NATIONAL BEEF QUALITY AUDIT – 2016: SURVEY OF CARCASS CHARACTERISTICS RELATED TO QUALITY, QUANTITY, AND VALUE THROUGH IN-PLANT AND INSTRUMENT GRADING ASSESSMENTS

A Thesis

by

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ABSTRACT

The National Beef Quality Audit – 2016 included in-plant cooler and instrument grading 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 across the United States. Approximately 10 percent of the day's production were evaluated for USDA quality grade (QG) and yield grade (YG) factors. Frequencies of traits evaluated are as follow: steer (66.5%), heifer (33.4%) sex classes; native (81.6%), dairy-type (16.3%), and *Bos indicus* (1.4%) estimated breed types; and dark cutter (1.9%). Mean USDA YG factors were USDA YG (3.1), adjusted fat thickness (AFT; 1.42 cm), loin muscle (LM) area (89.5 cm^2), hot carcass weight (HCW; 390.3 kg), and kidney, pelvic, and heat fat (KPH; 1.9%). Frequency distribution of USDA YG were YG 1 (9.6%), YG 2 (36.7%), YG 3 (39.2%), YG 4 (12.0%), and YG 5 (2.5%). Mean USDA QG traits were USDA QG ($Select^{96}$), marbling ($Small^{70}$), overall maturity (A^{64}), lean maturity (A^{55}), and skeletal maturity (A^{69}). Frequency distributions of USDA QG were Prime (3.8%), Choice (67.3%), Select (23.2%), and lower score (5.6%). Marbling score distributions were Slightly Abundant or greater (0.85%), Moderate (7.63%), Modest (23.54%), Small (39.63%), Slight (23.62%), and Traces or less (0.83%)

One week of instrument grading data were collected each month from 5 beef processing corporations encompassing 18 facilities beginning January 2016 through December 2016 to allow the evaluation of seasonal trends (n = 4,544,635 carcasses). Mean USDA YG factors were USDA YG (3.1), AFT (1.37 cm), LM area (88.9 cm^2), HCW (393.6 kg), and KPH

(1.9%). Frequency distribution of USDA YG were YG 1 (9.5%), YG 2 (34.6%), YG 3 (38.8%), YG 4 (14.6%), and YG 5 (2.5%). Monthly HCW means were as follows: January (397.6 kg), February (397.2 kg), March (396.5 kg), April (389.3 kg), May (384.8), June (385.0), July (386.1 kg), August (394.1 kg), September (399.1 kg), October (403.9 kg), November (403.2 kg), and December (401.9 kg). 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^{83}), and December (Small^{79}). Both mean HCW and marbling scores declined in the months of May and June. These data indicate the range of carcasses that are being produced currently. 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.

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NOMENCLATURE

AFT	Adjusted Fat Thickness
AMS	Agricultural Marketing Service
HCW	Hot carcass weight
KPH	Kidney, pelvic, and heart fat
LM	Loin muscle
NBQA	National Beef Quality Audit
NBQA-1991	National Beef Quality Audit-1991
NBQA-1995	National Beef Quality Audit-1995
NBQA-2000	National Beed Quality Audit-2000
NBQA-2005	National Beef Quality Audit-2005
NBQA-2011	National Beef Quality Audit-2011
NBQA-2016	National Beef Quality Audit-2016
NCRBS	National Consumer Retail Beef Study
PYG	Preliminary Yield Grade
QG	Quality Grade
SRM	Specified Risk Materials
USDA	United States Department of Agriculture
VIA	Video Image Analysis
YG	Yield Grade

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CHAPTER I

INTRODUCTION

Following its inception in 1927, beef grading has become an increasingly standard practice in the industry, with 94.4% of federally inspected fed steers and heifers graded in 2015 (USDA, 2015b). Beef carcass quality grades provide the basis for a value-based marketing system by separating carcasses into groups based on expected palatability (USDA, 2016). Furthermore, beef processing facilities can use beef carcass yield grades to optimize efficiency and predict product volume. Beef grading standards have continued to evolve to maintain functionality in an ever-changing industry, with the most recent standards released in 2016.

The first NBQA was conducted in 1991 to create a nationwide snapshot of the status of the beef industry at that time. Following the completion of NBQA-1991, the Executive Summary called to repeat the NBQA 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. To keep with technology trends in the industry, NBQA-2011 included instrument grading data collection over the course of the year in order to evaluate seasonal trends in USDA quality and yield factors (Gray et al., 2012).

NBQA-2016 continues the trend of documenting and analyzing the quality and consistency of the US fed beef industry. Just as in NBQA-2011, data were collected on the harvest floor and in the cooler in facilities across the country, in addition to instrument grading data. These cooler and instrument grading data were compiled to create a representation of the US fed beef industry in 2016.

CHAPTER II

LITERATURE REVIEW

History of Beef Grading

In 1924, the United States Department of Agriculture (USDA) published Bulletin No. 1246 “Market Classes and Grades of Dressed Beef,” which contained the first beef grading standards (Davis and Whalin, 1924). The factors included in these standards were conformation, finish, and quality. Conformation referred to the general build and form of the carcass, finish was defined as the thickness, color, character, and distribution of the fat, whereas quality was outlined as the thickness, firmness, and strength of the muscle fiber and connective tissue, as indicated by color of the lean, marbling, and age. The standards were revised in 1926, and set the basis for the voluntary grading service to begin in 1927. Throughout the years, many revisions have been made to the official grading standards. In 1941, the terminology for carcass grades were established as Prime, Choice, Good, Commercial, Utility, Cutter and Canner. Fat color was removed from the carcass grade standards in 1949 (USDA, 2016).

Murphey et al. (1960) found that the yield of boneless, closely-trimmed retail cuts from the round, loin, rib, and chuck could be predicted using finish and conformation. Additionally, there was a significant value difference between high and low yielding carcasses of the same grade. This instigated the development of the dual grading system, and cutability grades became official in 1965. In 1975, conformation was eliminated from the quality grade standards. Due to findings from the National Consumer Retail Beef Study (NCRBS), Good was replaced by Select in order to better align with consumer perceptions

(Savell et al., 1989). Beef grading has increased in popularity since its development, with 94.4% of all federally-inspected fed steers and heifers graded in 2015 (USDA, 2015b). The most recent grading standards became effective in March 2016 (USDA, 2016).

National Beef Quality Audit – 1991

Before the first National Beef Quality Audit (NBQA), Lambert (1991) wrote a paper that emphasized areas of beef production where there were "lost opportunities." The industry was not fully capitalizing on these opportunities resulting in a higher end price for the consumer and consequently decreased consumption per capita. Some of these areas included hot-iron branding, feed efficiency, retail shrink, out of stock retail products, and excess fat. In 1991, it was estimated that $11.999 billion were lost because of the industry's shortcomings (National Cattlemen's Association, 1992). While there will always be some capital in opportunities that are lost, Lambert (1991) emphasized practices that would decrease or help offset the cost of production.

NBQA-1991 was conducted to determine the target improvements for the next 10 years, and it also established a baseline for future studies. Quality defects resulted in $279.82 per head of "lost opportunities" (National Cattlemen's Association, 1992). The industry set four objectives as a result of this study: attack waste, enhance taste, improve management, and control weight (National Cattlemen's Association, 1992). The goal to reduce excess fat was consistent with the findings from the National Consumer Retail Beef Study (NCRBS) that consumers were making an effort to purchase cuts with less external fat (Savell et al., 1989). Consumers wanted the taste fat, but did not want the waste fat.

The mean carcass USDA yield grade (YG) results from NBQA-1991 were: USDA YG (3.2), adjusted fat thickness (AFT; 1.5 cm), loin muscle (LM) area (83.4 cm^2), hot carcass weight (HCW; 345.0 kg), and kidney, pelvic, and heart fat (KPH; 2.2%; (Lorenzen et al., 1993). The mean USDA QG traits were: USDA QG (Select ^{86}), marbling score (Small^{24}), lean maturity (A^{63}), skeletal maturity (A^{75}), and overall maturity (A^{69}) (Lorenzen et al., 1993). When compared with the 1974 USDA Market Consist Report (Abraham, 1977), a decrease was found in USDA YG, AFT, and KPH percentage (Lorenzen et al., 1993). Additionally, LM area and HCW increased (Lorenzen et al., 1993). Following NBQA-1991, there was a request to repeat the NBQA within the next 5 years to better understand what changes, if any, had occurred (National Cattlemen's Association, 1992).

National Beef Quality Audit – 1995

The second NBQA was conducted 4 years after NBQA-1991 to assess what improvements had occurred within the industry, as well as identify areas requiring additional focus. Mean USDA YG factors were: USDA YG (2.8), AFT (1.2 cm), LM area (82.6 cm^2), HCW (339.2 kg), and KPH (2.1%) (Boleman et al., 1998). USDA QG traits were: USDA QG (Select ^{79}), marbling score (Small ^{06}), lean maturity (A^{54}), skeletal maturity (A^{63}), and overall maturity (A^{60}) (Boleman et al., 1998). In comparison to NBQA-1991 (Lorenzen et al., 1993) changes had resulted in a leaner product as indicated by decreased USDA YG, AFT, HCW, and percentage of KPH (Boleman et al., 1998). However, there was also a decrease in USDA QG and marbling score (Boleman et al., 1998). NBQA-1995 demonstrated improved management practices across the industry confirming the impact of producer education.

National Beef Quality Audit – 2000

McKenna et al. (2002) reported mean USDA YG and QG traits: USDA YG (3.0), USDA QG (Select ^{85}), AFT (1.2 cm), LM area (84.5 cm^2), HCW (356.9 kg), KPH (2.4%), marbling score (Small^{23}), and overall maturity (A^{66}). When compared with NBQA-1995 (Boleman et al., 1998), USDA YG and HCW numerically increased, and AFT decreased (McKenna et al., 2002). Furthermore, the percentage of Prime and Choice carcasses increased from NBQA-1995 (National Cattlemen's Beef Association, 2000). The combination of these changes indicated that producers could genetically select for less external fat in beef products and a greater amount of marbling, which increased the value of beef.

National Beef Quality Audit – 2005

The NBQA-2005 USDA YG and QG were: USDA YG (2.9), USDA QG (Select^{90}), AFT (1.3 cm), LM area (86.4 cm^2), HCW (359.9 kg), KPH (2.3%), marbling score (Small^{32}), and overall maturity (A^{64}; (Garcia et al., 2008). The noteworthy differences from NBQA-2000 (McKenna et al., 2002) were the increases in HCW, USDA QG and YG.

National Beef Quality Audit – 2011

Moore et al. (2012) reported the USDA QG and YG means from NBQA-2011 as follows: USDA YG (2.9), USDA QG (Select^{93}), AFT (1.3 cm), LM area (88.8 cm^2), HCW (374.0 kg), KPH (2.3%), marbling score (Small^{40}), and overall maturity (A^{59}). Both HCW and LM area numerically increased. The NBQA-2011 was the first of the NBQAs to include instrument grading data (Gray et al., 2012), which allowed for seasonal trends of carcass traits to be evaluated. The instrument grading USDA YG and QG means were: USDA YG (2.86), AFT (1.19 cm), LM area (88.39 cm^2), HCW (371.3 kg), marbling score ($Small^{49}$) (Gray et al., 2012). Throughout the course of the year, mean HCW and AFT reached their peaks in November 2010 and decreased to the lowest point in May of 2011. In contrast, mean marbling score increased beginning in November 2010 to its highest point in March 2011, and decreased through the end of the year (Gray et al., 2012).

Instrument Grading

In 1978, the General Accounting Office issued a report to Congress that the accuracy and precision of beef grading needed to be improved (Staats, 1978). Cross et al. (1984) evaluated the percentage of error in both USDA QG and YG of a 3-member grading panel that then were compared to the national percentage of error. From these comparisons, it was determined that little improvement could be made fin the accuracy of USDA QG, however, efforts to improve USDA YG could greatly improve accuracy under the present grading system. Additionally, postmortem factors such as chilling time before ribbing, covered ribeye surfaces, and lighting during grading affected lean maturity and marbling scores (Johnson et al., 1986).

One of the key messages from NBQA-2005 (Smith et al., 2006) was the need to implement instrument grading. Traditionally, beef grading has involved subjective measurements conducted by an on-line human grader for both USDA YG and QG. While USDA YG measurements can be obtained using ribeye dot grids and fat probes, it is not realistic that they can be used on every carcass for grading when the line is operating over 350 carcasses per hour (Woerner and Belk, 2008).

The USDA and NASA collaborated in 1979 to identify technology that would satisfy the beef industry's need for an objective grading measurement. Two technologies that were identified to have potential to be valuable were ultrasound and video image analysis (VIA) (Cross and Whittaker, 1992). A request for proposal (RFP) was awarded to Kansas State University to develop an appropriate instrument, and the VIA began to be tested at the USDA's Meat Animal Research Center (Clay Center, NE). Cross et al. (1983) reported that VIA had greater potential for use in predicting USDA YG than QG. Despite the advancements in VIA, the beef industry continued to pursue an instrument that could execute carcass evaluations on an unchilled, unribbed carcass. Although some studies have shown ultrasound technology to be able to estimate backfat thickness and marbling score (Brethour, 2000), an on-line ultrasound system has not been developed. In 1989, NCBA listed instrument grading as a top priority again and VIA was identified as the most useful technology (Woerner and Belk, 2008).

Instrument grading was approved for official USDA measurement of LM area in 2001, as well as YG and marbling score in 2007 (Mafi et al., 2014). Accuracy, precision, and producer confidence of USDA YG and 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). The latest guidelines for instrument grading were published in 2015; these guidelines entail a trained plant employee using the instrument, adjusting for any advanced maturity or quality defects, as well as stamping the carcass with the grade (USDA, 2015a). Instances in which the AMS grader is not required to accept the grade indicated by the instrument data output are advanced maturity, dark cutting characteristics, or fat pulls. Additionally, the AMS grader may override the instrument if the difference between the instrument output and visually assessed factors exceed the following thresholds: marbling (40 degrees or greater), LM area (6.45 cm^2 or greater), final yield grade (0.50 or greater) or would result in a different yield grade (USDA, 2015a). As the beef industry continues to focus on a value-based marketing system, producer and packer confidence in the grades becomes more crucial. Additionally, consistency should continue to be rewarded, and quality defects discounted.

Quality Defects

One of the primary “lost opportunities” in beef production comes from quality defects that result in a discount such as dark cutting, blood splash, and calloused ribeyes (National Cattlemen's Association, 1992). These defects can be caused by several factors, some of which are management related and therefore can be avoided or reduced.

Dark cutting beef is a result of long-term stress that depletes the glycogen stores necessary to produce lactic acid and reduce the pH of muscle during rigor mortis (Scanga et al., 1998a). National Cattlemen's Association (1992) reported a loss of $5.00 per head due to dark cutters. Although the cause of dark cutting is primarily understood, there are multiple factors that contribute to long-term stress such as weather, handling practices, and animal disposition (Scanga et al., 1998a). While improved management practices may reduce the incidence of dark cutters, it is not likely that it can be fully eliminated (Janloo et al., 1998). However, McGilchrist et al. (2012) examined the intrinsic physiologic differences between animals. This study determined that cattle with a greater proportion of fast glycolytic type IIX muscle fibers are more likely to have greater stores of glycogen in the muscle, leading to a decreased frequency of dark cutting. Animals that are more likely to have a greater proportion of type IIX muscles fibers are those that are young or selected for increased muscling (McGilchrist et al., 2012).

Ecchymosis, or blood splash, occurs when an animal has elevated blood pressure prior to exsanguination (Food Science Australia, 1997). Stunning and preslaughter excitement cause an increase in blood pressure. However, if exsanguination occurs and releases the blood pressure immediately after stunning, the incidence of blood splash can be greatly reduced (Food Science Australia, 1997). Blood splash is unappealing to the consumer, and also increases concerns of microbial growth as blood is a vehicle for microorganisms (Hui, 2012).

Muscular steatosis, commonly known as calloused muscle, is a condition where muscle fibers are replaced by fat cells (Innes and Sanders, 1962). Steatosis is most often found in young, fed cattle (Innes and Sanders, 1962). The cause of steatosis is unknown, although it may be linked to strenuous muscle use, specifically in the muscles in use when an animal rears on its hind legs (Swatland, 1995). Symptoms are not typically present in the living animal, and it is discovered postmortem when ribbing, resulting in the name “calloused eye” (Swatland, 1995).

Loin Muscle Area and Size

Beginning with the NBQA-1995 there has been a continuous increase in both LM area and HCW (Moore et al., 2012). This has been a concern for the industry since Dr. Gary Smith discussed the effect of carcass size on steak thickness and cooking time in the Executive Summary of the first NBQA (National Cattlemen's Association, 1992). Steaks sold in food service are typically cut to weight, which could lead to customer and consumer dissatisfaction as the steak thickness decreases to accommodate larger sizes. A market update from the CAB Insider (Dykstra, 2016) looked at the relationships between HCW, LM area, and USDA YG. The optimal steak was identified as 12 oz. with a 1 inch thickness. For a carcass weight of 925-930 lb., only YG 4 carcasses had the “right size” LM area to deliver the steak they desire (Dykstra, 2016).

In contrast, Bass et al. (2009) investigated the relationship between LM area and the acceptability of portion sizes of 14 other muscles. The retail portion size of 7 of the muscles were not affected by LM areas outside of the commercially acceptable range (Bass et al., 2009). This study concluded that LM area was not an accurate indicator of additional muscles’ size. Another study used a retail setting with different categories of LM area to identify consumer trends (Sweeter et al., 2005). The size categories were: Average (80-90 cm^2) and Large (105-119 cm^2). Results of the study indicated that there is no optimal LM size for consumers; however, there is a consumer trend toward larger LM sizes (Sweeter et al., 2005)

Yield Grade and Breed Type

Beef carcass YGs were first developed based on a set of small-framed cattle that were primarily purebred Herefords (Lawrence, 2016). Contrarily, cattle today are a wide range of breed types and frame sizes, primarily medium and large. Whereas, currently 64% of fed cattle are black-hided due to a change in management practices to increase Angus influence in the herd (Dykstra, 2016), there has been a recent climb in the percentage of fed Holstein cattle. Lawrence et al. (2010) found that the USDA YG equation was a poor indicator of red meat yield of beef-type cattle, and is unable to estimate red meat yield of Holstein cattle.

While the YG equation calculates a linear relationship between LM area and HCW (USDA, 2016), Lawrence (2016) states that only a portion of the relationship is linear with the key component being quadratic. Lawrence goes on to state that the widespread use of instrument grading systems could easily allow the industry to implement a yield system based on more appropriate factors to achieve a more accurate YG.

Ossification and Dentition

Traditionally, USDA QG scoring utilized lean and skeletal maturity to obtain overall maturity of a beef carcass. Both overall maturity and marbling score are balanced to obtain the USDA QG (USDA, 2016). Recently, there has been an interest in using age obtained by dentition to stratify beef carcasses into relative maturity groups (Acheson et al., 2014; Semler et al., 2016). Dentition is currently used to segregate cattle that are 30 mo of age or greater to identify which specified risk materials (SRM) must be removed. Carcasses that are determined to be an overall maturity of "A" are typically between 9 and 30 mo of age (Tatum, 2007).

Loin muscle steaks were obtained from grain-fed animals found to be < 30 mo of age by dentition of varying skeletal maturity classes. Steaks were evaluated by a trained sensory panel and no differences were found between skeletal maturity classes. Marbling scores effectively identified eating quality differences between steaks. Therefore, for all grain-fed animals found to be < 30 mo of age by dentition, USDA QG could effectively be assigned based solely on marbling score (Acheson et al., 2014).

Semler et al. (2016) compared LM steaks from 2 dental age classes (< 30 mo and ≥ 30 mo). Within each dental age class, ossification maturity classes and marbling scores were identified. Within each dental age class, differences between maturity groups were not detected. However, more intense grassy and bloody/serumy flavors and decreased tenderness were associated with the dental age class ≥ 30 mo. This study concluded that ossification-based maturity did not accurately identify differences between age classifications (Semler et al., 2016).

CHAPTER III

MATERIALS AND METHODS

In-plant Data Collection

Before data collection, a correlation meeting was held to emphasize clarity and consistency of data collected between cooperating collaborators. In-plant cooler assessments were conducted at 30 federally inspected beef processing facilities, which were selected to represent the fed beef industry across the United States. 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 process cattle for 2 shifts a day.

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, VIA camera, or blotting paper), apparent breed type (native, dairy, or *Bos indicus*), sex class, country of origin, 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 humps (rhomboideus muscle, 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, PYG, percentage of KPH, and marbling score were evaluated by United States Department of Agriculture, Agricultural Marketing Service, Meat Grading and Certification Branch personnel (USDA, 2016). In plants that removed KPH before grading, the estimated KPH value used by the facility was denoted.

The factors that were collected using data sheets during cooler assessments were entered in a Microsoft Excel spreadsheet. The USDA (2016) relationship between marbling, maturity, and carcass quality grade was used to determine final QG (Figure 2). The QGs were reported according to the United States standards for grades of carcass beef (USDA, 2016). YGs were calculated using the factors collected: AFT, LM area, HCW, and KPH percentage. The equation was as follows: 2.50 + (2.50 x adjusted fat thickness, inches) + (0.20 x percent kidney, pelvic, and heart fat) + (0.0038 x hot carcass weight, pounds) – (0.32 x area ribeye, square inches) as stated in the official USDA standards (USDA, 2016).

Instrument Grading Data Collection

Instrument grading was performed according to the procedures outlined by the USDA in QAD Procedure 515 (USDA, 2015a). The calibrated camera was placed onto the LM between the 12^{th} and 13^{th} rib for each side of the carcass, and AFT, LM area, and marbling score were measured. USDA YG was calculated using the mean AFT, mean LM area, HCW, and mean KPH percentage and the USDA QG was calculated using the maximum marbling score from both sides. Carcass factors such as HCW, sex class, breed type, and advanced maturity, as well as any carcass defects (dark cutter, blood splash, calloused ribeye, etc.), were manually entered into the computer system by a plant employee.

The AMS agent may reject the carcass for instrument grading if it was ribbed on a bias, not split properly to allow for assessment of maturity, there were fat pulls, or it was ribbed in the incorrect location. Furthermore, the AMS Agent may make adjustments or override the grade entirely if the difference between the visually assessed characteristics and the instrument output exceeded the following thresholds: Marbling score (≥40 degrees), LM area (≥6.45 cm^2), fat thickness (≥0.51 cm), PYG (≥1.27 cm), final YG (≥0.50) (USDA, 2015a).

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 (January 2016-December 2016). 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.

Statistical Analysis

All analyses were performed using JMP Software (JMP®, Version 10. SAS Institute Inc., Cary, NC, 1989-2007.) and Microsoft Excel for Mac 2016. The Fit Y by X function was used for analysis of variance, 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.

CHAPTER IV

RESULTS AND DISCUSSION

In-plant

The mean USDA YG for this study was 3.1 (Table 2). Means for USDA YG were 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 3 shows the frequency distribution of carcasses by YG increments. The frequencies are YG 1 (9.6%), YG 2 (36.7%), YG 3 (39.2%), YG 4 (12.0%), and YG 5 (2.5%). Moore et al. (2012) reported YG frequencies from NBQA-2011 as YG 1 (12.4%), YG 2 (41.0%), YG 3 (36.3%), YG 4 (8.6%), and YG 5 (1.6%). The mean of USDA YG factors were AFT (1.4 cm), HCW (390.3 kg), LM area (89.5 cm^2) and KPH (1.9%) Table 2). When compared to NBQA-2011, mean AFT, HCW, and LM area all numerically increased. This increase in mean AFT and HCW contributed to the increase in frequency of USDA YG 3, 4, and 5. The most notable difference was a 16.3 kg increase in mean HCW from NBQA-2011 (Moore et al., 2012).

In 2015, 27.0% of federally inspected steers and heifers in the United States were presented for USDA YG (USDA, 2015b). Lawrence (2016) discussed the limitations of the USDA YG equation and its ability to predict red meat yield. The equation was developed in the 1950s from the typical cattle of that time period: small-frame, early maturing cattle (Lawrence, 2016). The range of cattle slaughtered today has become substantially more diverse and no longer can be represented by those small-frame cattle.

Beginning with NBQA-1995, there has been a continued increase in HCW. Bunting (2015) discussed potential reasons for carcasses continuing to get heavier, and processing facilities' labor costs and cattle availability are at the forefront. Heavier carcasses allow facilities to process the same number of cattle with the same amount of labor, and result in a greater amount of salable beef. For this reason, discounts for lighter than average carcasses are typically more severe than those slightly above average. Additionally, reduced cattle numbers limit the packers' ability to discount heavy-weight carcasses. While HCW is the trait that is most often economically discounted, LM area typically does not increase with HCW past 409.1 kg, and heavier carcasses result in an increased frequency of YG 4 and 5 (Stalcup, 2016). As HCW continues to increase, effect on steak thickness and consumer preferences becomes more crucial. Dykstra (2016) evaluated the relationship between USDA YG, HCW, and steak size in which the target steak was 2.54 cm thick, and weighed approximately 340.2 g. To achieve this steak 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 were found to generally prefer thicker steaks with a smaller surface area (Maples et al., 2016). The correlation constant between HCW and LM area ($r = 0.38$) indicates that while there is a positive relationship between the two traits, a larger HCW does not always result in a larger LM area.

Figure 5 demonstrates the frequency distribution by carcass weight groups. Lambert (1991) stated that a lost opportunity was outlier cattle and reported approximately 1.5% of carcasses above 409.1 kg. The current study observed almost half (44.1%) of carcasses surveyed to exceed 409 kg. McKenna et al. (2002) addressed concerns of discounts for carcasses above 431 kg. The frequency of carcasses exceeding 431 kg were NBQA-2000 (4.6%) (McKenna et al., 2002), NBQA-2005 (5.1%) (Garcia et al., 2008), NBQA-2011

(11.1%) (Moore et al., 2012), and NBQA-2016 (18.7%). However, Moore et al. (2012) reported in NBQA-2011 that carcasses were more frequently discounted that exceeded 454 kg. NBQA-2011 reported 3.7% of carcasses greater than 454 kg (Moore et al., 2012) and the current study shows 8.0% of carcasses. In response to the continued increase in HCW, the threshold for heavy-weight discounts has been set at 477.3 kg. Five percent of the carcasses surveyed in NBQA-2016 exceeded this threshold. Kay (2012) referenced increased carcass size as a method to combat reduced cattle numbers. Whereas total number of cattle slaughtered is the lowest in years, 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).

The least squares means for carcass traits within USDA YG are reported in Table 14. As USDA YG increased from YG 1 to YG 5, AFT and HCW increased ($P < 0.05$) and LM area decreased ($P < 0.05$). 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 significant difference was found between USDA QG, marbling score, and KPH percentage. Table 17 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 while 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 0.335 (Moore et al., 2012). This decrease in the correlation coefficient could be a result of external fat increasing more rapidly than marbling.

In this study, carcasses with KPH removed on the harvest floor and an estimated KPH value for grading purposes were differentiated from those where the USDA AMS agent reported the actual KPH percentage during grading. The least squares means between carcasses with estimated and actual KPH percentage are summarized in Table 16. Carcasses graded with actual KPH percentage possessed increased USDA YG, HCW, LM area, and KPH percentage, along with decreased AFT ($P < 0.05$). It is worth investigating the economic impact of calculating USDA YG using a standard KPH percentage.

The mean USDA QG in this study was Select^{96} (Table 2). 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 were Prime (3.8%), Choice (67.3%), Select (23.2%), and other (5.6%). The “other” category included Standard, Commercial, Utility, dark cutter, blood splash, hard bone, and calloused eye. NBQA-2011 frequency of USDA QG were Prime (2.1%), Choice (58.9%), Select (32.6%), Standard (5.1%), Commercial (0.9%), and Utility (0.3%) (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 the 1974 Market Consist (Abraham, 1977) reported 74% Choice, NBQA-2016 found the highest frequency of Choice carcasses (67.3%). The percentage of carcasses that graded Prime has increased numerically from NBQA-2005 (Garcia et al., 2008). The increase in dairy-type carcasses (+6.4 percentage points) 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.

The mean marbling score was (Small^{70}), lean maturity (A^{55}), skeletal maturity (A^{69}) and overall maturity (A^{64}; Table 2). Marbling score increased from previous studies, continuing the trend beginning with NBQA-1995. Lean maturity remained constant from NBQA-2011, however skeletal and overall maturity both numerically increased. Table 11 reports the characteristics of overall maturity where A maturity comprised 94.4% of carcasses surveyed and B maturity 3.9%. When compared with NBQA-2011, the percentage of A maturity carcasses increased from 92.8%, while the percentage of B maturity carcasses decreased from 6.0% (Moore et al., 2012).

The occurrence of marbling scores overall and within quality grades are reported in Table 7. For both Prime and Choice, the greatest proportion of carcasses were within the lowest third of the grade (low Prime = 83.1%, low Choice = 55.5%). However, the majority of carcasses qualifying for Select were in the top half of the grade (high Select = 61.2%). Table 12 reports the least squares means of carcass traits within quality grades. As USDA QG increased from Select to Prime, USDA YG, AFT, and HCW increased ($P < 0.05$). In contrast, LM area decreased as USDA QG increased from Select to Prime ($P < 0.05$). Throughout the previous NBQA, there has been a consistent trend of carcasses with higher USDA QG possessing numerically larger HCW and smaller LM areas.

Table 8 contains the distribution of carcasses by USDA QG and USDA YG. The largest percentage of carcasses (29.9%) were Choice YG 3. The frequency of carcasses that were Choice or Select, USDA YG 2 or 3 was 70.7%. This is decreased from NBQA-2011 (72.0%) (Moore et al., 2012). Garcia et al. (2008) reported non-conforming carcasses (those grading Standard or below and/or USDA YG 4 and 5) to account for 18.3% of all carcasses and Moore et al. (2012) found 15.6%, as compared to the 18.2% in the current study. This is consistent with the increased frequency of USDA YG 4 and 5 found in NBQA-2016.

Carcasses that were classified as dark cutters by the USDA AMS agent were recorded along with the percentage grade discount. The percentage discounts were as follows 20% (4.3%), 30% (1.2%), 40% (1.2%), 50% (16.67%), 60% (3.1%), 66% (47.5%), 70% (3.1%), 80% (1.9%), 90% (0.6%) and 100% (19.75). The overall presence of dark cutting was 1.9%, which was decreased numerically from NBQA-2011 (3.2%) (Moore et al., 2012). The least squares means of carcass traits separated by dark cutter and normal carcasses are presented in Table 24. Carcasses characterized as dark cutter demonstrated decreased mean USDA YG, AFT, HCW, and marbling score, along with increased LM area ($P < 0.05$). This is consistent with the findings of Janloo et al. (1998) who indicated dark cutting carcasses typically possess larger LM area, and decreased AFT and USDA YG. Similarly, McGilchrist et al. (2012) reported that carcasses with larger LM area typically had a lower incidence of dark cutting. Blood splash (0.2%) numerically decreased from NBQA-2011 (0.3%) (Moore et al., 2012).

The frequencies of estimated breed type were native (81.6%), dairy (16.3%), and *Bos indicus* (1.4%). When compared to NBQA-2011, there was a 6.4 percentage point increase in dairy-type and a 6.7 percentage point decrease in native cattle. This increase in dairy-type cattle is consistent with the results 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). 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). Table 22 reports the least squares means of carcass traits within estimated breed type. Native carcasses possessed the highest

USDA YG (3.1), AFT (1.5 cm), HCW (390.3 kg), and KPH (2.0%; $P < 0.05$). Dairy type carcasses had the highest QG (Choice^{17}), marbling score (Small^{86}), and the smallest AFT (0.9 cm) and LM area (80.6 cm^2; $P < 0.05$). Additionally, of the dairy carcasses surveyed, 8.0% graded USDA Prime. This is consistent with the findings from Albrecht et al. (2006) in which Holstein carcasses possessed a greater amount and finer flecks of marbling. *Bos indicus* carcasses had the lowest USDA YG (2.6), USDA QG (Select^{67}), KPH (1.0%), lean maturity (A^{49}), skeletal maturity (A^{59}), and overall maturity (A^{55}; $P < 0.05$).

Steers accounted for 66.5% and heifers composed 33.4% of carcasses surveyed. The numerical increase in frequency of steers from NBQA-2011 (63.7%) (Moore et al., 2012) is consistent with the increase in dairy steers. The least squares means within sex class are reported in Table 21. Steers possessed higher mean USDA QG, HCW, and KPH ($P < 0.05$). Heifers had increased mean AFT, LM area, marbling score, lean maturity, skeletal maturity, and overall maturity ($P < 0.05$). Table 23 reports the least squares means of carcass traits by estimated breed type and sex class. Native steers possessed the highest USDA YG (3.2), HCW (401.1 kg), LM area (91.2 cm^2), and KPH (2.1%; $P < 0.05$). Native heifers had the highest AFT at 1.6 cm and the lowest HCW at 374.0 kg ($P < 0.05$). Dairy steers had the lowest USDA YG (3.0), AFT (0.9 cm), LM area (80.5 cm^2) and the highest marbling score (Small^{86}; $P < 0.05$).

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 thirty mo by dentition or age records to qualify for A maturity. Carcasses that were identified as 30 mo or over by inspection ink on the vertebral column and/or a facility specific indicator were recorded as such. Table 25 summarizes the least squares means of carcass traits by dental age class.

Carcasses that were classified as under 30 months by dentition had increased USDA QG and LM area, and decreased AFT, HCW, marbling score, skeletal, and overall maturity ($P <$ 0.05). There was no difference between mean lean maturity scores between the dental age classes ($P > 0.05$). Research has found no difference in palatability between ossification groups within dental age classes (Acheson et al., 2014; Semler et al., 2016). Raines et al. (2008) found dentition to be a better predictor of actual age than USDA maturity score.

Instrument Grading

Instrument grading means are presented in Table 3. The mean USDA YG was 3.1. The YG distribution was YG 1 (9.5%), YG 2 (34.6%), YG 3 (38.8%), YG 4 (14.6%), YG 5 (2.5%) (Figure 16). The YG distribution from NBQA-2011 was YG 1 (15.7%), YG 2 (41.0%), YG 3 (33.8%), YG 4 (8.5%), and YG 5 (0.9%) (Gray et al., 2012). The mean YG factors were AFT (1.37 cm), LM area (88.9 cm^2), HCW (393.6 kg), and KPH (2.1 %; Table 3). The mean YG factors from NBQA-2011 are as follows: AFT (1.20 cm), LM area (88.45 cm^2), and HCW (371.28 kg) (Gray et al., 2012). Similar to the in-plant results, the increase in HCW was the most notable.

Gray et al. (2012) reported 95.1% of carcasses within the HCW 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 percentage point decrease in carcasses within the acceptable HCW range is consistent with the increase in mean HCW. Since the NBQA-2011, some USDA Certified Programs have updated their specifications to account for the increase in carcass size. The current acceptable HCW range is 272.2 kg to 477.3 kg. The present study recorded 95.0% of carcasses within this HCW range. Additionally, the LM area range required for some USDA

Certified Programs is 64.5 cm^2 to 103.2 cm^2. This study found 86.7% of carcasses to have a LM area within this range.

Least squares means for carcass traits by YG are reported in Table 15. As YG increased from YG 1 to YG 5, AFT, HCW, and marbling score increased ($P < 0.05$), and LM area decreased ($P < 0.05$). The changes in AFT, HCW, and LM area are to be expected as they are all factors in the USDA YG equation. Table 20 presents least squares means for carcass traits within fat thickness groups. Marbling score, YG, and HCW increased ($P < 0.05$) as fat thickness increased. The correlation between AFT and marbling score was 0.3642 as compared to NBQA-2011 (r = 0.35) (Gray et al., 2012). As previously seen, carcasses with a greater amount of AFT generally have amount of marbling (Jeremiah, 1996). Between fat thickness groups, LM area differed with 0.76 to 0.99 cm and 1.02 to 1.25 cm possessing the largest LM are (90.5 cm^2), and <0.51 cm with the smallest LM area (81.8 cm^2). Least squares means for carcass traits within HCW groups are reported in Table 18. As HCW increased, YG, HCW, LM area, and marbling score increased ($P < 0.05$).

The lowest percentage of YG 4 (11.08%) and 5 (1.47%) were observed in May of 2016 (Figure 10). NBQA-2011 also reported the lowest percentage of YG 4 (6.9%) and YG 5 (0.6%) in May of 2011 (Gray et al., 2012). The highest percentage of YG 4 (16.76%) and YG 5 (2.94%) occurred in January of 2016 which was consistent with January 2011 (YG 4: 9.1%, YG 5 1.1%) (Gray et al., 2012). When comparing the current frequency of YG 4 and YG 5 to NBQA-2011, there was a 9.5% increase in the month of January. Throughout the entirety of the year, frequency of YG 4 and YG 5 carcasses increased substantially from NBQA-2011 (+5.6 percentage points and +1.4 percentage points, respectively) (Gray et al., 2012).

Figure 7 presents seasonal changes in mean AFT by estimated breed type and sex class. Mean AFT reached its lowest point in May of 2016 (1.26 cm) and its maximum point in November 2016 (1.47 cm). Native heifers possessed the highest AFT ($P < 0.05$) through the entire year, while dairy steers and dairy heifers consistently had the lowest AFT ($P < 0.05$). Gray et al. (2012) also reported native heifers as having the highest AFT.

Figure 8 presents seasonal changes in mean LM area by month. Mean LM area was the lowest (86.69 cm^2) in June 2016, and reached its peak (91.38 cm^2) in November 2016. Native steers possessed the largest LM area throughout the year, reaching the highest point (93.99 cm^2) in November 2016. NBQA-2011 also found native steers to possess the largest LM area, with a peak (93.0 cm^2) in November 2010 (Gray et al., 2012). Mean HCW reached its lowest point (384.8 kg) in May 2016, and its highest point (406.5 kg) in October 2016 (Figure 9). 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 steers consistently had the heaviest HCW ($P < 0.05$) over all months, and reached their heaviest (422.3 kg) in November 2016. Gray et al. (2012) also found in NBQA-2011 that native steers had the heaviest HCW with the highest weight (395.4 kg) in November 2010. Dairy heifers possessed the lightest HCW and reached their lowest weight (345.1 kg) in September 2016.

The mean marbling score presented in Table 3 was Small^{75}. This is increased from the mean marbling score of Small^{49} from NBQA-2011 (Gray et al., 2012). Table 10 reports the distribution of USDA QG by day of the week graded. Cattle that are slaughtered on Friday and Saturday and graded the next week may have an increased chilling time compared to those slaughtered earlier in the week. In this study, the greatest percentage of carcasses that graded Prime were graded on Monday (Table 10). Carcasses chilled greater than 24 h were found to have a greater amount of marbling and higher quality grades (Calkins et al., 1980). Table 13 reports the least squares means for carcass traits within QG. As QG increased from "other" to Prime, mean AFT, KPH, and HCW increased ($P < 0.05$). The "other" category included Standard, Commercial, Utility, dark cutter, blood splash, and hard bone. Select carcasses possessed the largest mean LM area (90.8 cm^2) and "other" carcasses had the smallest LM area (78.9 cm^2).

Steers accounted for 65.9% and heifers 34.1% of all carcasses surveyed. The frequency of estimated breed type was native (91.9%), dairy (7.8%), and other (0.3%). The frequency of native steers, native heifers, dairy steers, and dairy heifers by month are presented in Figure 6. Native steers are consistently the most prevalent followed by native heifers.

Figure 11 shows the frequency distribution over QG over the course of the year. Prime reached its highest frequency (5.0%) in November 2016, and its lowest (3.0%) in August 2016. Choice was at its highest (72.6%) in February 2016, and its 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 are presented in Figure 12. Mean marbling score reached its peak ($Small^{80}$) in November 2016, and its lowest point ($Small^{67}$) in June 2016 (Figure 12). In NBQA-2011, Gray et al. (2012) reported the highest mean marbling score ($Small^{60}$) in March 2011. Dairy heifers possessed the highest marbling score

($P < 0.05$) throughout the year, with the highest mean marbling score (539.6) in September 2016.

Frequency of USDA certified programs by month is reported in Figure 13. February had the lowest frequency of carcasses that were certified (20.5%). Figure 14 presents the distribution of dark cutters by month. The highest incidence of dark cutters (0.74%) occurred in October 2016, and the lowest (0.33%) in January 2016. Gray et al. (2012) found the highest frequency (1.94%) in September 2011, and the lowest (0.38%) in March 2011. Scanga et al. (1998b) reported that temperature changes 1 to 3 d before slaughter create stress and increase the occurrence of dark cutters

Table 9 presents the distribution of carcasses by USDA QG and USDA YG. As in the in-plant assessment the greatest proportion of carcasses were Choice YG 3 (30.4%). The frequency of carcasses that were Choice or Select, YG 2 or 3 was 69.7%. Gray et al. (2012) found a similar percentage of carcasses (70.5%) within this range. Non-conforming carcasses are those that are Standard or below and/or YG 4 or 5. Of the instrumentally surveyed carcasses 18.6% were non-conforming, as compared to 18.2% for the in-plant surveyed carcasses.

In-plant and Instrument Grading Comparison

The in-plant assessment included a total of 9,106 carcasses, while the instrument grading encompassed 4,544,635 carcasses. Collecting carcass information through both methods allows comparison between the two, and gives credibility to previous NBQAs that utilized solely in-plant assessments. Table 4 reports the comparison of mean carcass traits between the in-plant and instrument grading data. Other traits that were consistent from the in-plant and instrument assessments were the percentage of carcasses that exceeded 477.3 kg (5%), the percentage of carcasses that were Choice or Select, YG 2 or 3 (70.7% and 69.7%, respectively), and the 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 AFT and marbling sore (r = 0.36) than the in-plant assessment (r = 0.24). Additionally, the in-plant results identified a higher frequency of dark cutters (1.9%) than the instrument grading dataset (0.49%). A possible reason for the decreased frequency of dark cutters in the instrument grading portion is that any defects must be manually logged into the computer system. The instrument grading assessment recorded a higher frequency of native (91.9%) and a lower frequency of dairy-type carcasses (7.8%) when compared to the in-plant results (81.6% and 16.3%, respectively). The estimated breed type is comparable to the manual entry of the dark cutters into the computer system. Furthermore, instrument grading data was 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%), and an increased frequency of YG 4 (+2.6%) when compared to the in-plant dataset (Figure 16). However, the frequency of YG between the two assessments is very consistent. When comparing the in-plant and instrument QG frequencies (Figure 15), the in-plant assessment found a slightly lower frequency of Choice carcasses (-4.1 percentage points) and a slightly higher frequency of Select carcasses (+1.5 percentage points). The similarity of results between the in-plant and instrument grading assessments gives confidence to the current and previous in-plant assessments and the increasing prevalence of instrument grading throughout the industry.

CHAPTER V

CONCLUSIONS

The fed steer and heifer beef industry is constantly changing. The NBQA allows a current benchmark to be established and progress to be evaluated. Through both in-plant cooler and instrument grading assessments, this iteration of the study found a numerical increase in mean USDA YG, USDA QG, AFT, HCW, LM area, and marbling score. Furthermore, an increase in dairy-type carcasses, 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, it is accompanied by an increase in size and fatness.

The instrument grading portion of the NBQA permitted the unique opportunity to evaluate trends in carcass traits over the course of the year. Mean AFT and HCW decreased to reach the lowest point in May 2016, and continued to increase through December 2016. Similarly, mean marbling score reached its peak in March 2016, declined to its lowest point in June 2016, and increased through the remainder of the study. These trends are remarkably comparable to those observed in NBQA-2011. As a result of this study, areas that require improvement are able to be targeted and a snapshot of the fed steer and heifer beef industry has been captured for 2016.

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APPENDIX A

TABLES

Table 1. 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. Means, standard deviations, and minimum and maximum values for USDA carcass grade traits.

Trait	*n*	Mean	SD	Minimum	Maximum
USDA yield grade	7,379	3.1	0.96	-0.7	9.3
USDA quality grade[1]	8,651	696	109.74	367	890
Adjusted fat thickness, cm	7,992	1.42	0.71	-1.02[4]	6.35
HCW, kg	8,493	390.3	46.51	195.9	616.4
LM area, cm^2	8,681	89.5	11.23	45.8	141.9
KPH, %	8,531	1.9	1.09	0	6.0
Marbling score[2]	8,660	470	103.91	200	970
Lean maturity[3]	8,741	155	23.63	110	490
Skeletal maturity[3]	8,061	169	34.48	110	480
Overall maturity[3]	8,730	164	27.15	115	445

[1]100 = Canner^{00}, 400 = Commercial^{00}, 600 = Select^{00}, and 800 = Prime^{00}.

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

[3]100 = A^{00} and 500 = E^{00}.

[4]Minimum value is less than 0 because of data conversion from a preliminary YG of less than 2.0.

Table 3. Instrument grading means, standard deviations, 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[2]	9.3
Fat thickness, cm	4,532,166	1.37	0.54	-2.0[2]	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}, 500 = Modest^{00}, 700 = Slightly abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

[2]Minimum value is less than 0 because of data conversion from a preliminary YG of less than 2.0.

Table 4. Means for USDA carcass grade traits between in-plant survey and instrument data.

Trait	In-Plant Survey (*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[1]	470	475

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

Table 5. Means for USDA carcass grade traits from NBQA-1991, NBQA-1995, NBQA-2000, NBQA-2005, NBQA-2011, and NBQA-2016.

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[1]	686	679	685	690	693	696
Adjusted fat thickness, cm	1.5	1.2	1.2	1.3	1.3	1.42
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[2]	424	406	423	432	440	470
Lean maturity[3]	163	154	165	157	154	155
Skeletal maturity[3]	175	163	167	168	162	169
Overall maturity[3]	169	160	166	164	159	164

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

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

[3]100 = A^{00} and 500 = E^{00}.

Table 6. 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}, 500 = Modest^{00}, 700 = Slightly abundant^{00}, and 900 = Abundant^{00} (USDA, 2016).

Table 7. 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: Standard, Commercial, Utility, dark cutter, blood splash, hard bone, and calloused ribeye.

Table 8. 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 9. 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.

Table 10. 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 11. Characteristics of overall maturity[1].

Overall maturity	*n*	Percentage of sample	Mean	SD	Minimum	Maximum
A	8,243	94.39	157.98	12.87	115	195
B	336	3.85	214.46	15.44	200	285
C	144	1.65	314.79	27.38	300	395
D	7	0.08	420.71	17.66	400	445

[1]100 = A^{00}, 200 = B^{00}, 300 = C^{00}, 400 =D^{00}, and 500 = E^{00}.

Table 12. 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)

Means within a row lacking a common superscript letter 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}, and 800 = Prime^{00}.

[3] 100 = Practically devoid^{00}, 300 = Slight^{00}, 500 = Modest^{00}, 700 = Slightly abundant^{00}, and 900 = Abundant^{00}.

[4] 100 = A^{00} and 500 = E^{00} (USDA, 2016).

Table 13. Instrument grading least squares means for carcass traits (SEM) within USDA quality grades.

Trait	USDA quality grade			
	Prime (n = 185,892)	Choice (n = 23,151,422)	Select (n = 954,662)	Other[1] (n = 98,271)
USDA yield grade	3.9[a] (0.00)	3.3[b] (0.00)	2.7[d] (0.00)	2.8[c] (0.00)
Fat thickness, cm	1.73[a] (0.00)	1.44[b] (0.00)	1.09[c] (0.00)	0.95[d] (0.00)
HCW, kg	407.2[a] (0.12)	397.1[b] (0.03)	379.9[c] (0.06)	377.5[d] (0.17)
LM area, cm^2	84.6[c] (0.03)	89.9[b] (0.01)	90.8[a] (0.01)	78.9[d] (0.09)
KPH, %	2.2[a] (0.00)	2.1[b] (0.00)	2.0[c] (0.00)	2.0[d] (0.00)
Marbling score[2]	757[a] (0.1)	497[b] (0.0)	366[c] (0.0)	340[d] (0.6)

Means within a row lacking a common superscript letter differ ($P < 0.05$).

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

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

Table 14. Least squares means for carcass traits (SEM) within USDA yield grades.

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

Means within a row lacking a common superscript letter differ ($P < 0.05$).

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

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

[3]100 = A^{00} and 500 = E^{00}.

Table 15. Instrument grading least squares means for carcass traits (SEM) within USDA yield grades.

Trait	USDA yield grade 1 (*n* = 417,848)	2 (*n* = 1,517,542)	3 (*n* = 1,703,769)	4 (*n* = 641,198)	5 (*n* = 110,785)
USDA yield grade	1.6[e]	2.6[d]	3.5[c]	4.4[b]	5.4[a]
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Fat thickness, cm	0.7[e]	1.1[d]	1.5[c]	2.0[b]	2.6[a]
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
HCW, kg	367.8[e]	382.8[d]	401.6[c]	421.0[b]	442.4[a]
	(0.07)	(0.04)	(0.03)	(0.06)	(0.14)
LM area, cm^2	102.0[a]	92.4[b]	86.4[c]	81.7[d]	77.2[e]
	(0.02)	(0.01)	(0.01)	(0.01)	(0.03)
KPH, %	1.7[d]	1.8[c]	1.9[b]	2.0[a]	2.0b
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Marbling score[1]	405[e]	450[d]	495[c]	532[b]	561[a]
	(0.1)	(0.1)	(0.1)	(0.1)	(0.4)

Means within a row lacking a common superscript letter differ ($P < 0.05$).

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

Table 16. Least squares means for carcass traits (SEM) of carcasses calculated with estimated and actual KPH percentage.

Trait	Estimated KPH[1] (*n* = 1,167)	Actual KPH (*n* = 6,212)
USDA yield grade	3.0[a]	3.1[b]
	(0.03)	(0.01)
Fat thickness, cm	1.4[a]	1.4[b]
	(0.02)	(0.01)
HCW, kg	385.7[a]	390.0[b]
	(1.08)	(0.58)
LM area, cm^2	88.2[a]	89.6[b]
	(0.26)	(0.14)
KPH, %	1.0[a]	2.4[b]
	(0.02)	(0.01)

Means within a row lacking a common superscript letter differ ($P < 0.05$).

[1]Estimated KPH is that is removed before grading and a standardized value is used.

Table 17. 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^{a} (0.4)	153^{b} (0.3)	152^{c} (0.3)	151^{c} (0.6)	153^{abc} (1.8)
Skeletal maturity[3]	159^{e} (2.6)	165^{de} (1.4)	167^{de} (0.6)	167^{cd} (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)

Means within a row lacking a common superscript letter differ ($P < 0.05$).

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

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

[3]100 = A^{00} and 500 = E^{00}.

Table 18. Instrument grading least squares means for carcass traits (SEM) within carcass weight groups.

Trait	Carcass weight group, kg						
	<272.6 (*n* = 31,444)	272.7 to 318.1 (*n* = 217,580)	318.2 to 363.5 (*n* = 854,704)	363.6 to 409.0 (*n* = 1,538,762)	409.1 to 454.4 (*n* = 1,254,920)	454.5 to 500 (*n* = 429,465)	>500 (*n* = 64,267)
USDA yield grade	2.2^{g}	2.5^{f}	2.8^{e}	3.1^{d}	3.4^{c}	3.7^{b}	4.1^{a}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Fat thickness, cm	0.7^{g}	1.0^{f}	1.2^{e}	1.3^{d}	1.5^{c}	1.7^{b}	1.9^{a}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
HCW, kg	253.6^{g}	301.7^{f}	344.5^{e}	387.0^{d}	429.2^{c}	471.2^{b}	517.7^{a}
	(0.12)	(0.03)	(0.01)	(0.01)	(0.01)	(0.02)	(0.07)
LM area, cm^2	71.0^{g}	78.3^{f}	83.7^{e}	88.1^{d}	92.3^{c}	96.4^{b}	99.5^{a}
	(0.07)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.05)
KPH, %	2.2^{a}	2.2^{b}	2.1^{c}	2.1^{d}	2.0^{e}	2.0^{f}	2.0^{g}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Marbling score[1]	399^{g}	437^{f}	459^{e}	474^{d}	485^{c}	501^{b}	522^{a}
	(0.7)	(0.2)	(0.1)	(0.1)	(0.1)	(0.2)	(0.5)

Means within a row lacking a common superscript letter differ ($P < 0.05$).

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

Table 19. 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} (0.05)	2.3^{k} (0.02)	2.5^{j} (0.02)	2.8^{i} (0.02)	3.0^{h} (0.01)	3.4^{g} (0.01)	3.7^{f} (0.02)	4.0^{e} (0.02)	4.2^{d} (0.04)	4.6^{c} (0.04)	4.8^{b} (0.08)	6.6^{a} (0.14)
USDA quality grade[1]	675^{f} (3.8)	691^{e} (1.9)	699^{d} (2.0)	704^{cd} (1.9)	709^{c} (1.8)	716^{b} (1.7)	718^{b} (2.7)	721^{b} (3.2)	719^{b} (5.6)	734^{a} (4.8)	746^{a} (5.6)	710^{bcd} (10.1)
Adjusted fat thickness, cm	0.2^{l} (0.01)	0.6^{k} (0.00)	0.9^{j} (0.00)	1.11^{i} (0.00)	1.4^{h} (0.00)	1.6^{g} (0.00)	1.9^{f} (0.00)	2.1^{e} (0.00)	2.4^{d} (0.00)	2.6^{c} (0.00)	2.9^{b} (0.01)	4.4^{a} (0.12)
HCW, kg	359.0^{a} (2.90)	371.2^{i} (1.50)	378.7^{h} (1.37)	383.7^{g} (1.27	393.1^{f} (1.28)	397.3^{e} (1.15)	400.2^{de} (1.68)	404.5^{cd} (2.05)	404.6^{bcd} (2.89)	411.7^{b} (3.04)	426.6^{a} (5.92)	411.0^{bc} (4.19)
LM area, cm^2	86.1^{e} (0.77)	87.1^{de} (0.43)	89.5^{bc} (0.39)	90.4^{b} (0.31)	91.3^{a} (0.30)	90.4^{b} (0.27)	90.3^{ab} (0.41)	89.3^{bc} (0.45)	90.0^{abc} (0.69)	88.2^{cd} (0.64)	90.5^{abc} (1.08)	86.1^{de} (1.07)
KPH, %	2.0^{abc} (0.07)	2.0^{abc} (0.04)	1.8^{def} (0.04)	2.0^{ab} (0.03)	2.0^{bc} (0.03)	1.9^{cde} (0.03)	1.8^{ef} (0.04)	2.1^{a} (0.05)	1.8^{fg} (0.08)	2.0^{abc} (0.08)	1.7^{bcdefg} (0.18)	1.6^{g} (0.11)
Marbling score[3]	407^{i} (6.1)	429^{h} (3.4)	446^{g} (3.3)	458^{f} (2.8)	468^{e} (2.8)	487^{d} (2.6)	498^{c} (3.9)	506^{bc} (4.5)	511^{bc} (6.7)	538^{a} (6.6)	543^{a} (16.2)	524^{ab} (10.5)
Lean maturity[4]	161^{a} (1.5)	154^{b} (0.6)	155^{b} (0.5)	154^{b} (0.5)	152^{cd} (0.4)	151de (0.4)	151de (0.5)	150^{e} (0.6)	150^{e} (0.8)	150de (1.0)	147^{e} (1.3)	155^{bc} (2.1)
Skeletal maturity[4]	164^{ef} (1.5)	162^{f} (0.8)	164^{ef} (0.8)	165^{e} (0.7)	166^{e} (0.8)	169^{cd} (0.8)	171^{bc}d (1.4)	172^{b} (1.5)	172^{bc}d (2.0)	173^{bc} (2.1)	164^{def} (2.5)	180^{a} (3.6)
Overall maturity[4]	163^{b} (1.2)	158^{f} (0.6)	160^{cdef} (0.6)	160^{cde} (0.5)	160^{df} (0.6)	161^{bce} (0.6)	162^{b} (1.0)	163^{b} (1.1)	162^{bcd} (1.5)	163^{bc} (1.5)	156^{ef} (1.6)	169^{a} (2.3)

Means within a row lacking a common superscript letter differ ($P < 0.05$).

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

Table 20. Instrument grading least squares means for carcass traits (SEM) within fat thickness groups.

Trait	Fat thickness, cm											
	<0.51 (*n* = 146,085)	0.51 to 0.74 (*n* = 410,416)	0.76 to 0.99 (*n* = 577,979)	1.02 to 1.25 (*n* = 860,635)	1.27 to 1.50 (*n* = 743,253)	1.52 to 1.75 (*n* = 717,301)	1.78 to 2.01 (*n* = 400,640)	2.03 to 2.26 (*n* = 283,289)	2.29 to 2.52 (*n* = 122,737)	2.52 to 2.77 (*n* = 69,508)	2.79 to 3.05 (*n* = 24,702)	>3.05 (*n* = 22,622)
USDA yield grade	1.9^{l} (0.00)	2.2^{k} (0.00)	2.5^{j} (0.00)	2.8^{i} (0.00)	3.2^{h} (0.00)	3.5^{g} (0.00)	3.9^{f} (0.00)	4.2^{e} (0.00)	4.6^{d} (0.00)	4.9^{c} (0.00)	5.2^{b} (0.00)	5.7^{a} (0.00)
Fat thickness, cm	0.37^{l} (0.00)	0.65^{k} (0.00)	0.89^{j} (0.00)	1.14^{i} (0.00)	1.39^{h} (0.00)	1.63^{g} (0.00)	1.89^{f} (0.00)	2.11^{e} (0.00)	2.36^{d} (0.00)	2.58^{c} (0.00)	2.90^{b} (0.00)	3.22^{a} (0.00)
HCW, kg	352.5^{k} (0.13)	367.5^{j} (0.08)	379.6^{i} (0.07)	388.1^{h} (0.06)	397.1^{g} (0.06)	403.2^{f} (0.07)	412.1^{e} (0.07)	415.0^{d} (0.11)	420.6^{c} (0.16)	424.7^{b} (0.23)	432.7^{a} (0.30)	432.4^{a} (0.43)
LM area, cm^2	81.5^{k} (0.06)	89.1^{c} (0.02)	90.5^{a} (0.02)	90.5a (0.01)	89.8^{b} (0.01)	88.9^{d} (0.01)	87.8^{e} (0.02)	87.1^{f} (0.02)	86.3^{g} (0.03)	85.6^{h} (0.04)	84.7^{i} (0.07)	84.8^{i} (0.07)
KPH, %	1.9^{j} (0.00)	1.9^{i} (0.00)	2.0^{h} (0.00)	2.1^{g} (0.00)	2.1^{f} (0.00)	2.2^{d} (0.00)	2.1^{e} (0.00)	2.2^{b} (0.00)	2.2^{b} (0.00)	2.3^{a} (0.00)	2.2^{c} (0.00)	2.1^{f} (0.01)
Marbling score[1]	376^{k} (0.3)	426^{j} (0.1)	443^{i} (0.1)	461^{h} (0.1)	482^{g} (0.1)	500^{f} (0.1)	518^{e} (0.2)	528^{d} (0.2)	541^{c} (0.3)	546^{b} (0.5)	558^{a} (0.8)	557^{a} (0.8)

Means within a row lacking a common superscript letter differ (*P* < 0.05).

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

Table 21. Least squares means for carcass traits (SEM) within sex class.

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

Means within a row lacking a common superscript letter differ ($P < 0.05$).

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

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

[3]100 = A^{00} and 500 = E^{00}.

Table 22. Least squares means for carcass traits (SEM) within estimated breed types.

Trait	Estimated breed type		
	Native (*n* = 6,057)	Dairy (*n* = 1,209)	*Bos indicus* (*n* = 60)
USDA yield grade	3.1[a] (0.01)	3.0[b] (0.03)	2.6[c] (0.18)
USDA quality grade[1]	705[b] (0.9)	717[a] (1.7)	667[c] (4.7)
Adjusted fat thickness, cm	1.5[a] (0.01)	0.9[c] (0.02)	1.2[b] (0.08)
HCW, kg	390.2[a] (0.57)	383.6[b] (1.06)	389.9[ab] (4.20)
LM area, cm^2	90.9[a] (0.13)	80.5[b] (0.26)	91.6[a] (1.06)
KPH, %	2.0[a] (0.01)	1.9[b] (0.04)	1.0[c] (0.12)
Marbling score[2]	469[b] (1.2)	486[a] (3.2)	382[c] (7.0)
Lean maturity[3]	153[b] (0.2)	156[b] (0.5)	149[a] (1.1)
Skeletal maturity[3]	169[a] (0.4)	165[b] (0.6)	159[b] (1.9)
Overall maturity[3]	162[a] (0.3)	161[a] (0.5)	155[b] (1.3)

Means within a row lacking a common superscript letter differ ($P < 0.05$).

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

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

[3]100 = A^{00} and 500 = E^{00}.

Table 23. Least squares means for carcass traits (SEM) of native steers, native heifers, and dairy steers.

Trait	Estimated breed type		
	Native Steers (n = 3,600)	Native Heifers (n = 2,416)	Dairy Steers (n = 1,167)
USDA yield grade	3.2[a]	3.1[b]	3.0[c]
	(0.02)	(0.02)	(0.03)
Adjusted fat	1.5[b]	1.6[a]	0.9[c]
thickness, cm	(0.01)	(0.01)	(0.02)
HCW, kg	401.1[a]	374.0[c]	384.2[b]
	(0.73)	(0.84)	(1.06)
LM area, cm^2	91.2[a]	90.6[b]	80.5[c]
	(0.16)	(0.20)	(0.26)
KPH, %	2.1[a]	1.9[b]	1.9[b]
	(0.01)	(0.02)	(0.04)
Marbling score[1]	463[c]	477[b]	486[a]
	(1.6)	(1.9)	(3.2)

Means within a row lacking a common superscript letter differ ($P < 0.05$).

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

Table 24. Least squares means for carcass traits (SEM) of dark cutter carcasses and normal carcasses[1].

Trait	Dark Cutter Carcass (*n* = 145)	Normal Carcass (*n* = 7,234)
USDA yield grade	2.8[a]	3.1[b]
	(0.09)	(0.01)
Fat thickness, cm	1.3[a]	1.4[b]
	(0.07)	(0.01)
HCW, kg	371.2[a]	390.7[b]
	(3.26)	(0.51)
LM area, cm^2	89.8[a]	89.5[b]
	(0.85)	(0.12)
KPH, %	1.8[a]	1.9[a]
	(0.08)	(0.01)
Marbling score[2]	433[a]	471[b]
	(8.0)	(1.1)

Means within a row lacking a common superscript letter differ ($P < 0.05$).

[1]Normal carcasses are those that are not dark cutters.

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

Table 25. Least squares means for carcass traits (SEM) of carcasses by dental age classification.

Trait	< 30 months (*n* = 7,293)	≥ 30 months (*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^{a} (1.1)	518^{b} (13.3)
Lean maturity[3]	153^{a} (0.1)	230^{a} (8.0)
Skeletal maturity[3]	168^{a} (0.3)	269^{b} (8.2)
Overall maturity[3]	161^{a} (0.2)	247^{b} (7.3)

Means within a row lacking a common superscript letter differ ($P < 0.05$).

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

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

[3]100 = A^{00} and 500 = E^{00}.

APPENDIX B

FIGURES

Car. ID/Sequence # ____________	L. MAT.	A	B	C	D	E			
Car. Wt. (lbs.)________	S. MAT.	A	B	C	D	E			
REA (in^2)___________	PYG	1	2	3	4	5			
Sex: S H B C	% KPH	0	1	2	3	4	5		
Native	MARB	PD	TR	SL	SM	MT	MD	SA	MA
Brahman	DARK C.	1/3	1/2	2/3	FULL	B. Spl.	Call.	Yellow Fat	
Dairy	PROGRAM	CAB	Top Ch.	NHTC	Grassfed	G______	In-House_______________		
USA CAN MEX		Angus Stamp	Organic	Natural	ASV	30 Month	Other__________________		

Figure 1. Example of data sheet used during data collection.

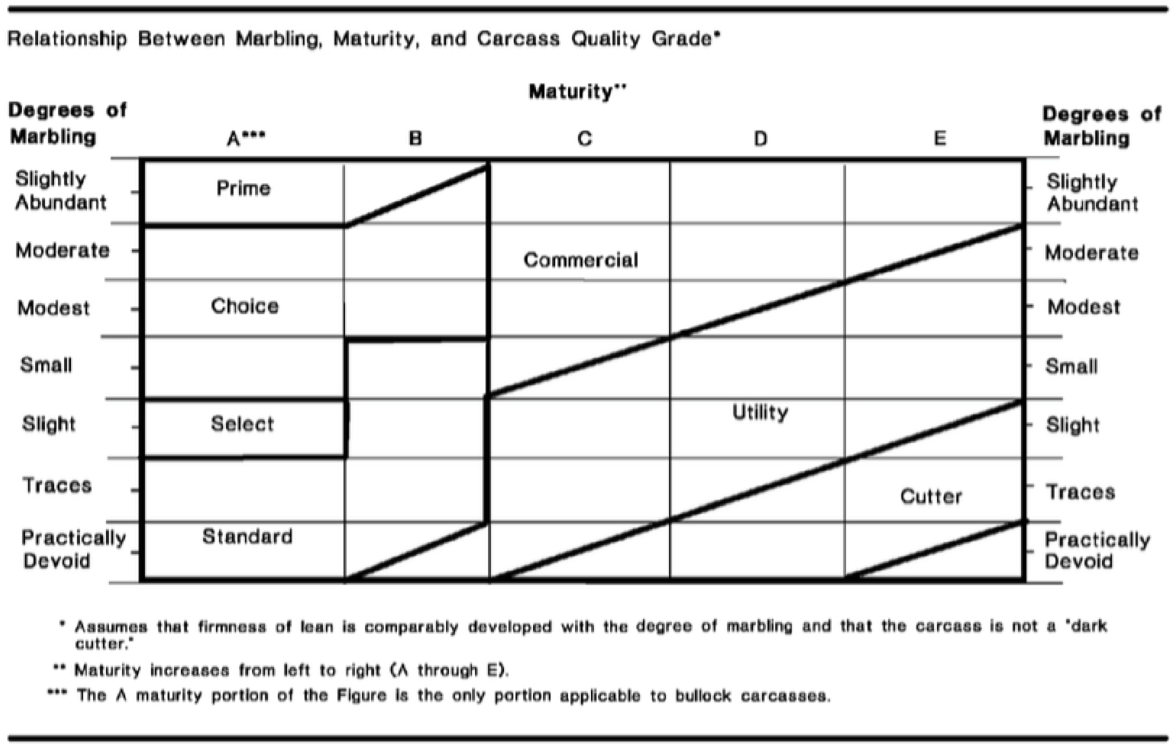

Figure 2. Relationship between marbling, maturity, and carcass quality grade chart (USDA, 2016).

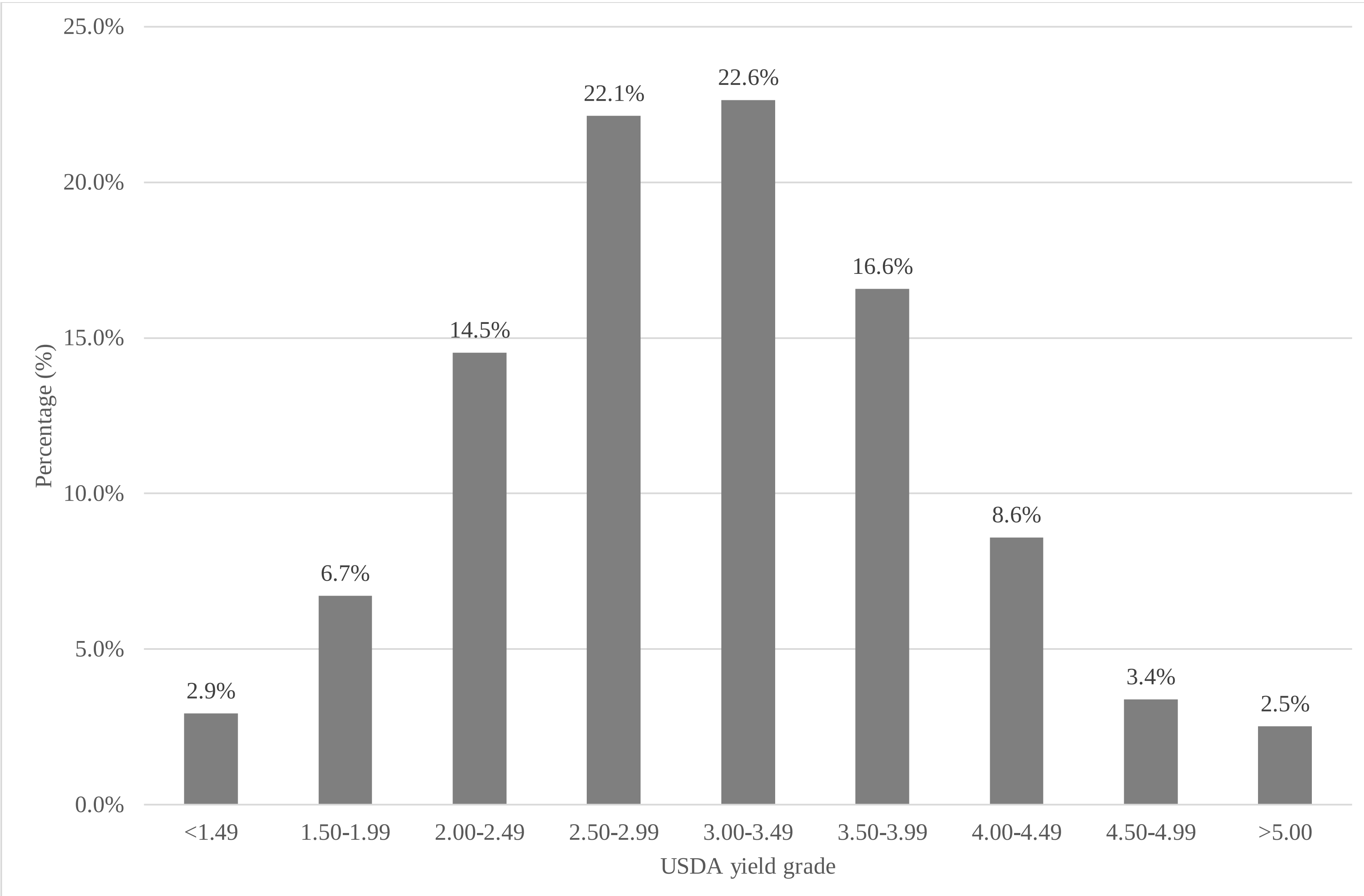

Figure 3. Frequency distribution of carcasses by one-half yield grade increments.

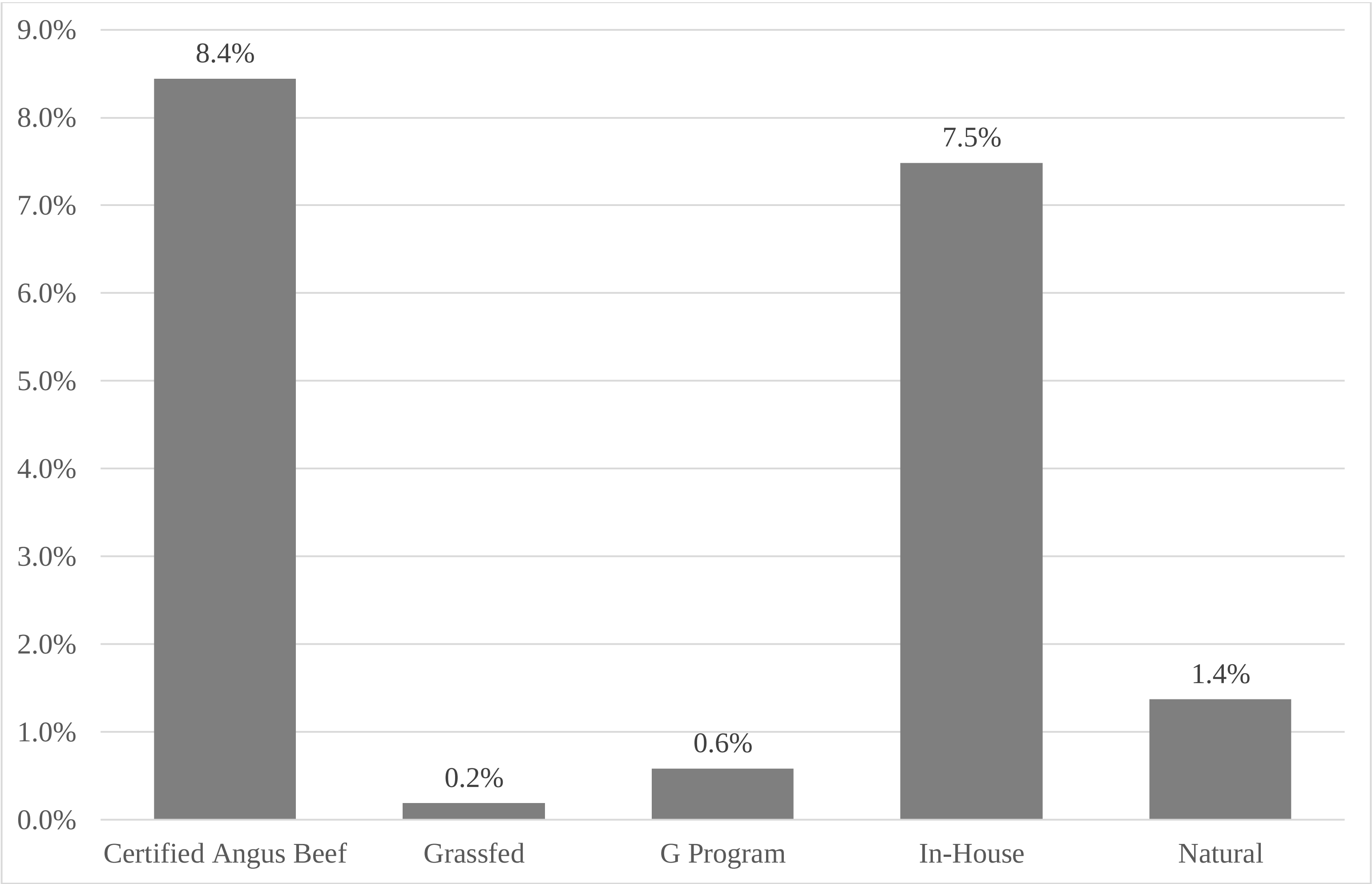

Figure 4. Frequency carcasses qualifying for certified programs[1].

[1]G Programs are USDA certified programs other than Certified Angus Beef

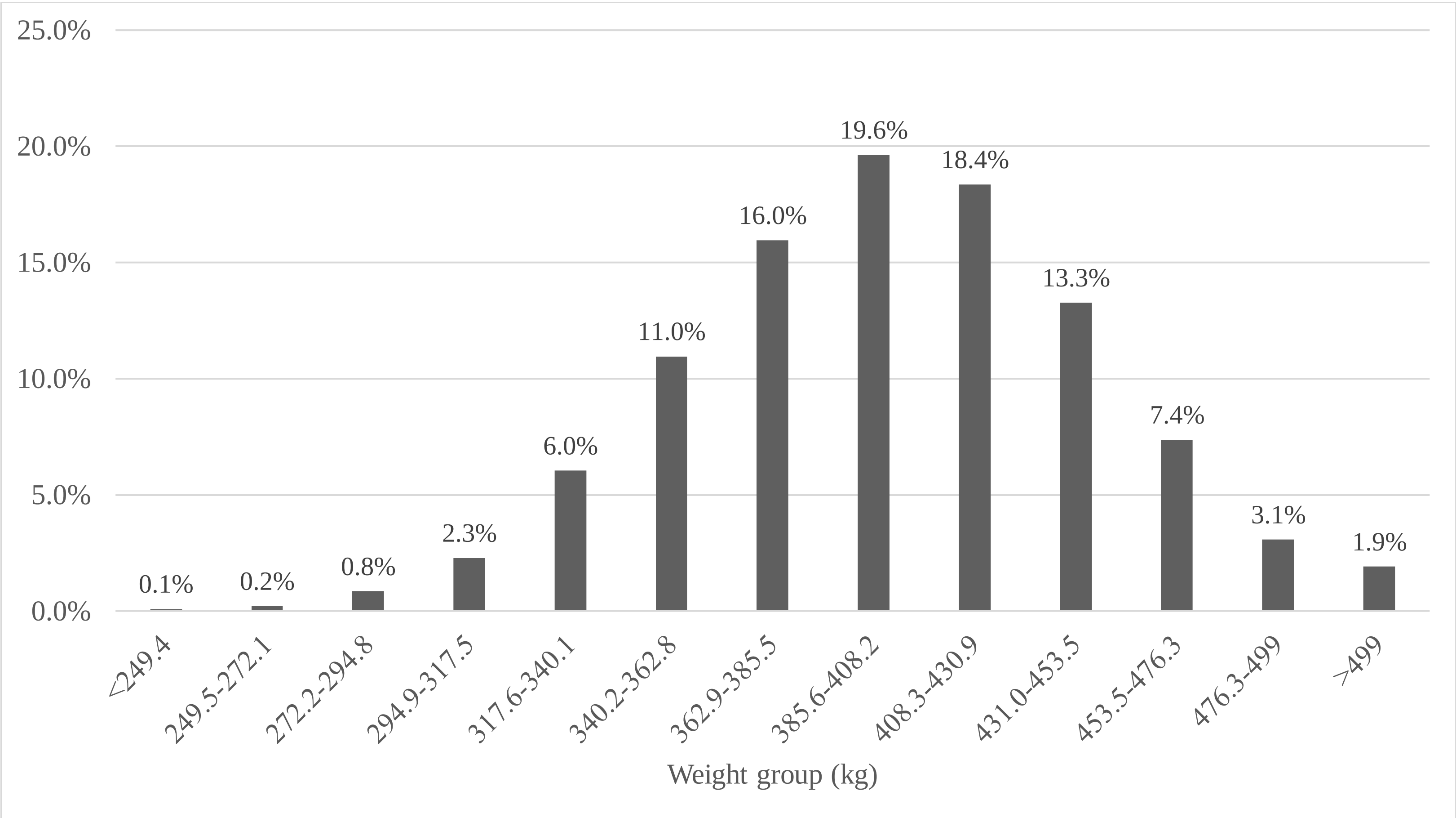

Figure 5. Frequency distribution by carcass weight groups.

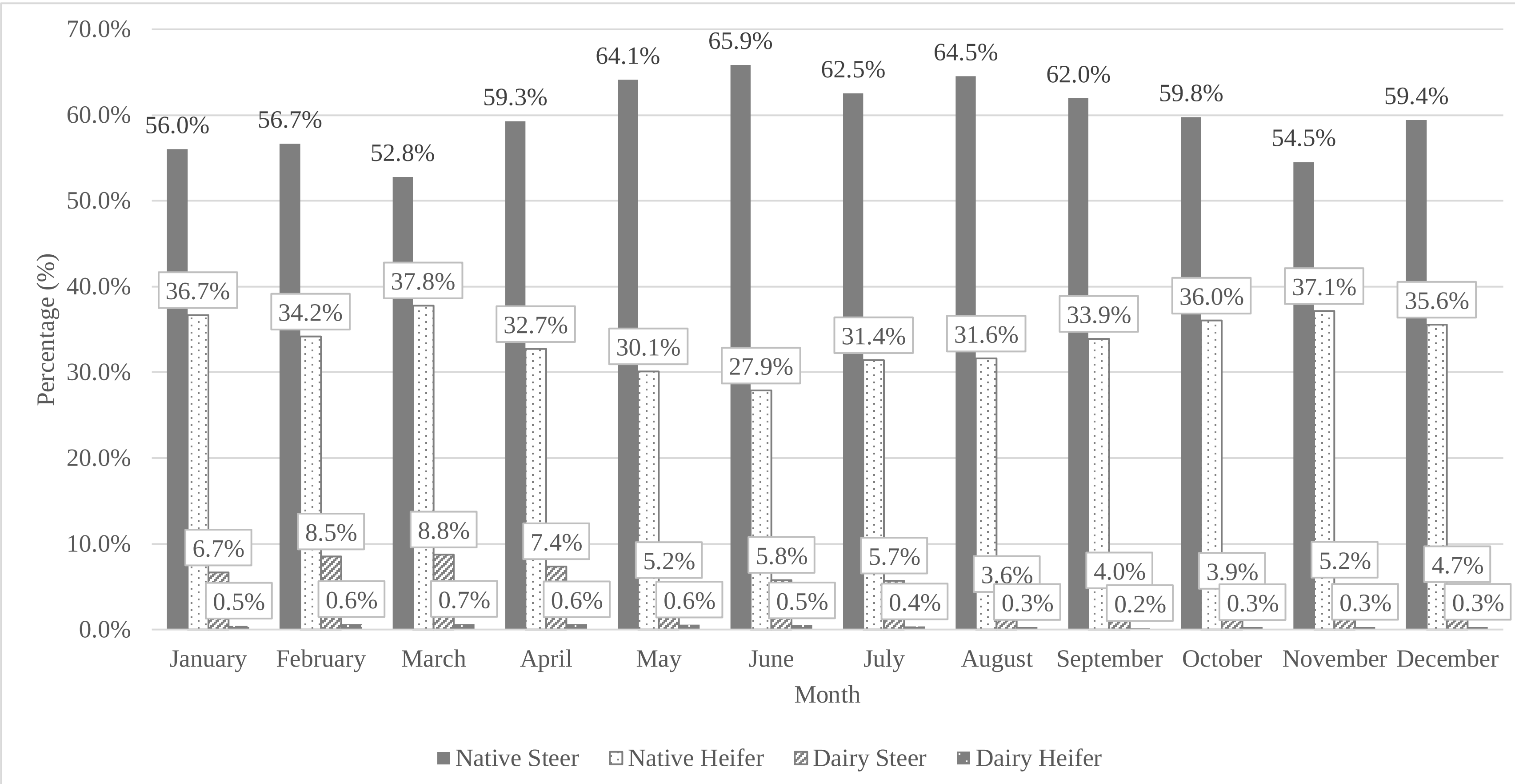

Figure 6. Frequency distribution of sex class by month.

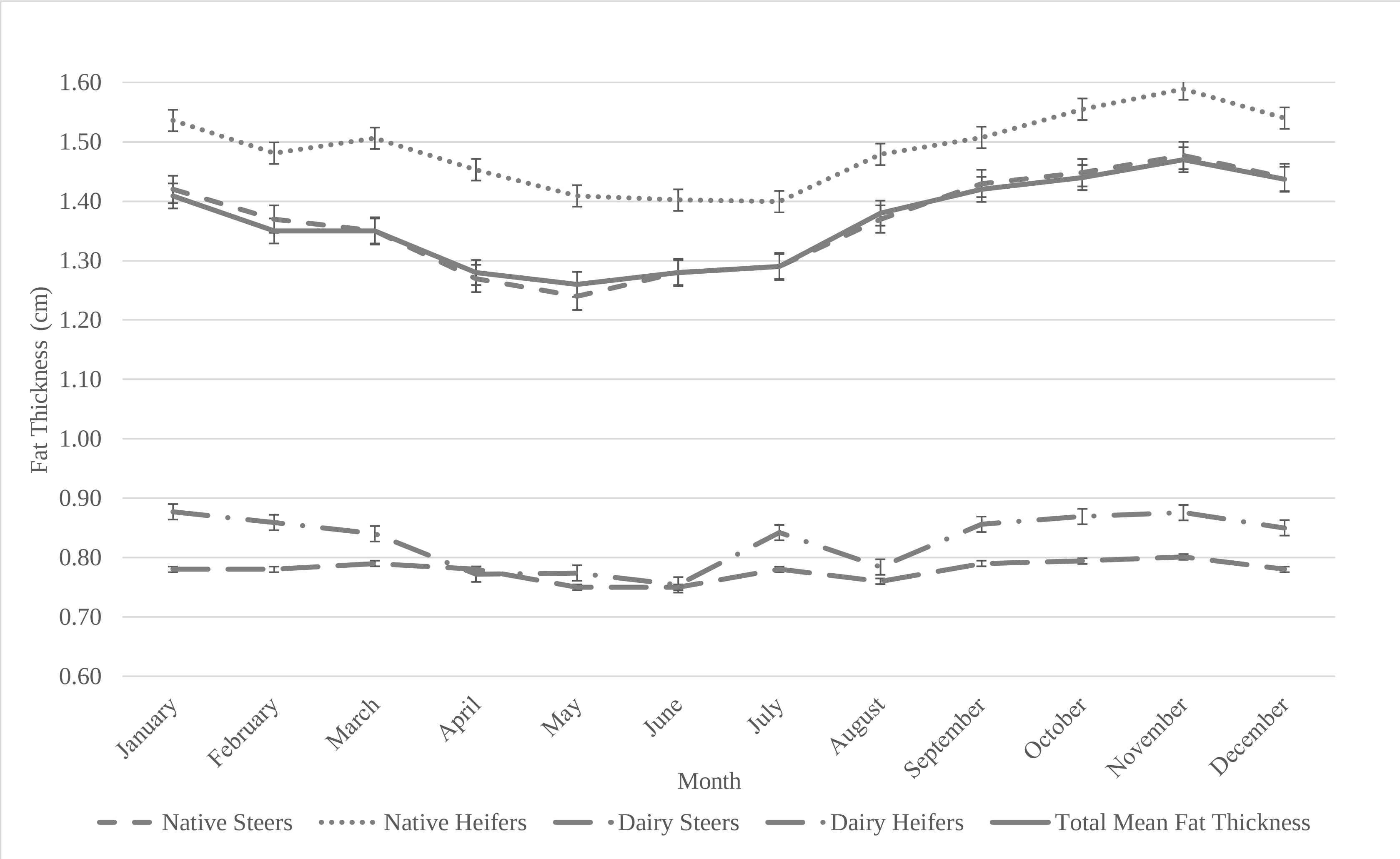

Figure 7. Seasonal changes in mean fat thickness[1] by month.
[1]Mean fat thickness is the mean for all observations.

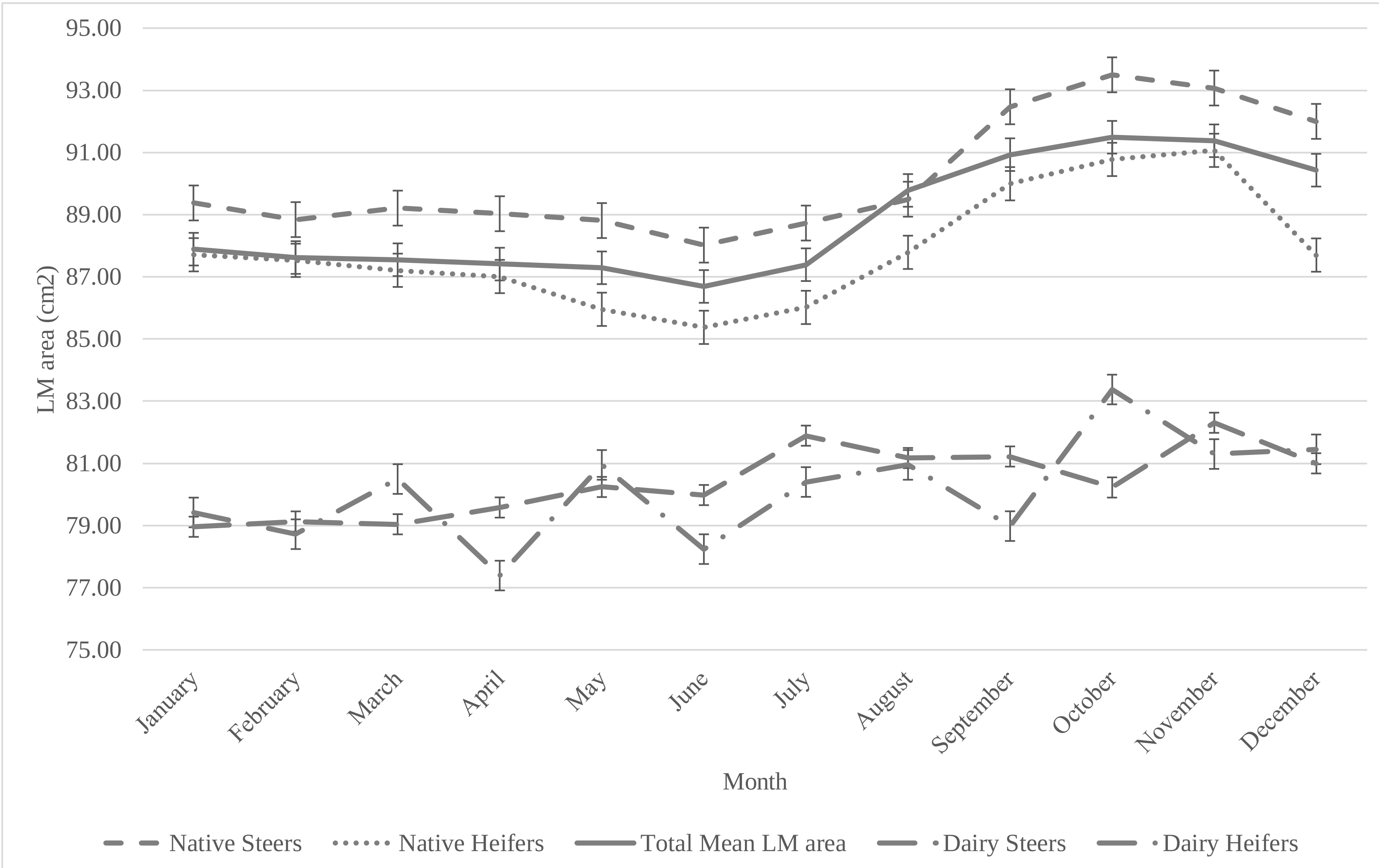

Figure 8. Seasonal changes in mean LM area by month.

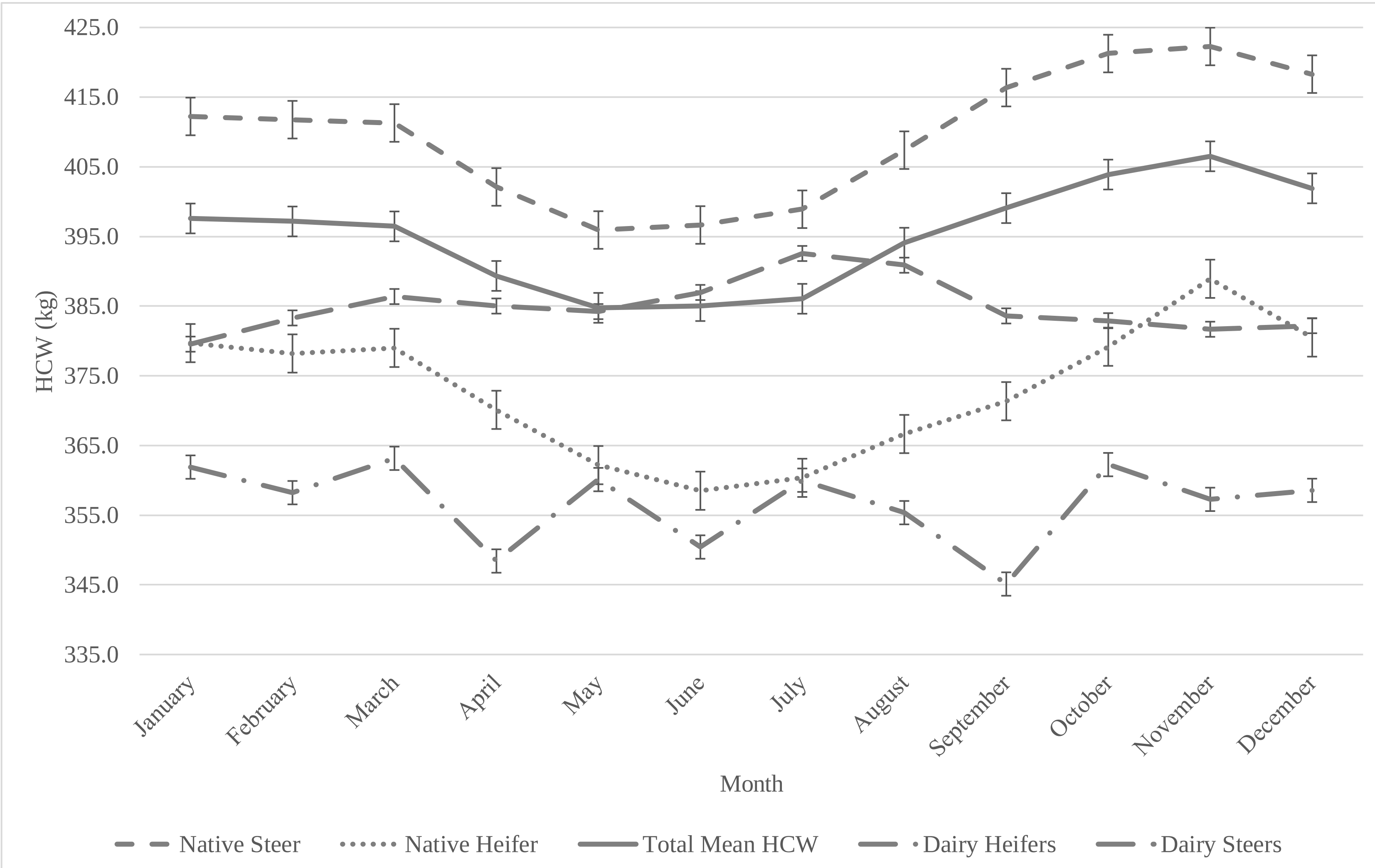

Figure 9. Seasonal changes in mean HCW by month.

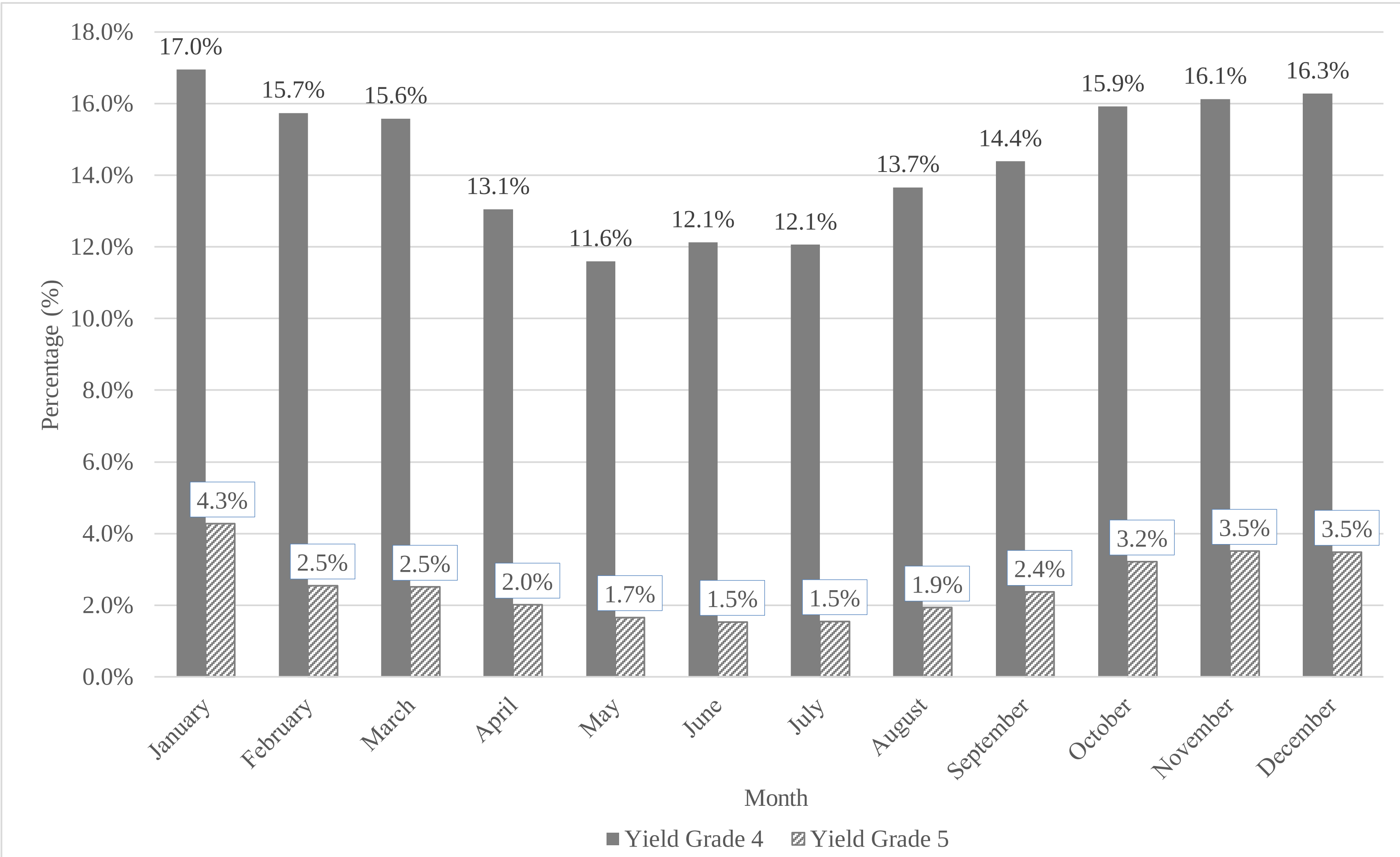

Figure 10. Frequency distribution of yield grade 4 and 5 carcasses by month.

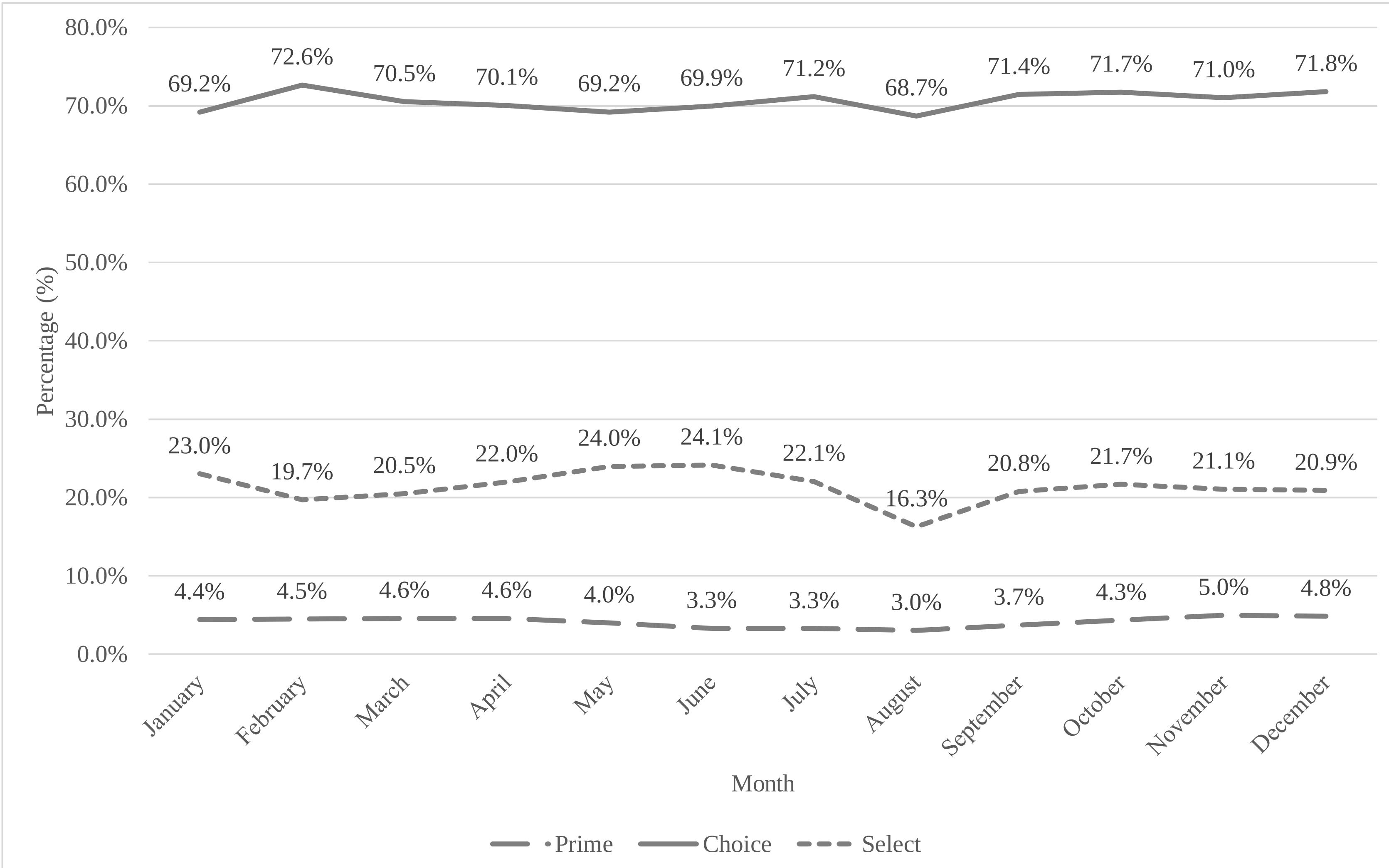

Figure 11. Frequency distribution of USDA quality grade by month.

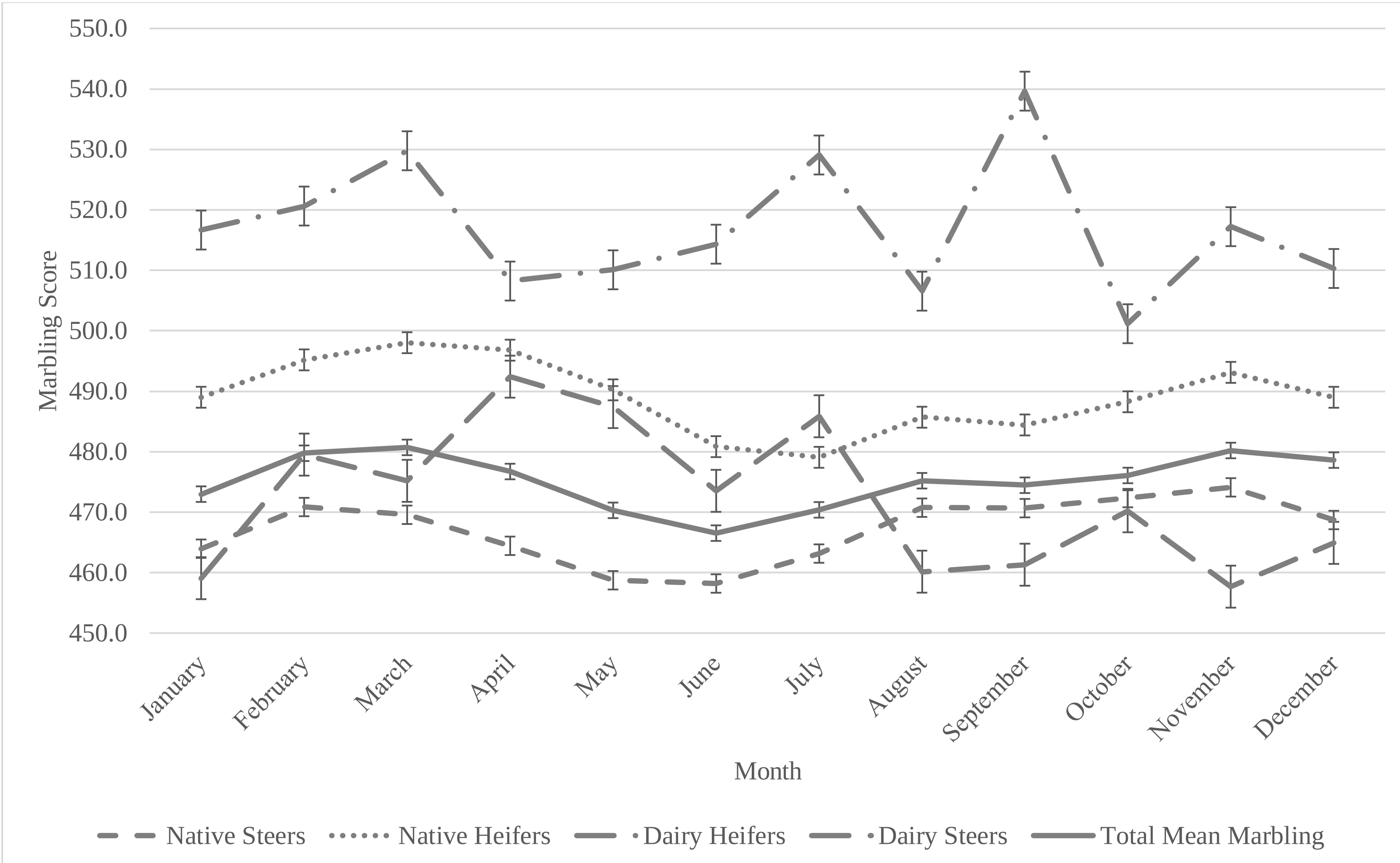

Figure 12. Seasonal changes in mean marbling scores[1,2] by month.

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

[2]Mean marbling score is the mean for all observations.

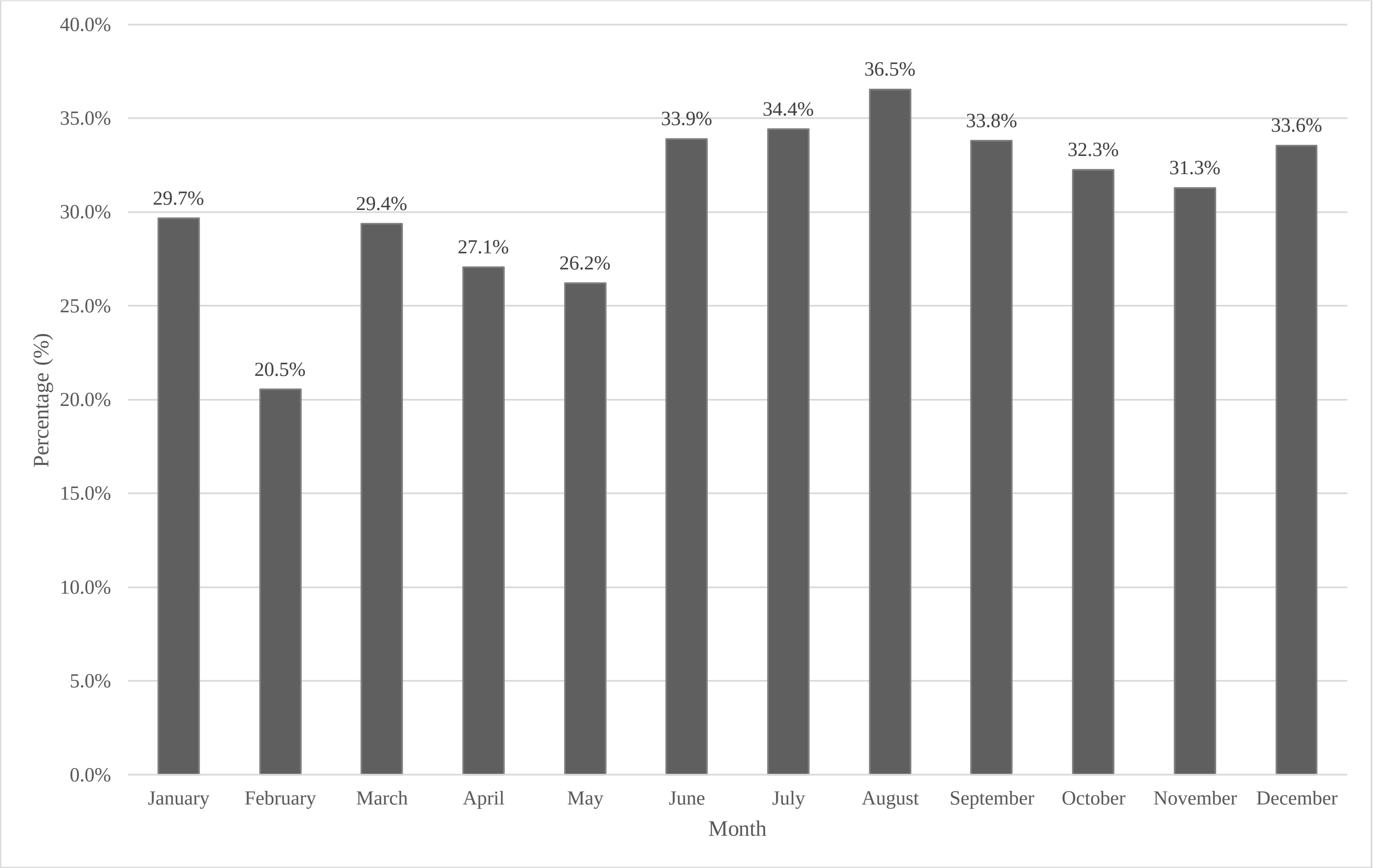

Figure 13. Frequency distribution of certified programs by month.

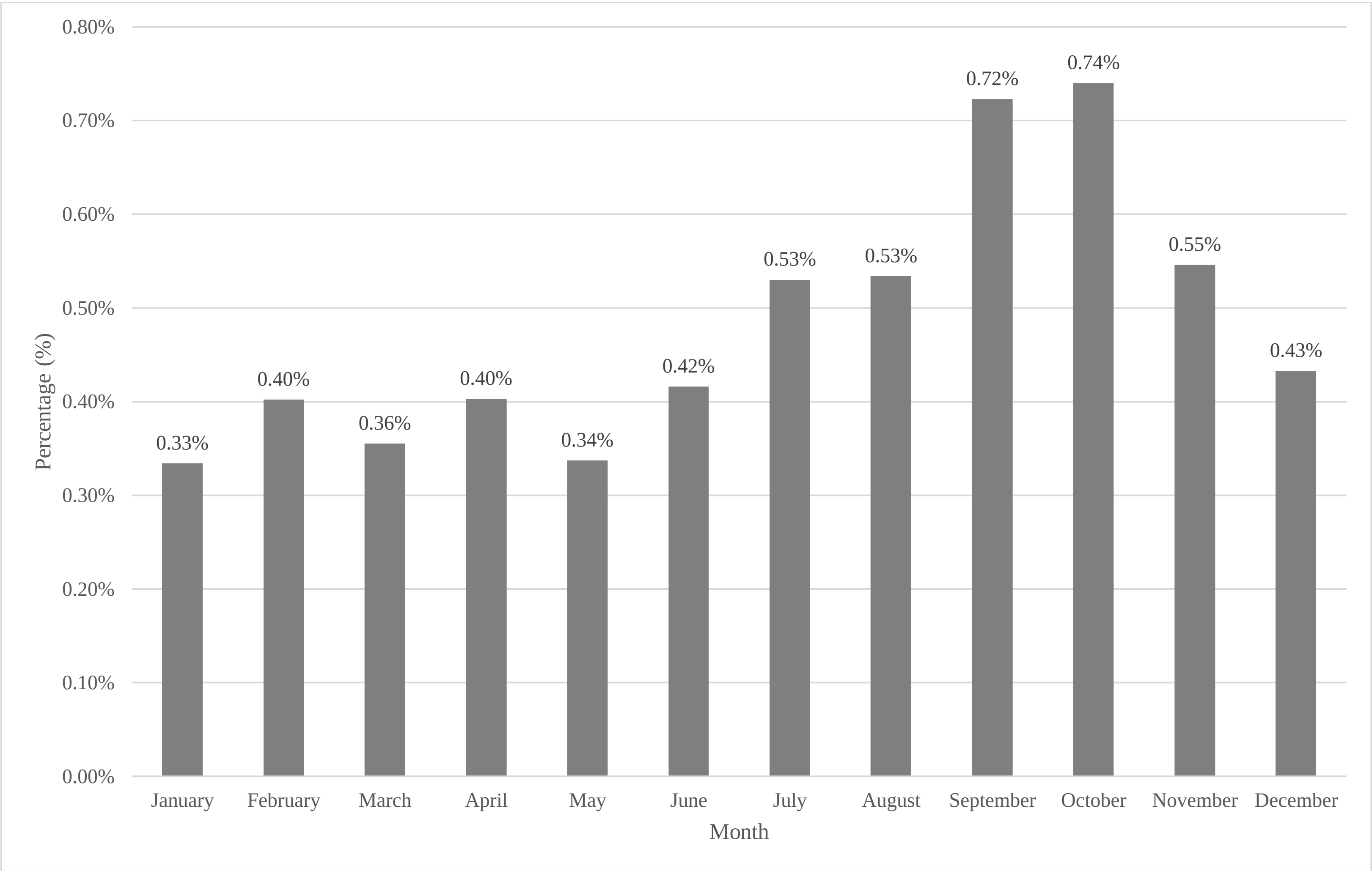

Figure 14. Frequency distribution of dark cutting carcasses by month.

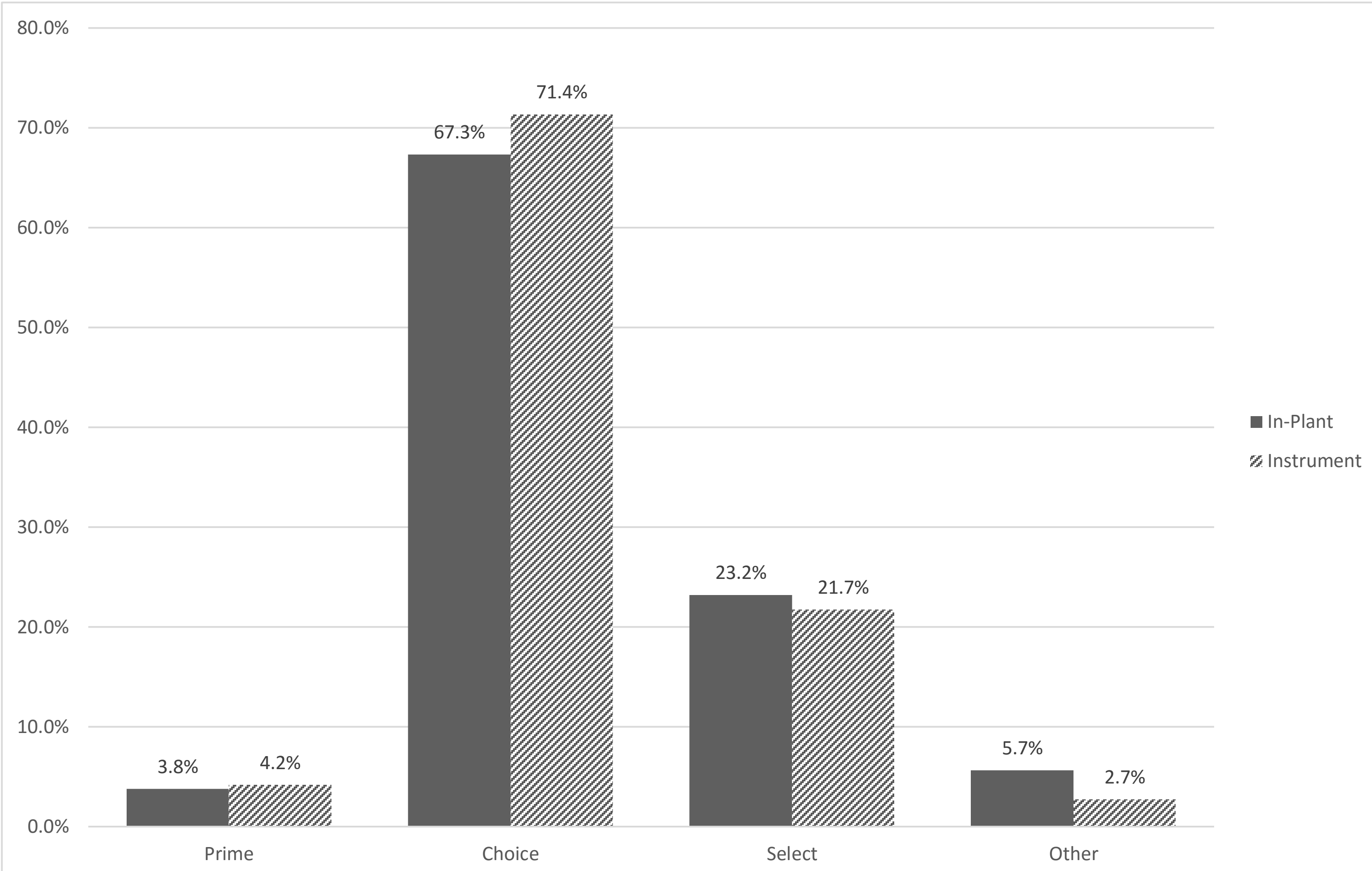

Figure 15. Instrument and in-plant comparison of frequency of USDA quality grades.

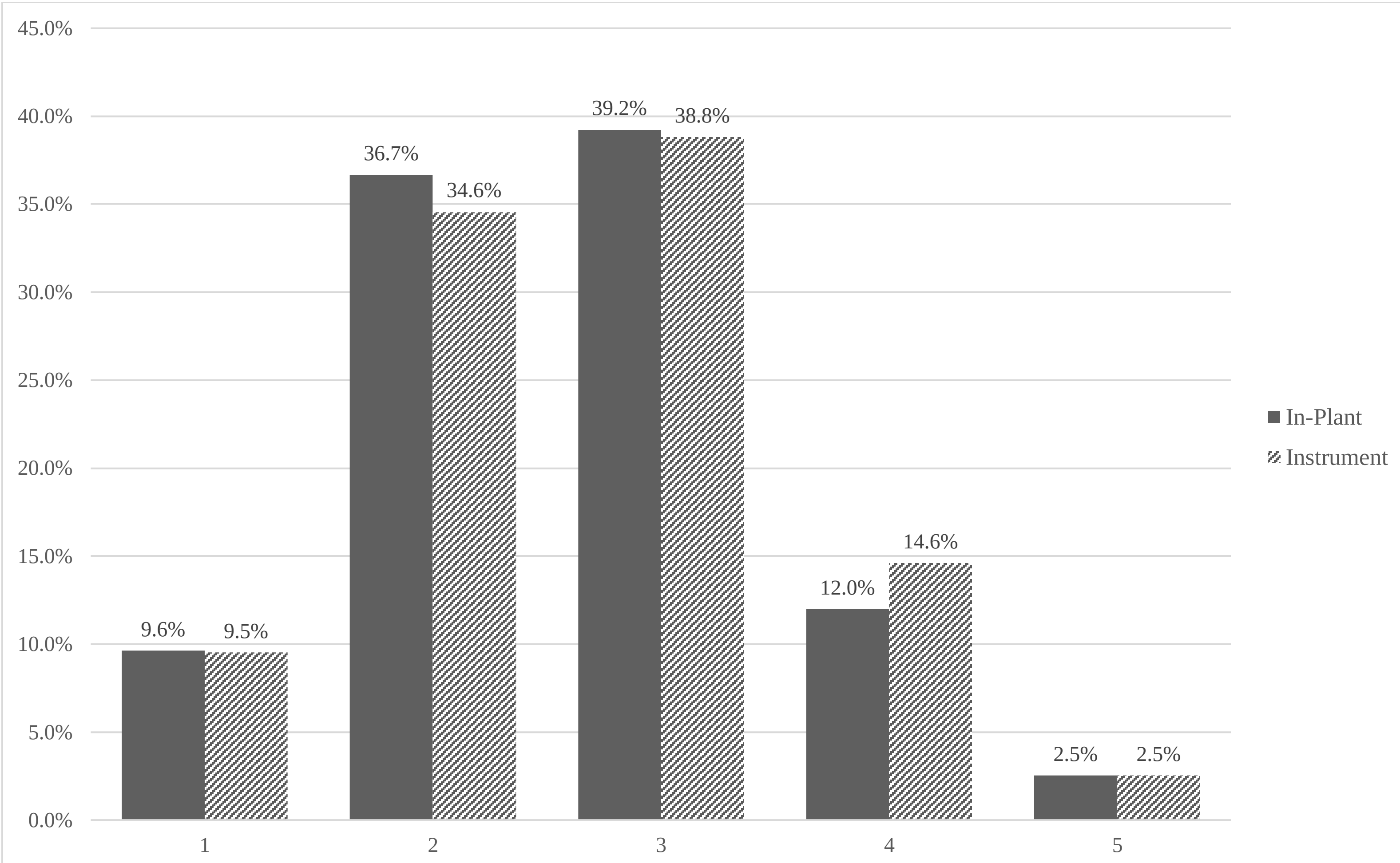

Figure 16. Instrument and in-plant comparison of frequency of USDA yield grades.