National Beef Quality Audit-2016: Transportation, mobility, and harvest-floor assessments of targeted characteristics that affect quality and value of cattle, carcasses, and by-products[1]

L. C. Eastwood,* C. A. Boykin,* M. K. Harris,* A. N. Arnold,* D. S. Hale,* C. R. Kerth,* D. B. Griffin,* J. W. Savell,*[2] K. E. Belk,† D. R. Woerner,† J. D. Hasty,† R. J. Delmore Jr.,† J. N. Martin,† T. E. Lawrence,‡ T. J. McEvers,‡ D. L. VanOverbeke,§ G. G. Mafi,§ M. M. Pfeiffer,§ T. B. Schmidt,# R. J. Maddock,‖ D. D. Johnson,¶ C. C. Carr,¶ J. M. Scheffler,¶ T. D. Pringle,** and A. M. Stelzleni**

*Department of Animal Science, Texas A&M AgriLife Research, Texas A&M University, College Station 77843; †Department of Animal Sciences, Colorado State University, Fort Collins 80523; ‡Beef Carcass Research Center, Department of Agricultural Sciences, West Texas A&M University, Canyon 79016; §Department of Animal Science, Oklahoma State University, Stillwater 74078; #Department of Animal Science, University of Nebraska-Lincoln, Lincoln 68583; ‖Department of Animal Sciences, North Dakota State University, Fargo 58108; ¶Department of Animal Sciences, University of Florida, Gainesville 32611; and **Department of Animal & Dairy Science, University of Georgia, Athens 30602

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 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.

Key words: audit, beef quality, carcass

© 2017 American Society of Animal Science. This is an open access article distributed under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)

Transl. Anim. Sci. 2017.1:229–238
doi:10.2527/tas2017.0029

[1]This study was funded, in part, by the Beef Checkoff.

[2]Corresponding author: j-savell@tamu.edu

Received April 5, 2017.
Accepted April 17, 2017.

INTRODUCTION

The National Beef Quality Audit (NBQA) is conducted about every 5 yr 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 (Boleman et al., 1998; Garcia et al., 2008; Lorenzen et al., 1993; McKeith et al., 2012; McKenna et al., 2002). Similar audits have been conducted in Canada to assess quality characteristics of cattle in the Canadian beef supply (Van Donkersgoed et al., 2001; Van Donkersgoed et al., 1997). 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

Animal care and use committee approval was not obtained for this study. Live cattle transportation and mobility data were collected strictly by observation, and all other data were collected on carcasses after immobilization.

Overview

Over the course of this study (March to November 2016), 17 in-plant harvest floor assessments were conducted (Table 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.

Table 1. 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

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 4 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, and shoulder (chuck). Quantification of brands was determined based on estimated size (length × 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 fetus presences were recorded at the viscera table.

Statistical Analyses

All data were analyzed using JMP Pro, Version 12.0.1 (SAS Inst. 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 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 12 h. 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.

Table 2. 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.

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 (Frese et al., 2016; Swanson and Morrow-Tesch, 2001).

Animal Identification Method

Animal identification data were collected in the previous 2 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 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% 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%).

Table 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).

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 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 3 previous audits (Garcia et al., 2008; McKeith et al., 2012; McKenna et al., 2002). 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 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% points from NBQA-2011 to NBQA-2016 (McKeith et al., 2012). Additionally, Holstein-influenced cattle in the population increased 14.9% points from the previous audit. Changes in relative abundance of black-hided cattle (declined)

Table 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).

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 (Boleman et al., 1998; Garcia et al., 2008; Lorenzen et al., 1993; McKeith et al., 2012; McKenna et al., 2002). 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 5). Cattle with multiple brands represented 1.6% of hide-on carcasses sampled (Table 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% 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 to 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 5 yr. This trend is likely due to increased producer participation and implementation of programs such as BQA.

Table 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).

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 (Bacon et al., 2000; Bosilevac et al., 2005; Dorsa, 1997; Elder et al., 2000; Huffman, 2002; 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 (Baird et al., 2006; Bosilevac et al., 2005; Loneragan and Brashears, 2005). Factors such as weather, lairage conditions, and seasonality can impact presence and amount of mud or manure on cattle arriving at harvest facilities (Arthur et al., 2010; Barkocy-Gallagher et al., 2003). Therefore, multiple interventions are employed throughout the beef slaughter process to reduce prevalence of pathogenic bacteria on carcasses (Bosilevac et al., 2006; Bosilevac et al., 2005; Castillo et al., 1998; Castillo et al., 1999; Gill and Landers, 2003; Graves Delmore et al., 1997; Hardin et al., 1995; Koohmaraie et al., 2005; Rekow et al., 2011).

Horn Evaluation

Horn prevalence has been evaluated since the original NBQA in 1991 (Boleman et al., 1998; Garcia et al., 2008; Lorenzen et al., 1993; McKeith et al., 2012; McKenna et al., 2002). For NBQA-2016, of total hide-on carcasses surveyed, 16.7% of cattle had horns and 83.3% did not have horns (Table 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% 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).

Table 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).

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 (Boleman et al., 1998; Garcia et al., 2008; Lorenzen et al., 1993; McKeith et al., 2012; McKenna et al., 2002). 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 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

Table 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.

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% 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 7). For all carcasses sampled, prevalence of bruises on the round, loin, rib, and chuck increased ($P < 0.05$) compared to NBQA-2011 (Fig. 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 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 (Ahola et al., 2011; Frese et al., 2016; González et al., 2012a; González et al., 2012b; Jarvis et al., 1995; Meischke et al., 1974; Miranda-de la Lama et al., 2014).

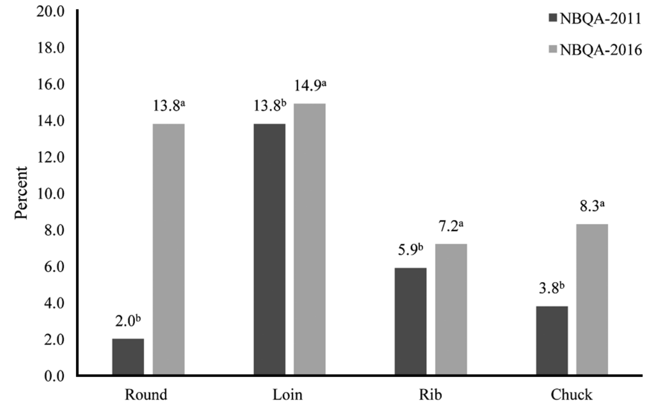

Figure 1. National Beef Quality Audit (NBQA): Frequency distributions of bruises in primals from all carcasses sampled in NBQA-2011 and NBQA-2016 ($\chi 2$ for round $P < 0.0001$, loin $P = 0.0022$, rib $P < 0.0001$, and chuck $P < 0.0001$). Means within primals with different superscripts differ ($P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

Table 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).

Dentition

Dentition has been assessed in the past 2 NBQA surveys (Garcia et al., 2008; McKeith et al., 2012). For all cattle surveyed, 80.5% had 0 permanent incisors (Table 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 (Boleman et al., 1998; Garcia et al., 2008; Lorenzen et al., 1993; McKeith et al., 2012; McKenna et al., 2002). Frequencies of offal condemnations by USDA-FSIS are reported in Table 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 (Fig. 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 (Boleman et al., 1998; Garcia et al., 2008; Lorenzen et al., 1993; McKeith et

Table 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.

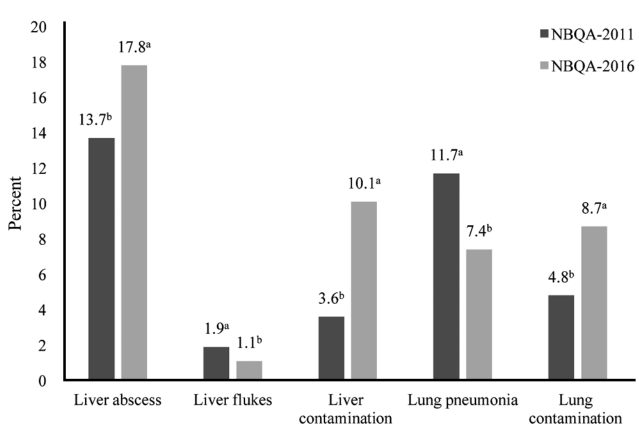

Figure 2. National Beef Quality Audit (NBQA): Frequency distributions for specific liver and lung condemnations from all carcasses sampled in NBQA-2011 and NBQA-2016 ($\chi 2$ for liver abscesses $P < 0.0001$, liver flukes $P < 0.0001$, liver contamination $P < 0.0001$, lung pneumonia $P < 0.0001$, and 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).

al., 2012; McKenna et al., 2002). 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 (Brown and Lawrence, 2010; Nagaraja and Lechtenberg, 2007; 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% points and tongue condemnations by 8.1% 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 on current management practices and implement innovative techniques to enhance beef quality and consistency in the U.S. supply chain.

LITERATURE CITED

Ahola, J. K., H. A. Foster, D. L. VanOverbeke, K. S. Jensen, R. L. Wilson, J. B. Glaze, T. E. Fife, C. W. Gray, S. A. Nash, R. R. Panting, and N. R. Rimbey. 2011. Quality defects in market beef and dairy cows and bulls sold through livestock auction markets in the Western United States: II. Relative effects on selling price. J. Anim. Sci. 89:1484–1495. doi:10.2527/jas.2010-3171

Arthur, T. M., D. M. Brichta-Harhay, J. M. Bosilevac, N. Kalchayanand, S. D. Shackelford, T. L. Wheeler, and M. Koohmaraie. 2010. Super shedding of *Escherichia coli* O157:H7 by cattle and the impact on beef carcass contamination. Meat Sci. 86:32–37. doi:10.1016/j.meatsci.2010.04.019

Bacon, R. T., K. E. Belk, J. N. Sofos, R. P. Clayton, J. O. Reagan, and G. C. Smith. 2000. Microbial populations on animal hides and beef carcasses at different stages of slaughter in plants employing multiple-sequential interventions for decontamination. J. Food Prot. 63:1080–1086. doi:10.4315/0362-028X-63.8.1080

Baird, B. E., L. M. Lucia, G. R. Acuff, K. B. Harris, and J. W. Savell. 2006. Beef hide antimicrobial interventions as a means of reducing bacterial contamination. Meat Sci. 73:245–248. doi:10.1016/j.meatsci.2005.11.023

Barkocy-Gallagher, G. A., T. M. Arthur, M. Rivera-Betancourt, X. Nou, S. D. Shackelford, T. L. Wheeler, and M. Koohmaraie. 2003. Seasonal prevalence of Shiga toxin-producing *Escherichia coli*, including O157: H7 and non-O157 serotypes, and *Salmonella* in commercial beef processing plants. J. Food Prot. 66:1978–1986. doi:10.4315/0362-028X-66.11.1978

Boleman, S. L., S. J. Boleman, W. W. Morgan, D. S. Hale, D. B. Griffin, J. W. Savell, R. P. Ames, M. T. Smith, J. D. Tatum, T. G. Field, G. C. Smith, B. A. Gardner, J. B. Morgan, S. L. Northcutt, H. G. Dolezal, D. R. Gill, and F. K. Ray. 1998. National Beef Quality Audit-1995: Survey of producer-related defects and carcass quality and quantity attributes. J. Anim. Sci. 76:96–103. doi:10.2527/1998.76196x

Bosilevac, J. M., X. Nou, G. A. Barkocy-Gallagher, T. M. Arthur, and M. Koohmaraie. 2006. Treatments using hot water instead of lactic acid reduce levels of aerobic bacteria and *Enterobacteriaceae* and reduce the prevalence of *Escherichia coli* O157:H7 on preevisceration beef carcasses. J. Food Prot. 69:1808–1813. doi:10.4315/0362-028X-69.8.1808

Bosilevac, J. M., X. Nou, M. S. Osborn, D. M. Allen, and M. Koohmaraie. 2005. Development and evaluation of an on-line hide decontamination procedure for use in a commercial beef processing plant. J. Food Prot. 68:265–272. doi:10.4315/0362-028X-68.2.265

Brown, T. R., and T. E. Lawrence. 2010. Association of liver abnormalities with carcass grading performance and value. J. Anim. Sci. 88:4037–4043. doi:10.2527/jas.2010-3219

Castillo, A., L. M. Lucia, K. J. Goodson, J. W. Savell, and G. R. Acuff. 1998. Use of hot water for beef carcass decontamination. J. Food Prot. 61:19–25. doi:10.4315/0362-028X-61.1.19

Castillo, A., L. M. Lucia, K. J. Goodson, J. W. Savell, and G. R. Acuff. 1999. Decontamination of beef carcass surface tissue by steam vacuuming alone and combined with hot water and lactic acid sprays. J. Food Prot. 62:146–151. doi:10.4315/0362-028X-62.2.146

Dorsa, W. J. 1997. New and established carcass decontamination procedures commonly used in the beef-processing industry. J. Food Prot. 60:1146–1151. doi:10.4315/0362-028X-60.9.1146

Elder, R. O., J. E. Keen, G. R. Siragusa, G. A. Barkocy-Gallagher, M. Koohmaraie, and W. W. Laegreid. 2000. Correlation of enterohemorrhagic *Escherichia coli* O157 prevalence in feces, hides, and carcasses of beef cattle during processing. Proc. Natl. Acad. Sci. USA 97:2999–3003. doi:10.1073/pnas.97.7.2999

Ferguson, D. M., and R. D. Warner. 2008. Have we underestimated the impact of pre-slaughter stress on meat quality in ruminants? Meat Sci. 80:12–19. doi:10.1016/j.meatsci.2008.05.004

Frese, D. A., C. D. Reinhardt, S. J. Bartle, D. N. Rethorst, J. P. Hutcheson, W. T. Nichols, B. E. Depenbusch, M. E. Corrigan, and D. U. Thomson. 2016. Cattle handling technique can induce fatigued cattle syndrome in cattle not fed a beta adrenergic agonist. J. Anim. Sci. 94:581–591. doi:10.2527/jas.2015-9824

Garcia, L. G., K. L. Nicholson, T. W. Hoffman, T. E. Lawrence, D. S. Hale, D. B. Griffin, J. W. Savell, D. L. VanOverbeke, J. B. Morgan, K. E. Belk, T. G. Field, J. A. Scanga, J. D. Tatum, and G. C. Smith. 2008. National Beef Quality Audit–2005: Survey of targeted cattle and carcass characteristics related to quality, quantity, and value of fed steers and heifers. J. Anim. Sci. 86:3533–3543. doi:10.2527/jas.2007-0782

Gill, C. O., and C. Landers. 2003. Microbiological effects of carcass decontaminating treatments at four beef packing plants. Meat Sci. 65:1005–1011. doi:10.1016/S0309-1740(02)00319-4

González, L. A., K. S. Schwartzkopf-Genswein, M. Bryan, R. Silasi, and F. Brown. 2012a. Relationships between transport conditions and welfare outcomes during commercial long haul transport of cattle in North America. J. Anim. Sci. 90:3640–3651. doi:10.2527/jas.2011-4796

González, L. A., K. S. Schwartzkopf-Genswein, M. Bryan, R. Silasi, and F. Brown. 2012b. Space allowance during commercial long distance transport of cattle in North America. J. Anim. Sci. 90:3618–3629. doi:10.2527/jas.2011-4771

Grandin, T. 2013. Recommended Animal Handling Guidelines & Audit Guide: A Systematic Approach to Animal Welfare. AMI Foundation, Washington, DC. http://animalhandling.org/ht/a/GetDocumentAction/i/93003 (Accessed 12 April 2017.)

Graves Delmore, L. R., J. N. Sofos, J. O. Reagan, and G. C. Smith. 1997. Hot-water rinsing and trimming/washing of beef carcasses to reduce physical and microbiological contamination. J. Food Sci. 62:373–376. doi:10.1111/j.1365-2621.1997.tb04004.x

Gray, G. D., M. C. Moore, D. S. Hale, C. R. Kerth, D. B. Griffin, J. W. Savell, C. R. Raines, T. E. Lawrence, K. E. Belk, D. R. Woerner, J. D. Tatum, D. L. VanOverbeke, G. G. Mafi, R. J. Delmore, Jr., S. D. Shackelford, D. A. King, T. L. Wheeler, L. R. Meadows, and M. E. O'Connor. 2012. National Beef Quality Audit–2011: Survey of instrument grading assessments of beef carcass characteristics. J. Anim. Sci. 90:5152–5158. doi:10.2527/jas.2012-5551

Greene, J. L. 2015. Country-of-Origin Labeling for Foods and the WTO Trade Dispute on Meat Labeling. Congressional Research Service, Washington, DC. https://fas.org/sgp/crs/misc/RS22955.pdf (Accessed 12 April 2017.)

Hardin, M. D., G. R. Acuff, L. M. Lucia, J. S. Oman, and J. W. Savell. 1995. Comparison of methods for decontamination from beef carcass surfaces. J. Food Prot. 58:368–374. doi:10.4315/0362-028X-58.4.368

Huffman, R. D. 2002. Current and future technologies for the decontamination of carcasses and fresh meat. Meat Sci. 62:285–294. doi:10.1016/S0309-1740(02)00120-1

Jarvis, A. M., L. Selkirk, and M. S. Cockram. 1995. The influence of source, sex class and pre-slaughter handling on the bruising of cattle at two slaughterhouses. Livest. Prod. Sci. 43:215–224. doi:10.1016/0301-6226(95)00055-P

Koohmaraie, M., T. M. Arthur, J. M. Bosilevac, M. Guerini, S. D. Shackelford, and T. L. Wheeler. 2005. Post-harvest interventions to reduce/eliminate pathogens in beef. Meat Sci. 71:79–91. doi:10.1016/j.meatsci.2005.03.012

Loneragan, G. H., and M. M. Brashears. 2005. Pre-harvest interventions to reduce carriage of *E. coli* O157 by harvest-ready feedlot cattle. Meat Sci. 71:72–78. doi:10.1016/j.meatsci.2005.04.005

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

Marti, D. L., R. J. Johnson, and K. H. Mathews, Jr. 2011. Where's the (Not) Meat? Byproducts from Beef and Pork Production. Economics Research Service, United States Department of Agriculture, Washington, DC. http://usda.mannlib.cornell.edu/usda/ers/LDP-M/2010s/2011/LDP-M-11-21-2011_Special_Report.pdf (Accessed 12 April 2017.)

McKeith, R. O., G. D. Gray, D. S. Hale, C. R. Kerth, D. B. Griffin, J. W. Savell, C. R. Raines, K. E. Belk, D. R. Woerner, J. D. Tatum, J. L. Igo, D. L. VanOverbeke, G. G. Mafi, T. E. Lawrence, R. J. Delmore, Jr., L. M. Christensen, S. D. Shackelford, D. A. King, T. L. Wheeler, L. R. Meadows, and M. E. O'Connor. 2012. National Beef Quality Audit-2011: Harvest-floor assessments of targeted characteristics that affect quality and value of cattle, carcasses, and byproducts. J. Anim. Sci. 90:5135–5142. doi:10.2527/jas.2012-5477

McKenna, D. R., D. L. Roeber, P. K. Bates, T. B. Schmidt, D. S. Hale, D. B. Griffin, J. W. Savell, J. C. Brooks, J. B. Morgan, T. H. Montgomery, K. E. Belk, and G. C. Smith. 2002. National Beef Quality Audit-2000: Survey of targeted cattle and carcass characteristics related to quality, quantity, and value of fed steers and heifers. J. Anim. Sci. 80:1212–1222. doi:10.2527/2002.8051212x

Meischke, H. R. C., W. R. Ramsay, and F. D. Shaw. 1974. The effect of horns on bruising in cattle. Aust. Vet. J. 50:432–434. doi:10.1111/j.1751-0813.1974.tb06864.x

Miranda-de la Lama, G. C., M. Villarroel, and G. A. María. 2014. Livestock transport from the perspective of the pre-slaughter logistic chain: A review. Meat Sci. 98:9–20. doi:10.1016/j.meatsci.2014.04.005

Nagaraja, T. G., and K. F. Lechtenberg. 2007. Liver abscesses in feedlot cattle. Vet. Clin. N. Am-Food A. 23:351–369. doi:10.1016/j.cvfa.2007.05.002

North American Meat Institute. 2015. Mobility Scoring for Cattle. https://www.youtube.com/watch?v = QIslfHCvkpg (Accessed 12 April 2017.)

Reinhardt, C. D., and M. E. Hubbert. 2015. Control of liver abscesses in feedlot cattle: A review. Prof. Anim. Sci. 31:101–108. doi:10.15232/pas.2014-01364

Rekow, C. L., M. M. Brashears, J. C. Brooks, G. H. Loneragan, S. E. Gragg, and M. F. Miller. 2011. Implementation of targeted interventions to control *Escherichia coli* O157:H7 in a commercial abattoir. Meat Sci. 87:361–365. doi:10.1016/j.meatsci.2010.11.012

Savell, J. W. 2016. Mud Reference Scoring System. http://agrilife.org/meat/files/2017/03/NBQA-Mud-Reference-Scoring-System.pdf (Accessed 29 March 2017.)

Swanson, J. C., and J. Morrow-Tesch. 2001. Cattle transport: Historical, research, and future perspectives. J. Anim. Sci. 79:E102–E109. doi:10.2527/jas2001.79E-SupplE102x

USDA-AMS. 2017a. Certified Beef Programs. Agricultural Marketing Service, United States Department of Agriculture, Washington, DC. https://www.ams.usda.gov/services/auditing/certified-beef-programs (Accessed 12 April 2017.)

USDA-AMS. 2017b. Country of Origin Labeling (COOL). Agricultural Marketing Service, United States Department of Agriculture, Washington, DC. https://www.ams.usda.gov/rules-regulations/cool (Accessed 12 April 2017.)

USDA-APHIS. 1993. Branding Practices in Beef Cow/Calf Herds: Beef Cow/Calf Health and Productivity Audit. Veterinary Services, Animal and Plant Health Inspection Service, United States Department of Agriculture, Washington, DC. https://www.aphis.usda.gov/animal_health/nahms/beefcowcalf/downloads/chapa/CHAPA_is_Branding.pdf (Accessed 12 April 2017.)

USDA-APHIS. 2009. Cattle Identification Practices on U.S. Beef Cow-calf Operations. Veterinary Services, Centers for Epidemiology and Animal Health, Animal and Plant Health Inspection Service, Washington, DC. https://www.aphis.usda.gov/animal_health/nahms/beefcowcalf/downloads/beef0708/Beef0708_is_CattleID.pdf (Accessed 12 April 2017.)

Van Donkersgoed, J., G. Jewison, S. Bygrove, K. Gillis, D. Malchow, and G. McLeod. 2001. Canadian beef quality audit 1998-99. Can. Vet. J. 42:121–126.

Van Donkersgoed, J., G. Jewison, M. Mann, B. Cherry, B. Altwasser, R. Lower, K. Wiggins, R. Dejonge, B. Thorlakson, E. Moss, C. Mills, and H. Grogan. 1997. Canadian beef quality audit. Can. Vet. J. 38:217–225.