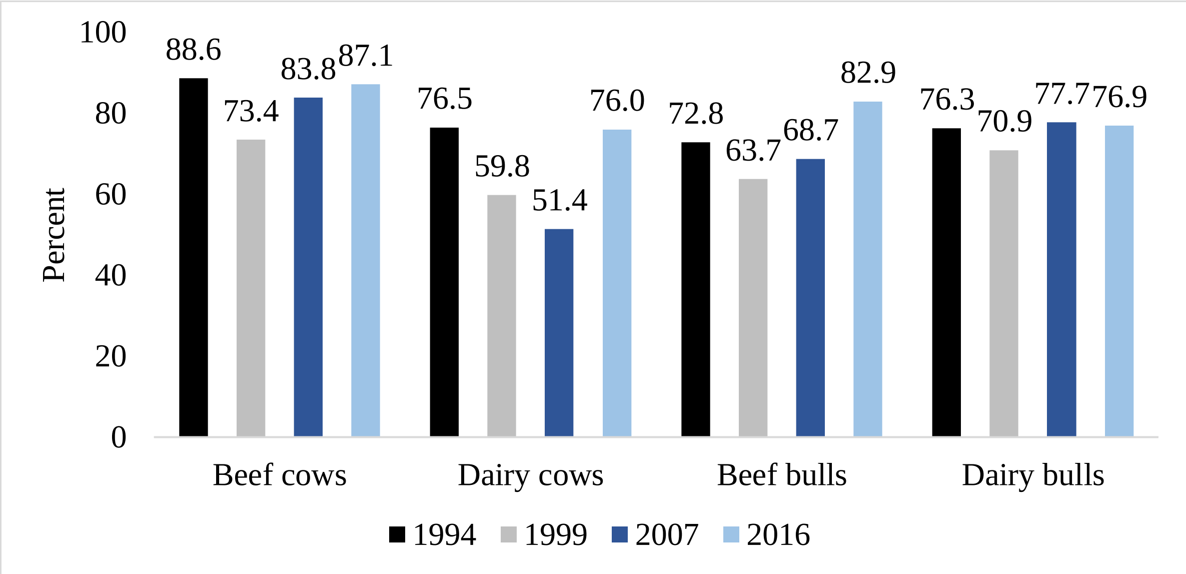


National Beef Quality Audit – 2016: Instrument and in-plant comparison of frequency of USDA quality grades

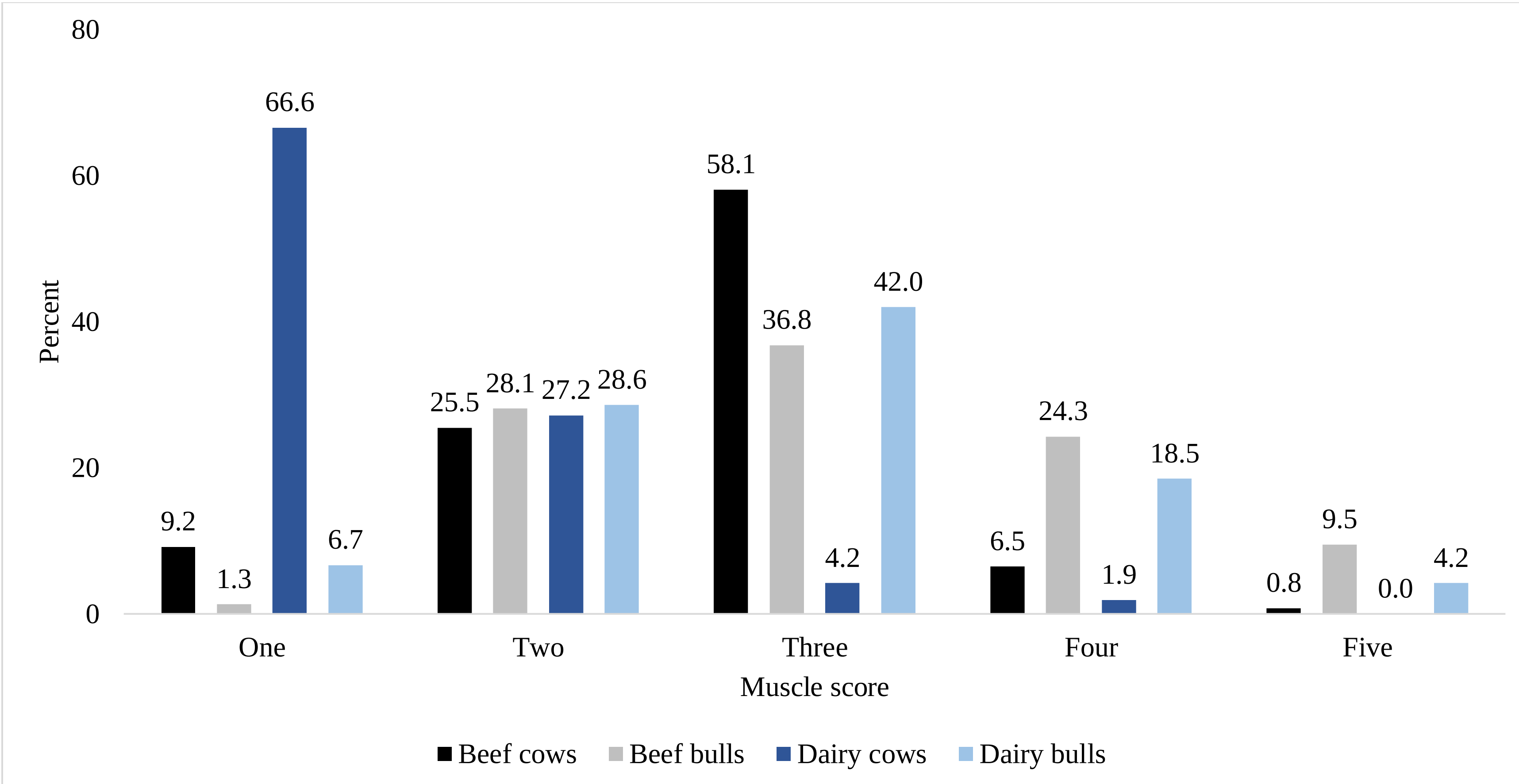


National Beef Quality Audit – 2016: Frequency distribution of dark cutting carcasses by month.

Market Cow/Bull



National Beef Quality Audit (NBQA): Percentage of sound (normal mobility) cattle observed in each of the National Market Cow and Bull Beef Quality Audits. Total number of observations were National Non-Fed Beef Quality Audit-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: beef cows (*n* = 2,237), dairy cows (*n* = 1,108), beef bulls (*n* = 419), dairy bulls (*n* = 79); NMCBBAQ-2007: beef cows (*n* = 2,807), dairy cows (*n* = 2,112), beef bulls (*n* = 431), dairy bulls (*n* = 130); NBQA-2016: beef cows (*n* = 1,557), dairy cows (*n* = 1,743), beef bulls (*n* = 321), dairy bulls (*n* = 52) (Smith et al., 1994; Roeber et al., 2000; Nicholson, 2008).


80
60
40
20
0
Percent
66.6
58.1
42.0
36.8
25.5
28.1
27.2
28.6
24.3
18.5
9.2
1.3
6.7
4.2
6.5
1.9
9.5
0.8
0.0
4.2
One
Two
Three
Four
Five
Muscle score
Beef cows
Beef bulls
Dairy cows
Dairy bulls

National Beef Quality Audit (NBQA): Frequency of muscle scores observed in surveyed animals. Muscle score was determined based on a 5-point scale: 1 – extremely light muscled, 3 – average muscled, 5 – extremely heavy muscled. Total number of observations were beef cows (*n* = 1,860), dairy cows (*n* = 2,809), beef bulls (*n* = 399), dairy bulls (*n* = 119).

National Beef Quality Audit (NBQA): Carcass bruise severity over the past twenty-two years in cows and bulls surveyed[1,2,3]

Bruise severity	1994	1999	2007	2016
Cows				
n	Unknown	4,848	5,092	4,262
No bruise	20.3%	11.8%	36.6%	35.9%
Minimal[4]	51.5%	77.2%	36.7%	67.3%
Major[4]	53.9%	41.7%	30.9%	45.1%
Critical[4]	30.7%	21.6%	12.4%	4.9%
Extreme[4]	nd[5]	2.4%	5.4%	1.4%
Bulls				
n	Unknown	831	477	389
No bruise	63.8%	47.1%	46.8%	57.1%
Minimal	25.3%	44.4%	31.5%	42.4%
Major	19.5%	16.7%	20.1%	21.9%
Critical	7.4%	6.9%	11.5%	1.5%
Extreme	nd	1.0%	7.6%	0.3%

[1] National Non-Fed Beef Quality Audit - 1994 (Smith et al., 1994); National Market Cow and Bull Beef Quality Audit - 1999 (Roeber et al., 2000); National Market Cow and Bull Beef Quality Audit - 2007 (Nicholson, 2008).

[2] Total number of observations for cow carcass bruises were: unknown (NNFBQA – 1994); 4,848 (NMCBBQA – 1999); 5,092 (NMCBBQA – 2007); 4,262 (NBQA – 2016). Total number of observations for bull carcass bruises were: unknown (NNFBQA – 1994); 831 (NMCBBQA – 1999); 477 (NMCBBQA – 2007); 389 (NBQA – 2016).

[3] Percentages do not add to 100% because some animals possessed multiple bruises, some of varying severity.

[4] Minimal (<0.45 kg carcass trim); major (0.45 kg to 4.54 kg carcass trim); critical (5.0 kg to 18.14 kg carcass trim); extreme (entire primal was trimmed).

[5] nd = not determined.

National Beef Quality Audit (NBQA): Frequency (%) of bruise severity

Severity[1]	Beef cows	Dairy cows	Beef bulls	Dairy bulls
Minimal	53.6	57.5	57.2	74.3
Major	39.7	37.6	38.8	24.8
Critical	5.6	3.7	3.9	0.0
Extreme	1.0	1.2	0.0	1.0

[1] Minimal (<0.45 kg carcass trim); major (0.45 kg to 4.54 kg carcass trim); critical (5.0 kg to 18.14 kg carcass trim); extreme (entire primal was trimmed).

Photos – include at least 2 relevant photographs (jpg format)

III. Lay Summary

Fed Harvest

The NBQA remains an important measure for the U.S. beef industry as it tries to improve quality and consumer demand. Characteristics evaluated in this audit will be relayed to cattle producers, which can ultimately enhance consistency and quality of cattle and beef products in the U.S. beef supply chain. Trends observed in NBQA-2016 included fewer cattle having identification; fewer black-hided cattle and more Holstein cattle; more cattle without a brand or horns; fewer carcasses without bruises; more liver, lung, and viscera condemnations; and fewer head and tongue condemnations. Data from this survey can be utilized in all segments of beef production to improve upon current management practices and implement innovative techniques to enhance beef quality and consistency in the U.S. supply chain.

Fed Cooler

The fed steer and heifer beef industry is constantly evolving and the NBQA allows a current benchmark to be established and progress to be evaluated. Through these assessments of beef carcasses across the United States and compared with the last audit, we found a numerical increase in mean USDA YG, USDA QG, AFT, HCW, LM area, and marbling score. Furthermore, an increase in dairy-type carcasses and percentage of carcasses grading USDA Prime and Choice, as well as frequency of USDA YG 4 and 5 was observed. These data indicate that while the industry is improving the quality of beef being produced, there is also an increase in size and fatness.

Fed Instrument

The instrument grading portion of the NBQA permitted the unique opportunity to evaluate trends in carcass traits over the course of a year. Mean FT and HCW decreased to reach the lowest point in May 2016, and continued to increase through November 2016. Similarly, mean marbling scores were at their highest at the beginning and end of the year and were at their lowest in May, June, and July. These trends are remarkably similar to those observed in NBQA-2011. Findings allow the beef industry access to the greatest volume of beef value-determining characteristics for the U.S. fed steer and heifer population ever reported.

Market Cow and Bull

Results from the NBQA-2016 show live cattle and carcass quality improvements in the market cow and bull beef sector compared to 2007. The most notable improvements include an increase in the percentage of cattle with normal mobility (particularly dairy cattle), a transition from thinner to more moderate body conditioned dairy cattle, and a decrease in the percentage of critical and extreme bruising on all carcasses. Additionally, results indicate the cattle industry has made improvements in hide contamination and carcass traits leading to increased value recovery for producers and processors.

Producers, academics, industry professionals, and government agencies may use the findings from the NBQA-2016 to direct the future of the cow and bull industry. Emphasis for extension education, beef quality assurance programs, and future research should be focused toward appropriate management of cull cows and bulls to increase muscle before harvest, marketing animals before physical defects are too severe and cause animal welfare concerns or carcass condemnations, and ways to further improve carcass bruising on the farm, in transport, and at the packing facility. Improving producers' and stakeholders' knowledge of production practices that can minimize profit loss, will allow them to be better equipped to implement management techniques that contribute increased profits and the advancement of the entire beef industry.

IV. Supplemental Information

a. Dissemination Plan/Progress Report

i. Publications, abstracts, manuscripts in progress, theses or presentations that have resulted from this research:

a) Abstracts: International Congress of Meat Science and Technology (ICoMST), 2017

b) Manuscripts in progress: 4

1. Fed harvest floor assessment published in Translational Animal Science, June 2017
2. Fed in-plant cooler assessment published in Journal of Animal Science, July 2017
3. Fed instrument assessment published in Journal of Animal Science, July 2017
4. Market Cow and Bull: two separate manuscripts submitted to Translational Animal Science (one accepted, one submitted, October 2017

c) Theses: Courtney Boykin and McKensie Harris, Texas A&M University

d) Presentations: At a minimum, 4

ii. Number of M.S. and/or Ph.D. students involved in this project

a) M.S. – 15

b) Ph.D. – 3

iii. Additional funding secured as a result of beef industry support of this project

None

b. Financial Report

i. Was the project completed on budget?

Yes

ii. If the project was completed under budget, why was the cost less than the original estimate?

Not applicable

c. Acknowledgement

Funded, in part, by the Beef Checkoff