



Final Report

2022 National Lamb Quality Audit:

In-plant Survey of Carcass Characteristics Related to Quality and Value of Fed Lambs and Mutton

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EXECUTIVE SUMMARY

The National Lamb Quality Audit-2022 (NLQA) was conducted to assess carcass quality characteristics of the U.S. lamb industry. In-plant assessments were conducted in four of the largest U.S. commercial lamb processing facilities across six production days from June to September 2022. Both hide-on and hide-off carcasses (n=2,605) and chilled carcasses (n=2,464) were surveyed. On the harvest floor, trained auditors collected data on mud scores, breed type, presence of horns, sex, wool length, and physiological age indicator data. Additionally, hot carcass weight (HCW), measured fat thickness (MFT), and reported USDA yield and quality grades were collected in the cooler. Among the carcasses that were audited for sex (n= 1,605), 63.2 percent were wethers, 31.5 percent were ewes, and 5.3 percent were rams. Of the 2,604 carcasses evaluated, 40.2 percent were speckle-faced (white-face and black-face cross), 38.8 percent were white-faced, 18.3 percent were black-faced, 1.46 percent had natural characteristics, and 1.72 percent were hair sheep. The average mud score was 2.12, and the average wool length was 5.03 cm. Additionally, 87.1 percent of the 2,437 carcasses presented two break joints, 5.70 percent with one break joint, and 7.18 percent with no break joints. The average USDA yield grade (YG) was 2.71, and 68.5 percent graded choice, 22.6 percent graded prime, and 8.9 percent were not graded. The average HCW (n=2,464) was 39.9 kg, whereas the MFT was 0.97 cm. In the present study, USDA YG was different ($P < 0.0001$) between plants that implement either probing at the 12th and 13th rib or use camera grading systems versus solely visual. Plants that did not use a camera grading system or probe had a lower USDA-reported YG and an almost two-yield grade difference between the calculated YG measurement. The 2022 NLQA in-plant survey of carcass quality characteristics will provide a current benchmark for carcass characteristics of lamb processed in the U.S. The data from this study can help industry segments understand and develop strategic initiatives to improve the quality of fed lamb and mutton.

Introduction

The U.S. sheep industry is an integral part of the agricultural sector. Despite facing various challenges, it remains an essential source of income for many producers. The lamb and wool industries contribute more than two billion dollars annually to the U.S. economy (Shiflett, 2017). The U.S. sheep population has declined over the last eight decades (NASS, 2023) and has faced increased competition from imported lamb from Australia and New Zealand (USDA ERS, 2020). Imports, along with increased domestic production costs, have raised concerns about the future viability of the U.S. lamb industry. (USDA ERS, 2020). To improve the competitiveness of U.S. lamb, the U.S. sheep industry is attempting to identify areas of improvement. Part of this effort involves benchmarking and understanding trends across the U.S. lamb industry.

The value of a lamb carcass is primarily influenced by the weight of lean tissue. Historically, the USDA grading system and hot carcass weight (HCW) have been crucial to valuing U.S. lamb. However, 98 percent of all lambs are categorized as Choice (CH) or Prime (PR), and there currently is no price differential between CH and PR (ASI, 2015; USDA NASS,2023). Therefore, there is no incentive to producers to increase the number of PR carcasses they raise. Furthermore, considering the majority of lamb carcasses are classified as CH or PR, it may be necessary to reassess the quality grading system for lamb in order to discover potential attributes that would facilitate distinguishing consumer preference between these two grades. Quality audits provide a benchmark using the current quality characteristics of that particular industry (NBQA, 2016). The National Lamb Quality Audit (NLQA) benchmarks different sectors of the lamb industry to identify opportunities and challenges. Moreover, these audits allow the industry to identify quality shortfalls and non-conformance, which, when addressed, can lead to greater profitability and resiliency (NCBA, 2016). In the

past 30 years, three NLQAs have been completed in 1992, 2007, and 2015 (Hoffman et al., 2015). There was in-plant carcass data collection for the 1992 and 2007 NLQAs, but that was not a part of the 2015 NLQA. The lack of consistent and frequent quality audits may inhibit the ability of the lamb industry to effectively track progress and ensure consistent reporting metrics across the industry over time. Improving the consistency and quality of lamb products can help maintain consumer demand and serve as a critical aspect of the industry's overall success. As the U.S. lamb supply chain currently lacks data on carcass quality characteristics, specifically the data captured in processing settings, the objective of the 2022 NLQA Phase I was to conduct an in-plant audit of carcass characteristics related to the quality and value of fed lambs and mutton.

Materials and Methods

All animal observations and measurements in the study were non-invasive and observational in nature. Therefore, an exemption was filed and granted by the Colorado State University Institutional Animal Care and Use Committee.

General Overview

In-plant audits were conducted in four federally inspected lamb processing facilities. Together, these facilities represent approximately 80 percent of fed lamb slaughter numbers in the United States. The assessments at each of the participating plants in Texas, California, and Colorado took place between June 2022 and September 2022 and were completed by researchers from Colorado State University and the University of Idaho. Visual evaluation of carcasses for characteristics identified as quality concerns from previous quality audits Hoffman et al., 2015 were conducted pelt-on and pelt-off. These included characteristics such as breed type, mud score, sex, wool length, and ossification of joints. Each facility was audited for 50 percent of a

typical day's production.

Wool and Pelt Evaluation

After exsanguination but before the pelt puller, trained personnel evaluated the pelt-on carcasses for breed type, mud score, wool length, contamination (i.e., presence of polypropylene), sex, and horn status. Breed type (i.e., white face, black face, speckle, natural, and hair) was detected based on face coloring, wool color, and identifying color characteristics on legs. Animals with a combination of white and black markings were put into the speckle category, representing those who were a cross of white and black face sheep. The mud scoring system used in the current study was adapted from the NBQA audit (NBQA, 2016). Lambs were assigned a score from 1 to 5, as follows: 1) clean pelt, no presence of mud; 2) small lumps of mud in limited areas of legs, side, and underbelly; 3) small and large lumps of mud in large areas of legs, side, and underbelly; 4) small and large lumps in even larger areas along the hindquarter, stomach, and front shoulder; 5) lumps of manure continuously throughout the entire body of the animal that are deemed high risk of contamination to the hide-off carcass. Wool length was visually assessed, estimated, and categorized by length in increments from zero to 2.54 cm, 2.54 to 5.08 cm, 5.08 to 7.62 cm, 7.62 to 10.16 cm, and longer than 10.16 cm wool. Shorn (absence of wool) was grouped into the 0 to 2.54 cm category, and if a hair sheep was identified, it was categorized separately.

Pelt-off Carcass Evaluation

After pelts were removed, carcasses were evaluated for physiological maturity indicators, which included the number of permanent incisors and the presence of ossification in carpal joints. Other evaluations included condemnations from heads with wool and pelt contamination. Heads evaluated for condemnation or heads that were subject to trimming by USDA Food Safety Inspection Service (FSIS) inspectors or plant personnel were not assessed for the number of

permanent incisors. Physiological indicators were recorded by one trained evaluator between the pelt puller and the evisceration station. The number of permanent incisors was determined using USDA Agriculture Marketing Service (AMS) standards of classification: 1) lamb: an immature ovine (usually less than 14 months of age) that has not cut its first pair of permanent incisor teeth, 2) yearling: an ovine (usually between 1 and 2 years of age) that has cut its first pair of permanent incisors but not the second pair., 3) sheep or mutton: an ovine (usually greater than 24 months of age) that has cut its second pair of permanent incisor teeth. Broken teeth and any defect preventing normal mastication were also recorded. Carpal joints were evaluated in accordance with incisors on the same carcass and categorized as either zero, one, or two break or spool joints according to USDA-FSIS visual standards (NASS, 2023).

Carcass Assessment

Lamb, yearling mutton, and mutton carcasses were randomly selected throughout the cooler 12-24 hours postmortem to represent approximately 50 percent of a day's fabrication levels. Hot carcass weight (recorded from the plant's carcass tag) reported USDA Yield Grade (YG), and Quality (QG) (both stamped on the carcasses) were recorded from each carcass.

Trained personnel measured fat thickness (MFT) at the 12th rib with a metal probe and recorded whether the animal had any maturity indicators, dentition (shown on the carcass tag), or if the presence of ossified joints that were assessed by evaluating spool joints.

Personnel of the Meat Grading and Certification Branch, USDA-AMS evaluated each lamb carcass for skeletal maturity, degree of flank streaking, and adjusted fat thickness, and then assigned the carcass quality grade. Since most lamb carcasses were not split between the 12th and 13th rib, trained USDA graders either used a probe or visual indicators to assess the yield grade of the carcass, depending on the plant. In addition to USDA YG and QG assessment, two trained

evaluators probed each of the same respective carcasses at the 12th and 13th rib to record a measurement for fat thickness.

Statistical Analyses

All analyses were performed using JMP[®] Software (JMP Pro, SAS Inst. Inc., Cary, NC), Microsoft Excel[®] (Microsoft Corporation, Redmond, WA), and R[®] (R Core Team, 2021, v.4.1.2). Summary statistics, which included frequency distributions, means, standard deviations, and minimum and maximum values for all outcomes of interest (i.e., USDA YG, calculated YG, CW, and MFT.) were determined using the distribution and summary functions of JMP. Data was analyzed using the Type III ANOVA procedure, a pairwise comparison was analyzed for dependent variables by treatment using the least squared means procedure in the 'lsmeans' package, of R[®] with the Tukey HSD adjustment. Dependent variables were YG, calculated YG, HCW, and MFT. Significance was determined if P-value ≤ 0.05 .

Results

Wool and Pelt-on Evaluation

The sex classification of carcasses included in the study (n=1,605) is reported in Table 1. Not all carcasses were captured for sex on the harvest floor due to space limitations at some of the plants audited. Of the carcasses evaluated, 63 percent (n = 1,012) were castrated males (wethers), 32 percent (n = 506) were females (ewes), and five percent (n= 87) were intact males (rams). A total of 2,604 carcasses were observed and categorized for mud score. Thirty-five percent (n = 906) scored a one, 35 percent (n = 901) scored a two, 17 percent (n = 454) scored a three, 10 percent (n = 259) were assigned a four, and three percent (n = 84) were assigned a five-mud score (Table 2). The wool length was observed for 2,604 carcasses of which 35 percent (n = 905) were shorn or had wool less than 2.54 cm, 31 percent (n= 817) presented with 2.54 to 5.08 cm wool, 27 percent (n = 703)

presented with 5.08 to 7.62 cm wool, five percent (n =135) 7.62 to 10.16 cm wool, 0.42 percent (n =11) had more than 10.62 cm of wool present, and one percent (n =33) were hair sheep (Table 3). There was a low correlation between mud score and wool length ($R^2 = 0.22$, $P \leq 0.001$; Figure 2). Breed type was also evaluated and recorded for 2,604 pelt-on carcasses. Forty percent (n = 1,046) were speckles (cross between black face and white face breeds), 39 percent (n = 1,010) were characterized as white-face, 18 percent (n = 477) were black-face, one percent (n =38) were natural/blue, and one percent (n =33) were hair sheep (Table 4).

Pelt-Off Carcass Evaluation

A total of n = 2,437 carcasses were evaluated and observed for the presence of spool joint(s) as an indicator of maturity. Eighty-seven percent (n = 2,123) presented with zero spool joints (considered lamb), 6 percent (n = 139) presented with one spool joint (lamb or yearling mutton), and 7 percent (n =175) presented with two spool joints (considered mutton) (Table 5). Dentition was observed and recorded as an indicator of maturity on 2,437 carcasses. Sixty-eight percent (n = 1,656) presented with zero permanent incisors (considered lamb), 10 percent (n = 251) presented with one permanent incisor (considered lamb), 19 percent (n = 468) presented with two permanent incisors (considered yearling mutton), 0.82 percent (n = 20) presented with three permanent incisors (considered yearling mutton), 0.95 percent (n = 23) presented with four permanent incisors (considered mutton), 0.41 percent (n = 10) presented with broken teeth, and 0.37 percent (n = 9) presented with heads that were condemned (no evaluation possible; Table 6). There was a statistically significant, but minor correlation between dentition and spool joints ($R^2 = 0.31$, $P \leq 0.001$; Figure 3).

Carcass Assessment

Carcass characteristics (n = 2,464) of lamb and mutton carcasses across all plants (A, B, C,

D) are presented in Table 7. Overall, the mean USDA YG was 2.71 ± 0.97 (Mean \pm SD), the mean USDA QG was CH, the mean HCW was 39.9 ± 9.08 kg., and the mean MFT was 0.97 ± 0.38 cm. The distribution of carcasses stratified by USDA QG and YG are presented in Table 8. There were differences in QG between YG 1 and 5, with only 4.8% of YG being graded as PR whereas 33.6% of YG 1 was graded as CH. To better understand the data, plants were grouped into two categories, i.e., those that used either a probe or camera grading system (plants A and C; Group 1) and those that used visual assessment (plants B and D; Group 2) to yield grade carcasses (Table 9). When grouped by the measurement system, Group 1 (i.e., probed or camera grading system) had a lower USDA YG (2.64 ± 0.90) compared to Group 2 (i.e., visual assessment) at 2.79 ± 1.05 ($P=0.001$). Additionally, when comparing the two groups based on calculated YG, there was evidence that the two groups differed ($P \leq 0.001$). For HCW, group 1 (38.00 ± 0.26 kg) differed from group 2 (41.40 ± 0.24 kg; $P \leq 0.001$). Similarly the fat thickness also differed ($P \leq 0.001$) between the groups with group 1 having 0.86 ± 0.01 cm and group 2 having 1.06 ± 0.01 cm. Table 10 shows the difference between USDA-reported YG and calculated YG measurements for each group. Group 1 (plants A and C), which utilized probe measurements or camera grading, showed a difference between the USDA YG (2.79 ± 1.05) versus the calculated YG (3.71 ± 0.05 ; $P \leq 0.001$). However, group 2 (plants B and D), which only used visual assessments, showed larger differences compared to group 1 with USDA YG (2.64 ± 0.90) and measured YG (4.51 ± 0.04) ($P \leq 0.001$).

Discussion

Sex

In the current study, most lamb carcasses were wethers and ewes, and less than six percent of the sample population were rams. Ram lambs are seldom harvested due to sexual

maturation that causes unpleasant meat characteristics. (Roisset-Akrim et al., 1997). Castration has been a widely used management practice in the U.S. While intact males grow more rapidly and are higher yielding, they also have more undesirable odors and flavors and lower tenderness (Siedman et al.,1982). Meat from rams also results in resistance from packers as the price differences between QG and retail acceptability are much lower (Siedman et al.,1982). A recent consumer study reported that meat from castrated animals scored higher in overall liking, flavor liking, and tenderness liking (Gravador et al., 2018). The low proportion of rams in the present study is expected with low consumer acceptance of ram meat. Due to low consumer acceptance of lamb, keeping the number of rams in the plant to a minimum is important to maintain consumer confidence and satisfaction with high-quality lamb products.

Wool and Pelt-On Evaluation

Mud scoring is still very important to characterize as mud and manure on fleeces and pelts of lambs processed is the largest source of carcass contamination (Bell and Hathaway, 1996). In the present study, 70 percent of carcasses scored a 1 or 2, indicating clean pelt conditions with low possibility of contamination. Pelt condition is based on several different environmental factors. Pelt encumbered with mud and manure can provide information on whether the sheep have been in wet or muddy conditions prior to shipment (Marcone et al., 2022). Mud-laden pelts also raise concern for animal welfare. It has been mentioned in cattle feedlots that cattle with excess mud on their hide reduces weight gain (Grandin, 2016). Additionally, increased mud on the pelt adds to the animal's weight and impacts the dressing percentage. A cattle study with 12,000 head indicated a significant reduction in dressing percentage by 0.90 percent from animals that scored 3 or 4 on the scale compared to no mud (Leaflet et al.,2008). Packers that are paying based on live weight are paying for the additional mud present, and producers that are being paid off hot

carcass weight are impacted by the decreased dressing percentage, which can impact profitability. Additionally, pelts with excessively laden mud usually reduce pelt value or are discarded, creating waste and unusable by-products. Season and geographic location of the plant also play a role in mud score (Leaflet et al.,2008). The mud score was not a significant concern in the present study. Since the present study was conducted in the summer months, capturing multiple seasons in future audits may be worthwhile.

The wool length was evaluated on 2,604 carcasses. The largest category represented was the shorn or less than 2.54 cm of wool (35 percent). Based on 2022 USDA-AMS data, 43.2 percent of carcasses were reported unshorn, and 52.8 percent were reported shorn during the weeks of plant audits. (USDA AMS, 2022). In the present study, we recorded a smaller population of shorn animals than USDA-AMS reported. This may be due to the location of the plants we audited during each reported week and the smaller sample size this audit evaluated compared to USDA-AMS data. Wool length impacts pelt quality, impacting how much of a premium or deduction the processor gets from the pelts. Pelt types are classified by wool length and wool fineness/fiber diameter, which can be impacted by breed type. Fine wool pelts from white-faced sheep are usually awarded a higher premium. Sheep pelts are a reliable by-product of lamb harvesting, so the industry should take action to ensure pelts are adding value to the industry. The correlation between mud score and wool length ($R^2= 0.22, P \leq 0.001$) indicates the prevalence of mud was not strongly correlated, yet still significant to wool length.

Breed Type

Speckle and white-faced breed types were the most commonly identified in the current study. Speckle-faced sheep are common as operations commonly cross a black-face sire on a white-face ewe to produce terminal crosses. Black-face breeds tend to have increased growth and

carcass traits, whereas white-face breeds tend to have higher maternal and wool traits (Schoenian, 2021). Rambouillet (white-face breed) is the most common breed in the U.S., especially in the western part of the U.S. (Schoenian, 2021). Based on the geographic location of the plants audited, it makes sense that these two breed types were most common in the current study.

Pelt-Off Carcass Evaluation

Break and spool joints, along with dentition, are used in the industry to determine maturity. Any carcass with at least one spool joint is either yearling lamb or mutton, depending on how many permanent incisors are present. Yearlings are animals between 12 and 24 months that have cut one pair of permanent incisor teeth, and mutton is from animals over 24 months of age that have cut two pairs of permanent incisor teeth (Sink and Caporaso, 1977). In the present study, we can directly observe the relationship between break/spool joints and dentition as they were recorded simultaneously. Over 93 percent of carcasses audited presented with one or two break joints and would be considered lamb based on USDA maturity indicators for ossification of joints. However, the dentition of the same carcasses audited resulted in 78 percent of carcasses displaying zero or one permanent incisor, indicating carcass maturity. When the correlation between the number of permanent incisors and spool joints was evaluated ($R^2 = 0.31$, $P \leq 0.001$), there was a significant relationship; however, the relationship would not be considered strong. According to USDA-NASS, during the audit period, 93.5 percent of slaughtered sheep carcasses were classified as lamb or yearlings and 6.5 percent as mature or mutton (USDA NASS, 2022). The break joints recorded in the current study indicated similar results to the USDA-NASS data by less than a percent difference. However, dentition results indicate larger differences from the USDA NASS data, where the current study indicates that 78 percent of carcasses would be considered lamb, 20 percent would be considered yearling mutton, and two percent would be considered mutton based

on dentition. This may be due to a smaller population size or specific days visited. Dentition classification is also important for export requirements and may result in discounts for processors, as no yearling mutton is eligible for export.

Normally, the front two cannon bones (trotter) are left attached to the lamb carcass, but one or both may be removed during processing. In this case, an imperfect break joint is considered a spool joint, and it is assumed there was a spool joint on any missing trotter. As outlined by USDA, a carcass with two perfect break joints will be classified as lamb or yearling mutton based on other evidence of maturity. In contrast, a carcass with spool joints on both trotters will be classified as a yearling mutton or mutton. To be considered mutton, carcasses must have two spool joints (USDA,1992). Currently, lamb and mutton classification vary between plants. In the current study, carcasses classified as lamb were 93 percent based on joints and 78 percent based on dentition. There was 7 percent for mutton based on joints and only 2 percent based on dentition. These inconsistencies suggest that further research evaluating maturity differences between dentition and spool joints needs to be conducted to indicate if the dentition is the most accurate representation of maturity for the USDA QG system.

Quality grading provides the basis to assist consumers in selecting meat cuts to satisfy eating (Jeremiah,1997). In Australia, maturity is solely based on dentition using the same classification systems as in the U.S. (Pannier et al., 2018). Meat Standards of Australia (MSA) quality grades have been identified as the most significant variable affecting a lamb consumer's willingness to pay decision. MSA uses animal age, pH monitoring, and carcass hanging methods to determine lamb quality. Based on consumer responses using MSA sensory protocols, it has been shown that Australian consumers are willing to pay double for a product graded “good every day” (three-star) quality compared to ungraded products. Additionally, consumers would pay up

to 1.90 times more for “better than every day” (four-star) and “premium quality” (five-star) lamb meat relative to a “good every day” (three-star) quality grade (Tighe et al., 2017). Further research evaluating consumer eating satisfaction between quality grades may be addressed to evaluate any additional factors separating the value of CH and PR carcasses.

Additionally, Tighe et al. (2018) identified that over 33 percent of consumers struggled to buy lamb that was both consistent and met their quality standards, and 75 percent said they would purchase more lamb if they had access to a tender and highly palatable product. Those results may indicate that eating quality is a larger driver for sales and may suggest the value of developing more robust quality standards and labels. Further research identifying the best method of determining maturity may help meet the eating satisfaction expectations of consumers and improve consistency within lamb products.

Categories such as age, QG, and YG help further differentiate the carcasses' value and consumer preference. The mean HCW for all plants was 39.9 kg, and the mean fat thickness was 0.97 cm. The average carcass weight from the National Agricultural Statistics Service (NASS) in 2022 was 31.8 kg. Specifically, during the audit period, carcass weights from NASS 2022 data averaged 30.4 kg, with the highest in June 2022 at 31.3 kg. The mean HCW in the current study was higher than NASS data, which may be largely due to the smaller population size in the current study.. However, it is important to consider the impact of sheep breeding seasonality and seasonal market fluctuations in lamb prices and availability, which can influence the decision to feed lambs beyond optimal harvest weight and maturity (Brady et al., 2003). Lamb production cycles typically involve breeding in the fall and spring lambing, with over 85 percent of U.S. lambs born between January and May (USDA APHIS, 2011). This seasonality poses challenges, as feedlots hold lambs on feed to meet demand during the summer months (Whaley et al., 2022).

This leads to the value of implementing camera grading systems for YG, which can increase consistency between MFT and reported USDA YG. In the current study, the difference between USDA YG and calculated YG was twice as large in group 2 compared to group 1 (Table 10). Specifically, the difference was 0.91 for group 1 and 1.87 for group 2. The need for an objective, accurate method of predicting red meat yields and the monetary value of lambs has been acknowledged previously as well (Cunha et al., 2004). An improved ability to quantify differences in fabrication yields would facilitate value-based marketing (Cannell et al., 2002). Prediction models using a Computer Vision System estimated more accurate carcass cutout yields than yield grades assigned by online graders, which can save money for processors (Cannell et al., 2002). Previous studies reported that a dual-component lamb vision system can accurately measure the longissimus muscle in a ribbed carcass, which allows measurement of the ribeye area (Cunha et al., 2004). However, lamb carcasses are traditionally not ribbed unless they are sent to fabrication or split into hind saddle and fore saddle to be sent for further processing at another facility. The current lamb YG equation does not factor in measurements of muscling, which can increase or decrease the YG and percent of boneless, closely trimmed retail cuts significantly. More research evaluating the relationship between fat thickness and distribution and assigned yield grade should be conducted in lambs to develop a more robust YG system potentially. Additionally, more research to understand the fat cost and the ideal degree of finish for lambs may indicate the potential need to move to a grid-based value system similar to the beef industry to improve the consistency of high-quality lamb products.

Further, the current equation for lamb yield grade is $YG = (12^{\text{th}} \text{ rib fat thickness} * 10) + 0.4$ and does not account for any weight or muscling differences. In the present study, USDA YG was different ($P \leq 0.001$) between plants that implement either probing at the 12th and 13th

rib or use camera grading systems (group 1) versus solely visual (group 2). Group 1 had a higher USDA-reported YG but had a lower difference in calculated YG, whereas Group 2 had a lower USDA-reported YG and an almost two-yield grade difference between the calculated YG measurement. This indicates that probing and camera grading systems may provide consistent YG systems, especially if plants pay based on USDA-reported YG.

Lamb Quality Grading and Eating Experience

In the present study, 91 percent of carcasses were graded CH or PR by USDA. However, the industry has no price spread between the two quality grades, which does not incentivize producers to achieve PR carcasses. Additionally, the frequency of PR carcasses is heavily correlated with increasing fat thickness within the present study. This indicates future research to evaluate the QG system in the U.S. The QG system in the U.S. is based on maturity and the amount of flank streaking within the carcass (USDA, 1992). However, mutton cannot grade PR (USDA, 1992). It is well known that many factors affect eating quality, including age. Similar to the U.S. system, Australia utilizes the same dentition classifications (MLA, 2019). Increased animal age is highly associated with decreased tenderness and consumer acceptability (Pannier, 2018). In Australia, it has been proposed to include factors such as lean meat yield, intramuscular fat, HCW, age, and even genetics into the QG model (Pannier, 2018). Further research identifying what lamb quality characteristics mean to each sector is crucial to understanding the best way to measure, incentivize, and evaluate the current QG system.

Conclusions

The 2022 NLQA in-plant survey serves as a baseline to measure and report lamb carcass traits in the U.S. production system. The sex class distribution, mud scores, wool length, breed type, maturity, and carcass characteristics of lamb and mutton from four federally inspected lamb

processing facilities were collected during the in-plant survey. Due to the 98 percent of lamb qualifying for PR and CH with no price spread between grades, it appears that lambs are primarily marketed on weight and YG. The YG evaluation technique varied across plants, and our results suggest that probe and camera grading measurement systems resulted in a smaller difference between USDA YG and calculated YG. Future audits capturing shifts in seasonality challenges should also be considered to evaluate the trends in quality, yield, and maturity indicators. Overall, the results from this audit will provide valuable information and data to the existing knowledge base of the lamb industry regarding carcass quality attributes.

Table 1. Sex classes identified across all plants in the 2022-NLQA audit (n = 1,605).

Sex	Number of Carcasses	Percent (%)
Castrated Male/Wether	1012	63
Female/Ewe	506	32
Intact Male/Ram	87	5

Table 2. Mud score across all plants in the 2022-NLQA audit (n = 2,604).

Mud Score ¹	Number of Carcasses	Percent (%)
1	906	35
2	901	35
3	454	17
4	259	10
5	84	3

¹Mud score was adapted from the NBQA 2016 audit and was determined using a ranking of 1-5:

- 1- Clean pelt, no presence of mud,
- 2- Small lumps of mud in limited areas of legs, side, and underbelly,
- 3- Small and large lumps of mud in large areas of legs, side, and underbelly,
- 4- Small and large lumps in even larger areas along the hindquarters, stomach, and front shoulder.
- 5- Lumps of manure continuously throughout the entire body of the animal that are deemed high risk of contamination to the hide-off carcass (NBQA, 2016).

Table 3. Wool length across all plants of the 2022-NLQA audit (n = 2,604).

Wool Length	Number of Carcasses	Percent (%)
< 2.54 cm	905	34
2.54 – 5.08 cm	817	31
5.08cm – 7.62cm	703	27
7.62cm – 10.16cm	135	5
> 10.16cm	11	0.4
Hair	33	1

Table 4. Breed type across all plants of the 2022-NLQA audit (n = 2,604).

Breed Type	Number of Carcasses	Percent (%)
Speckle	1,046	40
White-Face	1,010	39
Black-Face	477	18
Natural/Blue	38	1
Hair	33	1

Table 5. Spool joints observed at all plants in the 2022-NLQA audit (n = 2,437).

Number of Spool Joints Present	Number of Carcasses	Percent of Total (%)
0	2,123	87
1	139	6
2	175	7

Table 6. Permanent incisors observed at all plants in the 2022-NLQA audit (n = 2,437).

Permanent Incisors Present	Number of Carcasses	Percent of Total (%)
0	1,656	68
1	251	10
2	468	19
3	20	1
4	23	1
Broken Teeth	10	0.4
Condemned	9	0.4

Table 7. Carcass characteristics of lamb and mutton carcasses across all plants in the 2022-NLQA audit.

Carcass Traits	n ¹	Mean	Standard Deviation	Minimum	Maximum
USDA Yield Grade ²	2,237	2.71	0.97	1.00	5.00
USDA Quality Grade ^{2,3}	2,237	724.38	45.76	700.00	800.00
HCW, kg	2,464	39.90	9.08	9.62	74.52
Fat Thickness, cm	2,464	0.97	0.38	0.12	2.79

¹Number of carcasses

²Does not include no roll carcasses (not graded by USDA)

³Scores are as follows: 700 = Choice, 800 = Prime

Table 8. Distribution (%) of carcasses stratified by USDA quality and yield grades in the 2022-NLQA Audit (n=2,237)¹.

USDA Yield Grade	USDA Quality Grade, %	
	Prime	Choice
1	4.8	95.2
2	29.3	70.7
3	18.0	82.0
4	29.5	70.6
5	33.6	66.4

¹Carcasses that were missing their USDA quality and or yield grade are not included

Table 9. Carcass characteristics of lamb and mutton carcasses by individual plant and summarized into two groups (1 and 2) observed in the coolers at all plants in the 2022-NLQA audit.

Carcass Traits	Plant A	Plant B	Plant C	Plant D	Group 1 ¹	Group 2 ²	Standard Error ³	P-Value ⁴ (Plant)	P-Value ⁴ (Group)
n ⁵	651	911	319	356	970	1267	-	-	-
USDA Yield Grade ⁶⁷	2.80 ^a	2.36 ^b	2.78 ^a	3.34 ^c	2.80 ^x	2.64 ^y	1.08	<0.001	<0.001
Calculated Yield Grade	3.65 ^a	4.45 ^b	3.85 ^a	4.67 ^c	3.71 ^x	4.51 ^y	1.71	<0.001	<0.001
HCW, kg ⁶	37.57 ^a	40.75 ^b	38.70 ^a	42.94 ^c	38.00 ^x	41.40 ^y	10.35	<0.001	<0.001
Fat Thickness, cm	0.83 ^a	1.04 ^b	0.90 ^a	1.09 ^c	0.86 ^x	1.06 ^y	0.44	<0.001	<0.001

¹ Plants A and C (probe or camera grading system)

² Plants B and D (visual assessment)

³ Largest standard deviation is reported

⁴ Significance $P \leq 0.05$

⁵ Number of carcasses surveyed at each plant

⁶ Does not include no roll carcasses (not graded by USDA)

⁷ YG = (MFT x 10) + .4

Table 10. The estimated difference in means between USDA yield grade and calculated yield grade of lamb and mutton carcasses broken out by in-plant grading systems in the 2022-NLQA audit.

Group	n ¹	USDA Yield Grade	Calculated Yield Grade ²	Standard Error ³	P-Value
Group 1 ⁴	970	2.80	3.71	0.03	<0.001
Group 2 ⁵	1267	2.64	4.51	0.02	<0.001

¹ Number of carcasses surveyed at each plant

² Calculated Yield Grade = $0.4 + (10 * 12^{\text{th}} \text{ rib fat thickness, inches})$

³ Largest standard deviation is reported.

⁴ Plants A and C (probe or camera grading system)

⁵ Plants B and D (visual assessment)

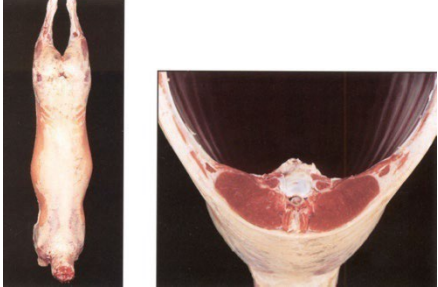
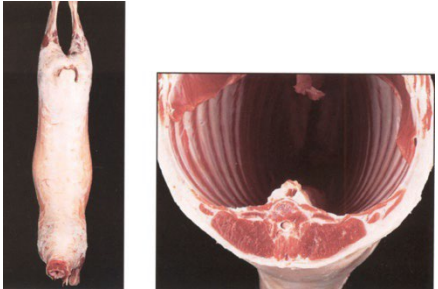
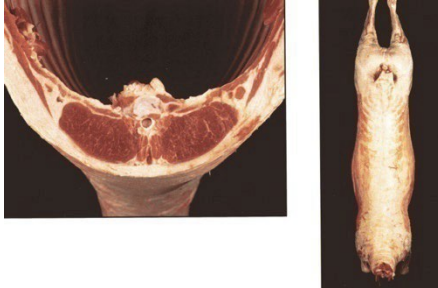
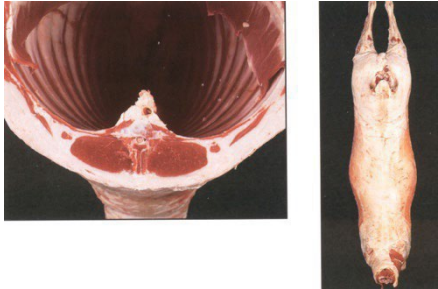
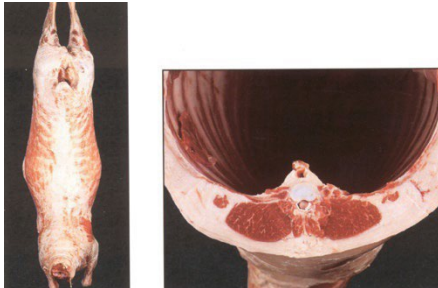
Yield Grade 1	A yield grade 1 has a thin layer of external fat over the back and loin and slight deposits of fat in the flanks and cod/udder. There is usually a thin layer of fat over the shoulders and outsides of the leg.	
Yield Grade 2	A yield grade 2 usually has a thin layer of fat over the back and loin, covering the muscles of the back. The top of the shoulders and the outside of the legs have a thin covering of fat and there are usually small deposits of fat in the flank or cod/udder.	
Yield Grade 3	A yield grade 3 usually has a moderately thick covering of fat over the back, the top of the shoulders is completely covered, and the legs are nearly completely covered. There are usually large deposits of fat in the flanks and cod/udder.	
Yield Grade 4	A yield grade 4 is usually completely covered in fat. There is usually a thick covering of fat over the back and a slightly thick covering over the shoulders and the legs. There are usually large deposits of fat in the flank or cod/udder.	
Yield Grade 5	A yield grade 5 has an adjusted fat thickness of more than 0.45 inches and the external fat covering on most parts of the carcass is usually greater than that of a yield grade 4.	

Figure 1. Overview of ovine yield grading and example images. Adapted from “The United States Standards for Grades of Lamb, Yearling Mutton, and Mutton Carcasses” (USDA-AMS, 2020). Images from Meat Animal Handbook, American Meat Science Association, 2001.

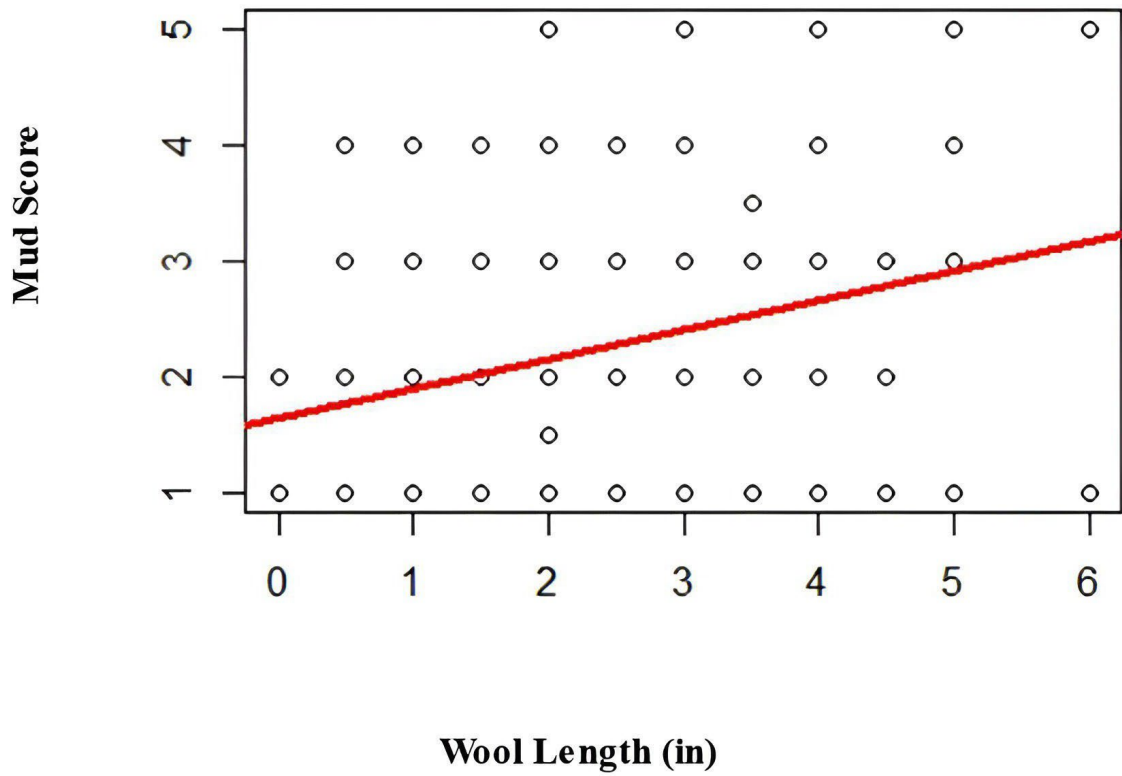


Figure 2. Correlation between wool length and mud score for lambs across all plants in the 2022-NLQA audit.

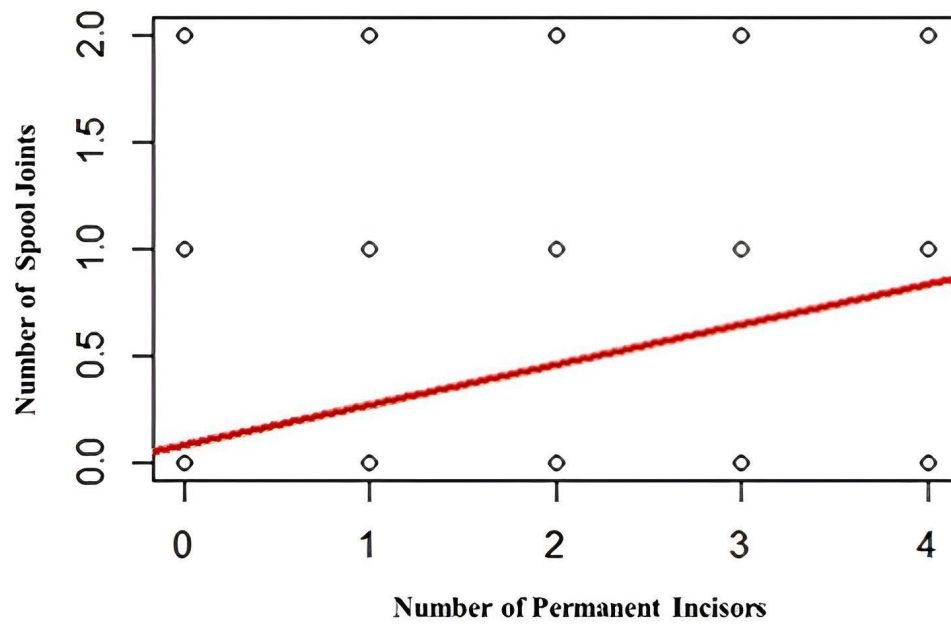


Figure 3. Correlation between permanent incisors and spool joints across all plants in the 2022-NLQA audit.

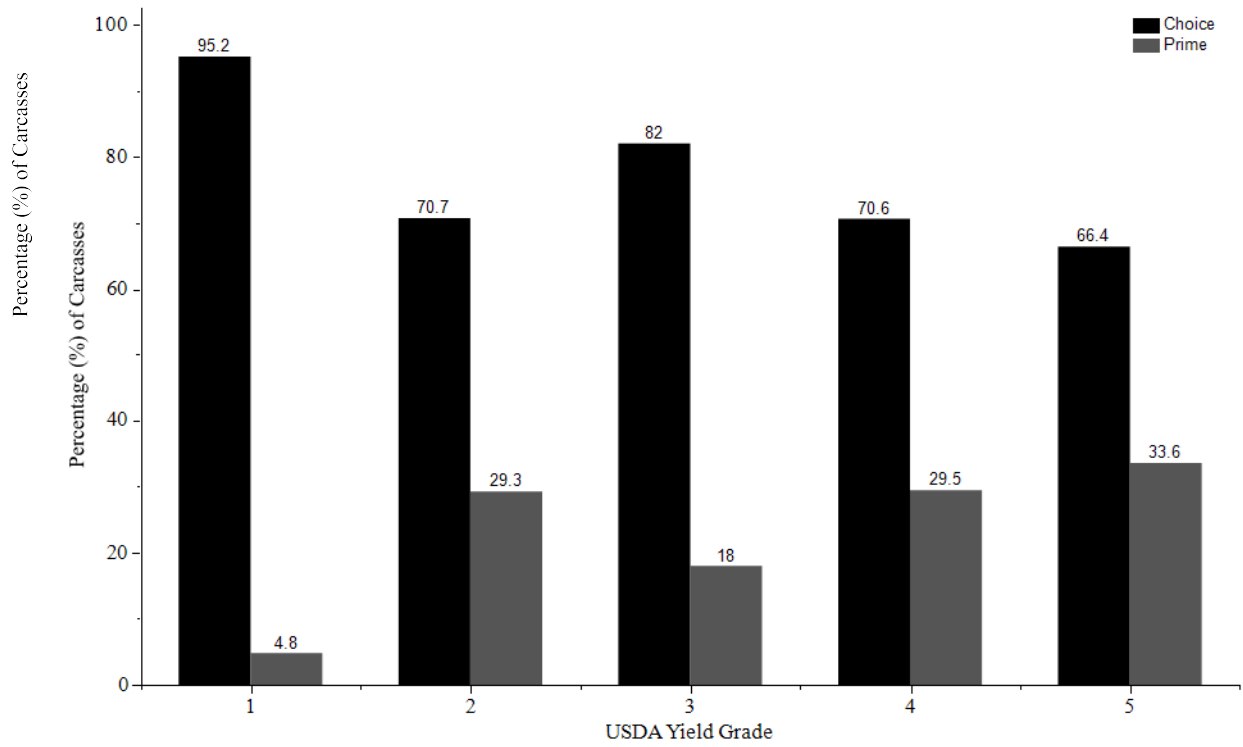


Figure 4. Distribution (percent) of carcasses stratified by USDA quality and yield across all plants in the 2022-NLQA audit (n=2,237)

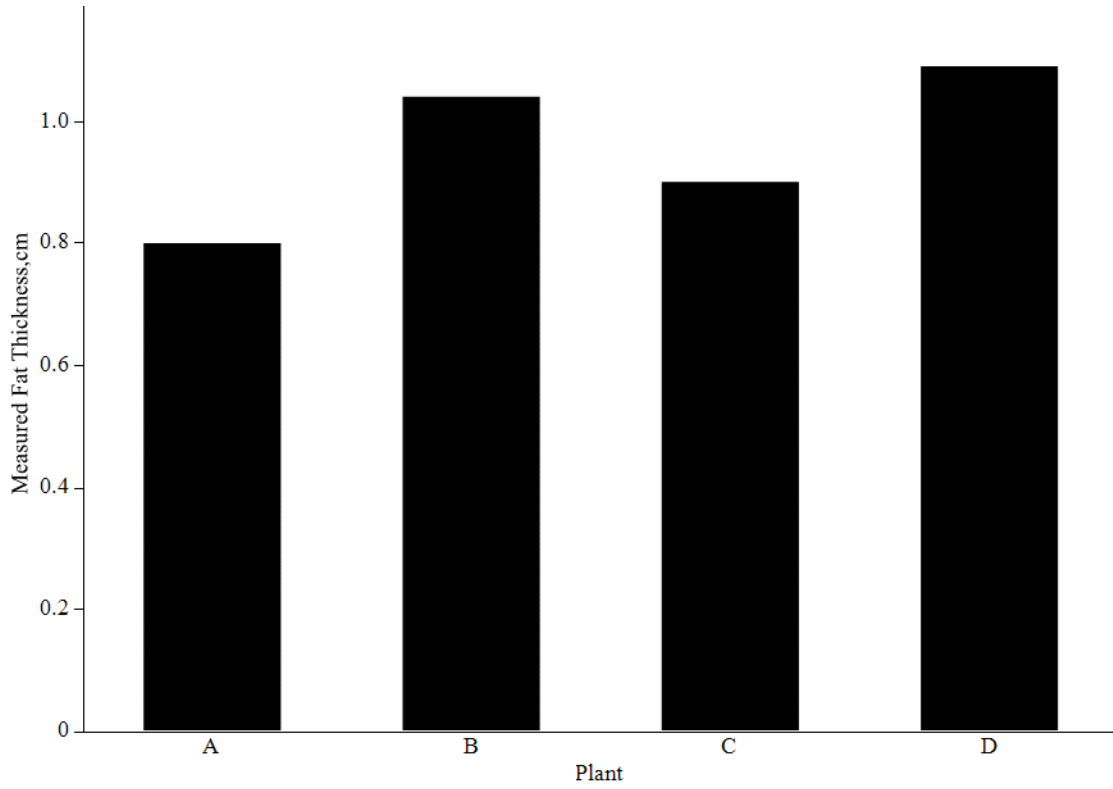


Figure 5. Measured fat thickness across all plants in the 2022-NLQA audit (n=2,237)

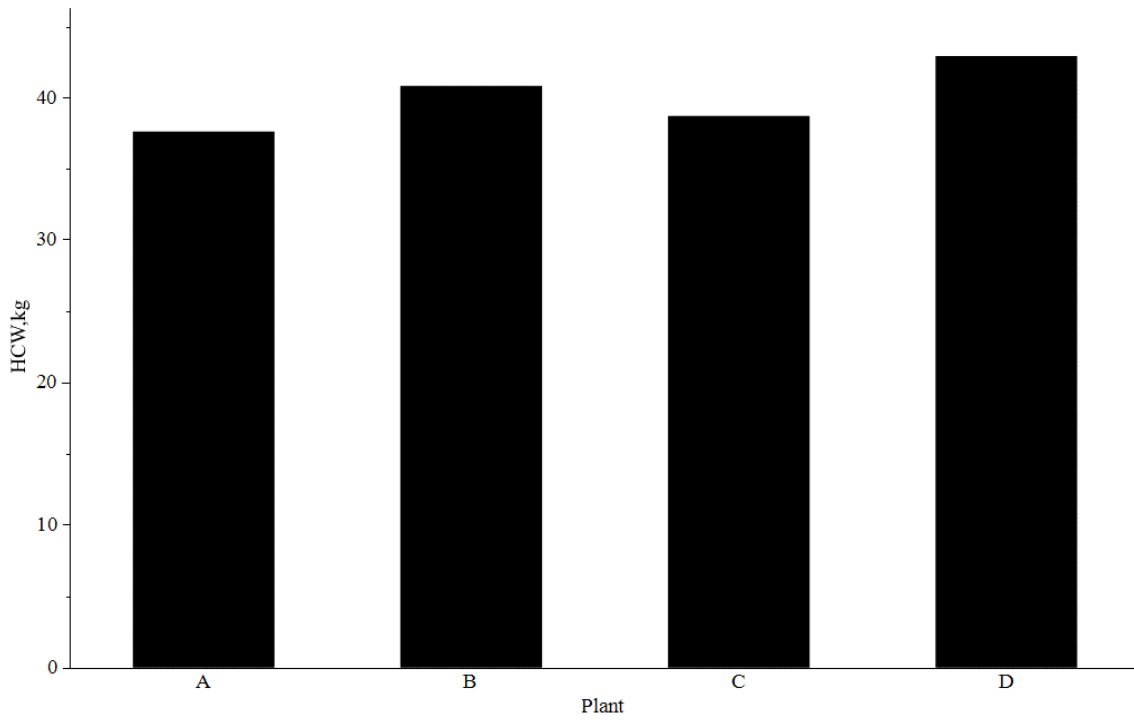


Figure 6. Hot carcass weight across all plants in the 2022-NLQA audit (n=2,237)

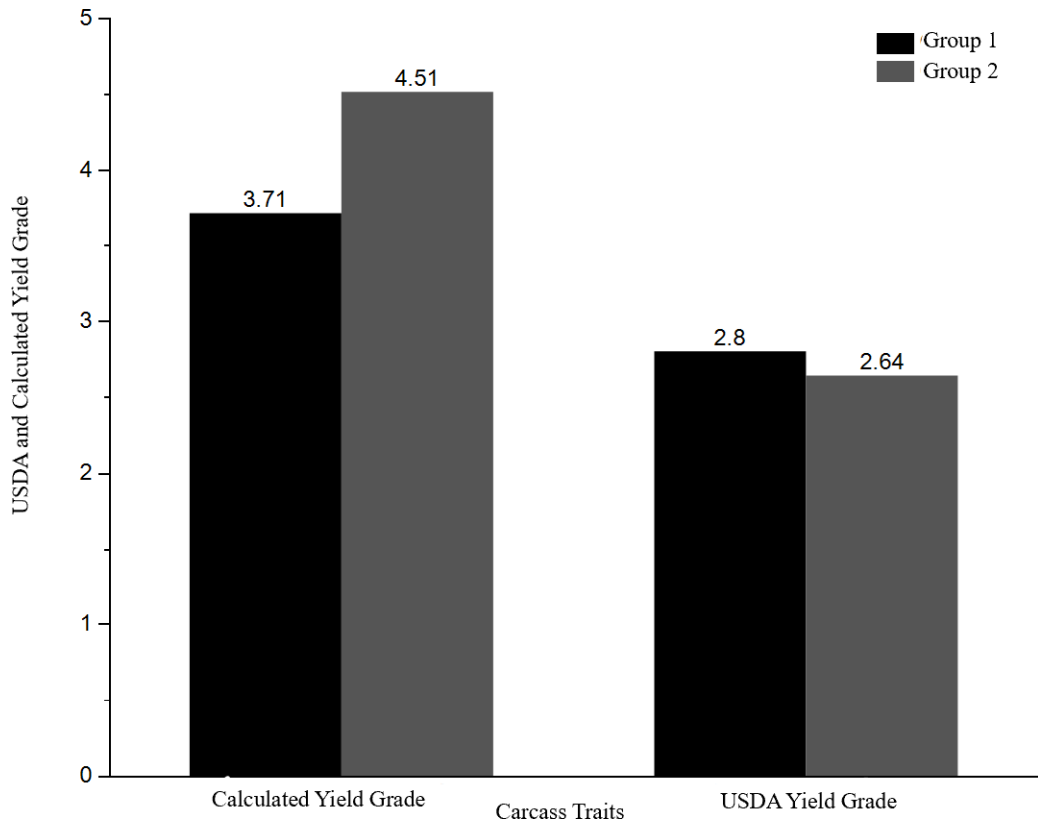


Figure 7. Estimated means between USDA yield grade and calculated yield grade of lamb and mutton carcasses compared between in-plant grading systems (Group 1- probe or camera grading and Group 2- visual assessment) in the 2022-NLQA audit.

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