

THESIS

2022 NATIONAL LAMB QUALITY AUDIT

PHASE I: SUPPLY CHAIN PERCEPTIONS OF THE U.S. LAMB INDUSTRY

PHASE II: IN-PLANT SURVEY OF CARCASS CHARACTERISTICS RELATED TO

QUALITY AND VALUE OF FED LAMBS AND MUTTON

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ABSTRACT

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The U.S. sheep and lamb population has slowly declined over the last eight decades, from 56 million head in 1942 to five million head in January of 2023. Sheep, often referred to as mutton in the meat industry, are mature animals that have at least two permanent incisors, spool joints, and are typically over 24 months of age. Lambs are considered young animals that lack permanent incisors, have at least one break joint, and are usually less than 14 months (USDA,1992). The U.S. lamb industry faces competition from imported lamb from Australia and New Zealand that is less expensive. This imported product increases the lamb supply within U.S. wholesale and retail stores, which, along with increased production costs, has raised concerns about the future viability of the U.S. lamb industry. In response to this pressure, the lamb supply chain can prioritize attributes that both reduce production costs and promote consumer demand. The first step in this process is to measure data from production through lamb carcass quality characteristics, especially data captured in the manufacturing settings. Benchmarking is necessary to identify needs to drive quality enhancements and to ultimately drive improvement and profitability of the lamb industry. The current National Lamb Quality Audit (NLQA) seeks to fill this gap by capturing baseline data from broad scope of the supply chain through perception surveys and in-plant audits. This baseline information will inform the lamb value

chain on the current perceptions and lamb quality characteristics that may aid in identifying attributes to reduce costs and increase consumer demand.

The NLQA, conducted three times since 1992, assesses the industry's progress on various quality characteristics that ultimately affect consumer demand for lamb. The most recent audit, conducted in 2015, primarily focused on the foodservice segment of the industry. As sheep genetics, management practices, available resources, and consumers' needs and expectations constantly evolve, more frequent audits that capture the entire supply-chain should be considered. The 2022 NLQA audit is designed to repeat successful portions of the 2015 audit, including a new supply chain survey to assess perceptions about the U.S. lamb industry and in-plant carcass characteristics.

In phase I, 155 surveys were conducted from May 2022 through September 2022 to understand and quantify perceptions of the U.S. lamb industry. The survey was administered using a software package (Qualtrics[®], Provo, Utah) customized to develop a structured order of questions for each industry segment. The survey was distributed via in-plant visits, social media, and email. Survey respondents remained anonymous, each taking approximately ten minutes to complete. Statistical analysis was conducted in Microsoft Excel and the Qualtrics[®] software. Thirty-two states were represented, with 88 percent of respondents identifying as the owner/operator of their respective business or operation and 86 percent representing commercial breeding operations. Respondents were asked to rank topics based on importance to their operation from 1 (least important) to 10 (most important). Animal welfare (8.9), lamb quality (8.4), and sustainability (7.6) were of most importance to producers. Respondents were also prompted to rank significant challenges in the industry (1=most important and 10=least

important). The most significant challenges identified were operation costs (3.04), market volatility (3.70), and labor (4.08). Open-ended responses for defining sustainability were sorted and narrowed in terms of descriptions to find commonalities between respondents. Central themes from respondents included environmental stewardship, profitability, and producing high-quality lamb products. Results from the survey will provide valuable insight to discern gaps and opportunities between producers' viewpoints and data collected in plants to develop educational material to improve lamb quality.

For phase II, 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. On each production day, 50 percent of carcasses harvested and chilled were surveyed. 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. The distribution and summary functions of JMP[®] Software were used to determine the frequency distributions, means, standard deviations, and minimum and maximum values. Data was analyzed using the Type III ANOVA procedure, and 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 at P -value ≤ 0.05 .

Phase II used in-plant assessments to benchmark current carcass quality characteristics related value of the fed lamb and mutton industry in the U.S. Among the carcasses (n = 1,605) that were audited for sex, 63.2 percent were wethers, 31.5 percent ewes, and 5.3 percent rams. Two percent of the carcasses were presented with horns. 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 indicating lamb, 5.70 percent with one break joint indicating yearling mutton, and 7.18 percent with no break joints indicating mutton. The average HCW (n=2,464) was 39.9 kg, whereas the MFT was 0.97 cm. The USDA stamped yield grade was 2.71 and 68.5 percent graded choice (CH), 22.6 percent graded prime (PR), and 8.9 percent were not graded. 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 to understand and develop strategic initiatives to improve the quality of fed lamb and mutton.

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CHAPTER 1: REVIEW OF LITERATURE

History of the U.S. Sheep Industry

The U.S. sheep industry is an integral part of the agricultural sector and despite facing various challenges, remains an essential source of income for many producers. The lamb and wool industry contribute more than two billion dollars annually to the U.S. economy (Shiflett, 2017). Prior to World War II, lamb meat was a by-product of the wool industry; however, as demand for wool declined and meat became the industry's primary commodity, there has been a consistent and slow decline in the sheep population (Jones, 2004). Sheep numbers peaked at 56 million head in 1945, and as of January 31, 2023, there were 5.02 million head of sheep in the U.S. (Jones, 2004; USDA NASS, 2023). Sheep are found in all regions of the U.S., with over 80 percent of the population located in the western part of the U.S. (ASI, 2015). Texas, California, Colorado, and Wyoming are the top four states in breeding sheep numbers (USDA NASS, 2023). The largest lamb harvesting production states are Colorado, California, and Texas, respectively, contributing over half of the production capacity in the U.S. (NASS, 2023). In 2021, the lamb industry in the U.S. faced various challenges, including persistent drought, increased feed costs, and other production limitations. Combined with strong slaughter ewe prices, these factors led to a significant increase in mature sheep slaughter (ALB, 2023). The ongoing decline in the U.S. sheep flock also resulted in a smaller lamb crop and reduced lamb supply (NASS, 2023). During the spring and summer months, there were indications of tighter supplies of feeder lambs, as reflected in lower on-feed numbers. Compared to the average cost of on-feed lamb supplies in 2022, 2015-2019 was approximately 7 percent lower (ALB, 2023). The declining sheep flock has had a direct impact on lamb production, which was down only 0.5 percent in 2022, but significantly lower (8 percent) compared to the 2015–2019 average. This decline in production

can be attributed to reduced lamb supply and decreased commercial slaughter (ALB, 2023). However, lamb weights were 4 percent heavier in 2022 due to a slowdown in slaughter lamb marketings (ALB, 2023). Commercial slaughter was down 9.1 percent, and federally inspected slaughter represented 85.4 percent of commercial slaughter in 2022.

In February 2023, USDA National Agricultural Statistics Service reported that lamb and mutton production was up nine percent (at 4,581,283 kilograms) compared to the same time in 2022. Similarly, sheep harvest rose to 154,800 head in 2023, up eight percent compared to January 2022. The reported average carcass weight was 39.0 kg in 2023 (USDA NASS, 2023)

The Importance of Quality Audits

Improving the consistency and quality of lamb products can help maintain consumer demand, a critical aspect of the industry's overall success. Quality audits provide a benchmark using current data relative to the consistency and quality characteristics. They allow the industry to identify quality shortfalls and non-conformance, which, when addressed, can lead to greater profitability and resiliency (Beef Quality Assurance, 2016). As consumer preferences and market opportunities change, consistently performed quality audits can provide relevant and timely reports on quality performance to industry partners. Additionally, results can help secure customer confidence in expanding domestic and export markets (Beef Quality Assurance, 2015). The beef industry has found significant success in outcomes and subsequent improvements from previous audits and has conducted audits every five years since 1991 (Beef Quality Assurance, 2015). For example, compared to 1991, the 2016 National Beef Quality Audit (NBQA) demonstrated improvements in quality grade (QG), longissimus muscle area (LEA), and increased HCW (Beef Quality Assurance, 2016). Additionally, the NBQA provides resources for producers to continually follow current trends and areas of improvement for beef quality to

maintain competitiveness of the U.S. beef industry. Previous studies have indicated that regular audits will promote consistency and improvement, aiming to improve the quality of U.S. lamb as a point of differentiation from imported products (Whaley et al., 2022).

Review of Past National Lamb Quality Audits

Over the past 30 years, three NLQAs have been completed in 1992, 2007, and 2015 (Hoffman et al., 2015). The 1992 audit identified different aspects of management practices to utilize in the creation of the Sheep Quality Assurance (SQA) program. The 2007 audit aimed to comprehensively collect data from all segments of the sheep industry, including producers, feeders, packers, purveyors, retailers, and wool processor warehouses, and the 2015 audit solely evaluated essential quality characteristics of food service, retailers, and distributors. The three previous audits in the last thirty years have had minimal in-plant data assessment. The goal of the NLQAs is to promote continuous improvement in U.S. lamb production, enhance consumer demand, and provide valuable education to producers. The lack of more consistent quality audits, especially when compared to the beef industry, impacts the ability of the lamb industry to effectively track progress and ensure consistent reporting metrics across the industry over time. To address these issues and further enhance the value and impact of NLQAs, reducing the time between audits can provide more frequent assessments of the industry's progress and identify areas that require attention and improvement in a more timely manner. It is also crucial to update and improve the adaptation and implementation of programs like SQA, which can help establish consistent quality standards and best practices throughout the lamb industry. Addressing these challenges of best practice adoption and consistent and continuous evaluation will enable NLQAs to contribute to the long-term growth and success of the U.S. lamb industry more effectively while meeting the evolving needs and expectations of consumers and producers alike.

The first NLQA was conducted in 1992 to identify the frequency of quality defects resulting from management practices across all production phases of lamb. The 1992 audit traced each lamb product from its origin through processing. Results estimated that lamb meat represented 85 percent of the producer's income, and wool and pelt products 15 percent. Problem areas identified in the 1992 audit were excess fat, carcass bruising, and wool contamination (Hoffman et al., 2015).

In 2007, the NLQA aimed to comprehensively audit all segments of the sheep industry, including producers, feeders, packers, purveyors, retailers, and wool processors/warehouses (Hoffman et al., 2015). Direct survey responses were obtained from sheep operations in 26 states, representing producers, feeders, wool handlers, and processors. The findings indicated a decrease in quality issues compared to previous years' audits. However, concerns regarding the availability of high-quality lambs for feeders and packers during the late spring and early summer were documented. According to the feeder survey, the highest-ranked problems on a 10-point scale were breeding quality (7.7), animal health (7.6), and diseases (7.2) (Hoffman et al., 2015).

The 2007 NLQA also evaluated packers and processors in several states, including California, Colorado, Iowa, New Jersey, New Mexico, South Dakota, and Utah. In 2007, the audit identified seasonal supply as a factor affecting quality, with heavy and fat carcasses being a significant issue in late spring and summer. Notably, all audited lambs at the processing plants were contaminated with mud and manure (Hoffman et al., 2015). In conclusion, the 2007 NLQA highlighted the importance of ensuring consistent quality in carcasses and products, addressing seasonality challenges, and identifying consumers' specific needs. These findings provided current insights for the industry to improve upon and indicated that hair contamination,

seasonality, and polypropylene contamination remained significant concerns from the 1992 audit.

The 2015 NLQA audit by Hoffman et al. focused on eating quality and factors related to consumer satisfaction with lamb at retail and foodservice. The objectives of that study were to determine U.S. retail and foodservice rank, definition, and relative preference for seven quality attributes including 1) origin; 2) sheep raising practices; 3) eating satisfaction; 4) weight/size; 5) product appearance/composition; 6) product convenience/form; and 7) nutrition/wholesomeness. One-hundred and twenty interviews were conducted (May 2014 to March 2015) with protein purchaser representatives of retail (n=60), foodservice (n=45), and purveyor (n=15). Shares of preference for all participants (n=120) indicated that eating satisfaction was the most critical quality attribute (39 percent; most commonly defined as flavor/taste) when purchasing lamb. When asked to describe quality, over 33 percent of respondents answered with flavor or taste. Subsequently, origin (e.g., locally raised, and American) and sheep-raising practices (e.g., grass-fed) were 2nd and 3rd, respectively.

Additionally, eating satisfaction generated the largest willingness to pay a premium of 18.6 percent if assured. Eating satisfaction is difficult to assess visually, according to foodservice and restaurants audited and they are willing to pay almost two dollars per pound more for products that consistently meet the eating satisfaction standards of consumers. The 2015 audit identified areas of improvement, such as eating satisfaction and flavor, to focus on moving forward.

Phase I and II of 2022 NLQA will build off previous audits by documenting and analyzing the industry's quality attributes through in-plant and survey data. Collecting and

analyzing this data will allow for the capture for the identification of areas for improvement for the industry moving forward.

Consumer Preferences of Lamb

Consumer needs and expectations evolve with time. As a result, the lamb industry must continually adapt to meet consumer expectations. Since the 1960s, per capita consumption has dropped from nearly 2.5 kg to less than 1 kg (USDA ERS, 2020). Presently, increasing demand is a significant opportunity for industry. Market research shows that 30 percent of U.S. consumers have not tried lamb, and 24 percent only eat lamb once yearly (ASI, 2015). Though lamb consumption is projected to remain reasonably stable, imports continue to challenge U.S. production. Currently, the U.S. is the world's third-largest importer of lamb and imports account for more than half of the U.S. supply and are mainly from Australia (approximately 75 percent) and New Zealand (approximately 24 percent; USDA ERS, 2020).

The decline in lamb consumption can be attributed to several factors identified by the American Lamb Board (ALB). Consumers have expressed uncertainty when it comes to consuming and purchasing lamb, mainly due to the price of lamb and taste preferences. In general, consumer demand drivers for lamb are products that are perceived as good value for money, low in fat, and consistently high in quality (ALB, 2021). To understand consumer preferences when purchasing lamb, the ALB conducted a survey in 2021 involving over 1000 participants—the survey aimed to determine the factors consumers consider when buying lamb. The results revealed that consumers with a positive experience with lamb associated it with attributes such as flavor, quality, tenderness, and freshness. Additionally, a significant number of consumers expressed a preference for purchasing U.S. lamb products. However, it was noted that

25 percent of participants were comfortable buying imported lamb, and approximately 33 percent stated that the country of origin did not matter to them (ALB, 2021).

The 2015 NLQA indicated that eating satisfaction was the most important quality attribute (39 percent; most defined as flavor/taste) when purchasing lamb. Thus, management that influences the fatness and flavor of lamb (e.g., days on feed, slaughter weight) should be considered in U.S. lamb production (Hoffman et al., 2015). A nationwide survey of lamb cutability traits conducted by Tatum et al. (1989) found that many lambs had excessive external fat. This is likely due to 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 in the supply-chain, as feedlots are required to hold lambs on feed to meet demand during the summer months (Whaley et al., 2022). The highest demand for lamb occurs in the spring, driven by holiday traditions and consumer taste preferences for spring lambs.

Grading and Assigning Value to Lambs

Historically, the USDA grading system and hot carcass weight (HCW) have been crucial to valuing U.S. lamb. Over 98 percent of all lambs are categorized as Choice (CH) or Prime (PR) (ASI, 2015). When assigning value and grading to lamb carcasses, a combination of factors such as live weight, hot carcass weight (HCW), yield grade (YG), and quality grade (QG) are used. Live weight refers to the weight of the lamb prior to processing, while HCW refers to the weight of the carcass after hide removal and evisceration. The YG measures the amount of lean meat in proportion to fat, and QG assesses flank streaking and physiological maturity

indicators. These factors determine the value and grade of the lamb carcass. The YG and QG provide transparency and standardization in the market, allowing buyers and consumers to make informed decisions based on the quality and characteristics of the lamb carcass. Carcass composition consists of muscle, fat, and bone to determine the percentage of boneless, closely trimmed retail cuts. Generally, carcass composition assessments serve three functions: 1) assign carcass value; 2) allow sorting for further processing; and 3) can transfer information back to the producer sector, regarding opportunities for improvement (Ward et al., 1995). Lamb carcasses are primarily valued for HCW and YG (Brady et al., 2003).

Grading is a voluntary process that involves classifying carcasses into homogeneous groups based on regulated attributes set by the USDA, such as physiological maturity and muscle conformation. The purpose of grading is to determine the value of the animal for producers, packers, and end consumers and to ensure consistent carcasses and fabricated products. The official standards for U.S. lamb grading were established in 1931 (ASI, 2015). These standards laid the foundation for the current USDA lamb quality grade system, which consists of four grades: Prime, Choice, Good, and Utility. Each grade has specific requirements regarding conformation, fat cover, and flank streaking, which a USDA grader assesses to determine the appropriate quality grade for the lamb.

USDA yield grading began in 1969 and was used to base the percentage of boneless, closely trimmed retail cuts of primals. Since the update in 1992, YG factors were modified to incorporate adjusted fat thickness between the 12th and 13th ribs. In sheep, USDA YG and QG must be done together on each eligible carcass (ASI, 2015). The adjusted fat thickness range for each YG is as follows: YG 1 - 0.00 to 0.38 cm; YG 2 - 0.38 to 0.64 cm; YG 3 - 0.64 to 0.89 cm; YG 4 - 0.89 to 1.14 cm; and YG 5 – 1.14 cm and greater (USDA, 1992). The current YG

equation for lamb is $YG = 0.4 + (10 \times \text{fat thickness, inches})$; (NDSU,2023). The lamb YG equation does not consider muscle by measuring the loineye area (LEA). Since most lamb carcasses are not split between the 12th and 13th rib, USDA graders use a probe or visual indicators to assess the YG of the carcass. Currently, there is little price difference between yield grades 1 to 4. A 2018 study showed over 43 percent of the 10,027 carcasses surveyed were assigned USDA YG 4 or 5 (Whaley, 2022). In comparison, the beef YG equation incorporates adjusted fat thickness, percent of kidney, pelvic, and heart fat (KPH), HCW, and ribeye area (REA). The equation for beef YG is $YG = 2.50 + (2.5 \times \text{adjusted fat thickness, inches}) + (.20 \times \text{percent KPH}) + (0.0038 \times \text{HCW, pounds}) - 0.32 \times \text{REA, square inches}$ (NDSU, 2021). Future research is needed to evaluate the YG system in lambs to evaluate whether it accurately represents the percent boneless, closely trimmed retail cuts. A good value-based payment system can incentivize producers to breed animals with attributes desired by consumers and can change based on changing demand (Gonzalo Delgado-Pando, 2021). Restructuring the value-based system may drive more consistency, especially through seasonality challenges.

Maturity indicators are also used to assess the value of lamb carcasses. The two common indicators are dentition, based on the number of permanent incisors, and ossification of the carpal joints. Ossification refers to the hardening of the joints, indicating maturity. Lamb carcasses are typically classified based on ossification, as dentition is highly variable. Based on the maturity indicators, most carcasses fall into one of three categories: lamb, yearling mutton, and mutton. These categories help further differentiate the maturity and value of the carcasses in the market.

Import Pressure

As imported lamb continues to contribute more than half the market share of lamb products in the U.S., improving and meeting the consumer needs for U.S. lamb important. The top four themes from the survey for challenges were animal welfare, sustainability, and source of product. Australian and New Zealand sheep farms are the largest in the world and are estimated to have two to eight times higher total returns than other global competitors. Combined these two countries represent over 90 percent of all lamb and sheep meat exported globally. Additionally, compared to the U.S., they have less than \$2/kg of live weight cash costs due to their extensive grazing systems, which decreases input costs significantly (MLA, 2019). Further opportunities for research into ways to reduce operational costs to increase not only profit margins for the producers but also decreases retail price of lamb to lessen may be necessary.

Conclusion

Three previous audits in the last thirty years have had minimal in-plant data assessment. U.S. lamb producers are facing several challenges that hinder the industry's growth. These challenges encompass import competition, low consumption, and demand, and increasing production costs. Past NLQAs were a starting place for the industry to identify these challenges. However, there is minimal data from past audits capturing the beginning of the supply chain and carcass quality characteristics. To enhance the industry, it is crucial to gain a comprehensive analysis through data collection to understand areas of improvement for each sector to meet evolving consumer needs, which is the intent of the 2022 NLQA.

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CHAPTER 2: 2022 NLQA PHASE 1: UNDERSTANDING SUPPLY CHAIN PERCEPTIONS: A CRUCIAL STEP IN IMPROVING THE U.S. LAMB INDUSTRY

Introduction

The lamb sector is important to the U.S. agricultural industry contributing over two billion dollars annually (Shifflet, 2017). The sheep production system is diverse in size and can be generally categorized into breeding, wool production, show operations, and feeding/finishing operations. The disruptions caused by the pandemic highlighted the importance of establishing strong connections and communication channels across the supply-chain (Helper and Soltas, 2021). Therefore, establishing a close working relationship between producers and stakeholders from across the entire supply-chain should enable the industry to better respond to changing market demands, address supply-chain challenges, and ensure the availability and quality of products.

The National Lamb Quality Audit (NLQA) benchmarks different sectors of the lamb industry to identify the opportunities and challenges. Since its inception in 1992, the audit has been conducted three times; 1992, 2007, and 2015 (Hoffman et al., 2015). Each of these audits have helped to develop priorities for the U.S. lamb industry. Historically, the research exploring the demand for U.S. lamb has focused on foodservice (Hoffman et al., 2015). Capturing the perceptions of critical stakeholders, particularly at the beginning of the supply-chain (e.g., breeders), is also important, especially considering the COVID-19 pandemic, which changed the industry's landscape. Packers slowed down production which created a backlog of slaughter ready lambs in the supply chain, which for producers caused more days on feed than normally. In the first quarter of 2020, lamb harvest was down six percent on a year-over-year basis in the U.S.

In Colorado, where majority of feeder lamb inventory is located, inventory numbers were up by 15 percent in April 2020. In May 2020, a 6,000 head reduction in harvest and reduced auction prices compared to May 2019 resulted in over \$342,000 lost in that month alone (American Sheep Industry Association, 2020).

The importance of quality in the sheep industry has been recognized by both producers and consumers for the past several decades (Montossi et al., 2013). However, there could be a difference in how quality is defined within the supply-chain. Producers tend to judge quality often focusing on technical attributes such as yield grade (YG) or hot carcass weight (HCW). On the other hand, consumers might be considering factors such as flavor and color when evaluating quality (Demey, 2003; Sepúlveda, 2008). In order to truly benchmark the state of the lamb industry, it is essential to capture data from all sectors involved, including producers. While previous audits focused on specific aspects of foodservice forward, capturing producers' perceptions is important to understand where gaps in alignment may exist. Therefore, Phase I of the 2022 NLQA focused on understanding producer perceptions of the lamb industry. This comprehensive approach will allow for a more holistic understanding of challenges and, more importantly, solutions that could improve product consistency and quality along the value chain.

Materials and Methods

Survey Approach

The producer perception survey was administered using software package (Qualtrics®, Provo, Utah) customized to develop a structured order of questions for each industry segment. The survey was distributed via in-plant visits, social media, and email. Survey respondents remained anonymous, each taking approximately ten minutes to complete. Respondents

completed an online survey from May 2022 to September 2022 with representatives from 32 states and Canada.

All industry segments answered five demographic questions during the first part of the survey. Respondents filled-in where their business/operation was located and their job title at their respective business/operation. Respondents were also asked to select their age split from 20 to 70 years into blocks of 10 years to help account for potential generational differences and their influence on perceptions within the lamb industry. Based on the respondent's response they were asked specific questions to their industry segment; they were directed to that specific section of the survey. The four industry segments included in the survey were: 1) breeding, wool, and show operations (9 questions), 2) feeder operations (10 questions), 3) packers and processors (13 questions), and 4) retailers and distributors (12 questions).

Questions were formulated based on themes from the 2015 NLQA. By asking targeted questions, valuable insights were gathered from stakeholders to understand the industry's current perceptions, identify potential improvement opportunities, and pressing challenges. Furthermore, respondents provided their definition of sustainability within the context of the lamb industry.

Data Analysis

Survey questions regarding current supply chain perceptions of the U.S. lamb industry were developed by Colorado State University. The survey was constructed for electronic dissemination using Qualtrics® Software (Qualtrics, Provo, Utah, USA). Methodology, data collection, and analysis was performed by Colorado State University. This survey was examined by the institutional review board (IRB) at Colorado State University (CSU IRB 3313). Additionally, analyses were performed using JMP® Software (JMP Pro, SAS Inst. Inc., Cary, NC), Microsoft Excel® for P.C. Frequency distributions, means, standard deviations, and

minimum and maximum values were determined using the distribution and summary functions of JMP and Qualtrics®. Thematic analysis was conducted on the three open-response survey questions. Analysis was conducted as explained by Braun and Clarke (Braun and Clarke, 2006). Open- responses for “In the next five years, what do you foresee will be your biggest opportunities? , “In the next five years, what do you foresee will be your biggest challenges?” , and “What does sustainability mean to your operation or business?” were sorted and narrowed in terms of descriptions to find commonalities between respondents.

Results

The analysis included 153 respondents. Thirty-two states and Canada (n=1) were represented (Figure 1), and the states with the most significant representation were Ohio (n = 16), Colorado (n = 12), and Utah (n = 10) (Figure 2). Of the responses, 88 percent identified themselves as owner or operator, four percent as chief executive officer or president, four percent as manager, one percent as a university or governmental official, and one percent as a lamb buyer (Figure 4). The distribution of respondents across the different age groups was 20-29 (8 percent), 30-39 (15 percent), 40-49 (28 percent), 50-59 (17 percent), and 60-69 (26 percent), and > 70 (eight percent). Survey respondents were distributed across industry segments as follows: 87 percent commercial breeding operations, 35 percent wool production operations, 21 percent feeders, 20 percent show operations, 15 percent retailers, seven percent packers/processors, and three percent distributors (Figure 4).

Over 75 percent of survey respondents identified themselves to be belonging in the breeding, wool, and show operations sector categories. When prompted to rank eight industry sector challenges (answered on a Likert scale from 1 = most important to 8 = least important), they identified the cost of operation (2.45), market volatility (3.61), and labor (3.69) (Table 1).

Three least important challenges were laws and regulations (5.15), transportation (5.36), and overfat/overweight lambs (7.29). Respondents ranked the importance of ten topics (1 = least crucial to business, 10 = extremely important) that face the breeding, wool, and show sectors of the industry. The top three important topics were animal welfare (8.76), sustainability (8.53), and lamb quality (8.04) for breeding, wool, and show operations (Table 2). The three least important topics for this sector were overfat lambs (4.64), no rolls/mutton (4.41), and grazing regulations (4.39). The types of production practices that operations participated in varied, but over 85 percent of the breeding, wool, and show operations in the current survey identified as having antibiotic-free programs.

Most survey respondents within the feeding operation sector represented small operations with under two hundred sheep on feed annually. In this survey, most operations source feed almost 100 percent locally within 100 miles. Similar to breeding, wool, and show operations, most feeding operations are family-owned and have less than ten employees. When prompted to rank industry sector challenges (1 = most important, 9= least important), the most crucial challenges identified are the cost of operation (2.94), supply-chain issues (i.e., plant capacity; 3.06), and consumer demand (3.94) (Table 3).

Feeding operations were asked to a ranking of importance of seven topics (1 = least crucial to business, 10 = extremely important) that face the feeding sector of the lamb industry, animal welfare (9.57), lamb quality (8.43), and sustainability (8.93) were the most important characteristics (Table 4). Similar to the breeding, show, and wool operations, the least important topics were overfat lambs (5.00) and no rolls/mutton (4.43).

There were eight packer/processor respondents. There were n= 8 packer/processor respondents included in the survey. From the current survey, 69 percent of processors sell whole

carcasses, 49 percent sell retail cuts, and 25 percent sell primals (Table 5). This adds up to more than 100 percent as processors could fit into more than one category. Most respondents identified as small processors (i.e., harvesting less than 500 animals per week; n = 6), and two processors harvest more than 1,500 animals per week. Plants varied in production methods consisting of one or multiple aspects of harvest, fabrication, and case-ready production operations.

Processors were asked to rank ten identified industry challenges within the last five years (1 = most challenging, 10 = least challenging; Table 6). The three most significant challenges identified were cost of operation (3.71), labor (3.86), and lamb supply for processing (4.00). The three least significant challenges identified were contamination/food safety (6.29), environmental regulations (6.43), and water (8.29). When processors were prompted with eight identified important topics (1 = least crucial to business to 10 = extremely important) that face their sector of the industry, loineye area (8.67), animal welfare (8.43), lamb quality (8.29) were the most important for processors (Table 7). In contrast, the least concerning are shelf-life (7.57) and fat (8.00). When sourcing lambs, processors indicated that they prioritize the purchase of antibiotic-free (8.80) and conventionally fed lambs (7.83; Table 8). Free-response questions were analyzed for a common theme and were grouped together based on themes and shown in Appendix 2. Central themes for challenges processors foresee in the next five years indicated that packers are concerned with finding a consistent supply of lambs year-round (67 percent) and operational costs (33 percent). Additionally, they identified increasing lamb demand (33 percent) and increasing retail and local markets (33 percent) as an opportunity to increase market space for the U.S. lamb processing industry.

In this survey, the retailers and distributors that were captured were small, direct-to-consumer businesses that were mainly associated with other sectors. Results from the current

survey suggest that these smaller direct-to-consumer businesses primarily source their lamb from the U.S. and Australia. Most products purchased are antibiotic-free (71.80 percent) and conventionally fed (grain-fed) (59.70 percent). This sector identified similar top challenges as others, including the cost of operations (3.13), consumer demand (3.63), and labor (4.00) (Table 9). Retailers and distributors foresee consumer demand and consistency in eating quality as challenges in the next five years (Appendix 2).

Discussion

Demographics

The objective of the current study was to evaluate specific sector perceptions about critical topics within the U.S. lamb industry. In the current survey, we captured various geographical regions across 32 U.S. states representing different climates, grazing regulations, and the purpose of the operation (meat and/or wool) . Based on 2023 NASS data, we captured all top ten sheep-producing states in the U.S (e.g. Texas, Wyoming, Utah, California, South Dakota, Colorado, Montana, Idaho, Iowa, and Oregon) NASS, 2023). The median age range for the respondents was 40-49 (n = 42), the average age of producers in U.S. agriculture is 57 years, which has increased by 1.2 years since 2012 (USDA, 2023). These survey results may have a lower average age range compared to the overall agricultural average due to the survey distribution method of only online and predominately distributed through social media channels. This could have attracted a younger demographic and influenced the age distribution of the respondents. However, there is no current data about the average producer age specific to the sheep industry, so it is hard to understand how representative this limited group of survey respondents are. All sectors were represented, with most respondents identifying themselves as part of a commercial breeding operation. This distribution closely aligns with the sector

representation in the sheep industry, where breeding animals account for over 75 percent of all sheep in the U.S. (NASS, 2023).

Breeding, Wool, and Show Operations

The majority of the respondents identified as associated with breeding, wool, and show operations. These sectors are pivotal in the foundation of the industry and provide and showcase genetic improvements for meat and wool production. According to the U.S Census of Agriculture, over 90 percent of operations in line have less than 100 sheep (USDA,2023). That is similar to our results, as the majority of producers captured in the sector had less than 100 sheep in their operation. Cost of operation, market volatility, and labor were identified as the most significant challenges in these sectors. Many factors contribute to operational costs. Feed costs are typically the most expensive expense for an operation (Lammers, 2007). The prices of feed ingredients for the past several years have continually increased. The sheep market inherently faces volatility influenced by factors such as drought or predators' losses. Additionally, lamb demand at retail is inelastic, which means slight changes in volume can create significant swings in price (ASI, 2015). At a national level over a span of eight years (2010 to 2018) hired labor costs have increased 258 percent, and operator/family labor costs have increased 24 percent (ASI, 2019).

Important topics identified in this sector were animal welfare, sustainability, and lamb quality. The increasing social and scientific concern regarding animal welfare has been growing, and the public perception of animal welfare drives improvements within the industry (De la Fuente et al., 2017). In a large global study that looked at international perceptions of animal welfare. The large majority of participants, 86.8 percent, agreed that animal welfare of farmed animals was important to them (Sinclair et al., 2022). Additionally, findings from the 2015

NLQA showed that companies would be willing to pay (WTP) up to 14 percent more for products assuring proper raising practices (Hoffman et al., 2015). Implementing proper management and welfare practices increases not only productivity but also profitability.

Topics that were not as important in this sector were no rolls/mutton and grazing regulations. No rolls/mutton may not matter to this particular sector if they are not feeding them to slaughter weights, and majority of lamb in the U.S. is sold on a live weight basis, not age quality indicators. (Thorne et al., 2021). There are many things that producers can do to manage lamb quality such as growth rates, grazing, and management practices (Penn State Extension, 2022). Based on the lamb lifecycle, this sector is the beginning of the supply chain, and most typically these sheep and lambs are managed in grazing systems. Stocking rates for grazing management in this sector are determined by the age of lamb, available forage, and duration of grazing. Under or over grazing will have the largest impact on the health of grasslands, as well as animal performance (Meehan et al., 2018). Grazing is largely utilized by producers in the Western U.S., with over 245 million public acres utilized by primarily beef and lamb (Bureau of Land Management, 2023). As grazing ruminants, lamb can improve the ecology of the land they graze such as sequestering carbon and supporting soil health (ALB,2023).

Feeder Operations

Feeding operations are a vital segment of the lamb industry as these operations feed and house animals until they have reached slaughter weight. Traditionally, lambs are bought from various sources and are fed in confinement until they are shipped to harvest. Colorado is home to the largest lamb feedlots in the U.S. with an average of 81,000 lambs on feed at any given time of the year (AMS, 2023). Large feedlots (>2,000 head) were not captured in the current study, so further research should be conducted to include large feedlots such as those in Colorado.

In the feeding sector, the most crucial challenges identified were the cost of operation, supply chain issues, and consumer demand. As expected, nearly all production expenses have increased in the last decade. Most notably, livestock farm-origin expenses have increased by 46 percent, and marketing, storage, and transportation expenses have increased by 59 percent (Myers, 2022). The COVID-19 pandemic caused production facilities within the supply-chain to restrict production or slow down, resulting in lower production volumes and a backlog of animals. According to data reported in May 2020, the COVID-19 pandemic resulted in 1.1 billion pounds of all meat produced below 2019 averages (Widmar et al., 2022).

Similarly, to the breeding, show, and wool operations, animal welfare, lamb quality, and sustainability were of upmost importance for the feeder operations in the current study. According to the ALB, industry stakeholders are committed to promote quality assurance, training, and existing sheep care resources to continually improve lamb care and well-being (ALB,2023). Lamb quality in this sector could mean achieving optimum weights and fat to meet the market's needs at a specific time of the year. According to Brady et al. (2003), the primary factors that determine the value of lamb carcasses are hot carcass weight (HCW) and yield grade (YG). As a result, this sector does not face challenges from lambs that are overweight or have excess fat. Sustainability in this sector can refer to optimizing finish or decreasing excessive fat, as well as increase water efficiency use (ALB,2023). Decreasing excessive fat can also increase lamb quality. As found, 2015 NLQA indicated that eating satisfaction was the most important quality attribute thus, management that influences the fatness and flavor of lamb (e.g., days on feed, slaughter weight) should be considered in U.S. lamb production (Hoffman et al., 2015).

Processors

Processors purchase lamb from feeding operations and prepare lamb for retail distribution. This sector identifies and establishes the value of the carcass by hot carcass weight (HCW), yield grade (YG), and quality grade (QG). Selling whole or half lamb for consumers to put into their freezers is the most common form of direct marketing lamb (Schoenian,2021). These lambs are sold by carcass weight and either shipped to the east coast or to further processing facilities.

For ranking of importance of essential lamb characteristics, loin eye area, animal welfare, and lamb quality (defined as CH or PR) were the most important to the processor. We did not ask which specific animal welfare or quality claims processors desired on their products. Future research into specific claims processors prefer, can help guide the producer segments on future management practices. A larger loin eye area increases HCW, which results in higher value as the majority of lambs' carcasses are primarily valued for HCW (Brady et al., 2003). Processors from the present prefer antibiotic-free and conventional-fed lamb when they source them. From the 2015 NLQA, retail markets in 11 states indicated almost a \$2.00/lb premium for source-branded, locally raised, and grass-fed label claims (Hoffman et al., 2015). Additionally, the 2015 NLQA responses to “What attributes would be of value for product and label of American Certified Lamb?” indicated largely grass-fed and a few antibiotic-free responses as central themes. Including processors in the current survey enables gathering additional data that can be effectively communicated to producers.

Retailer and Distributor

Retailers and distributors represented a small amount of the surveys represented. To capture more respondents in this sector, an additional survey will be conducted in 2023 as Phase

III of the 2022 NLQA, which will closely mimic the 2015 NLQA survey to correlate similarities and differences in the retailer/consumer segment to be able to compare directly from 2015 to 2023.

Though, the surveys captured in this present study were newer companies (0 to 5 years old), with the majority representing direct to consumer markets. There is an opportunity to continue increasing lamb products in the grocery store or restaurant plate. Additionally, retailers and distributors purchase roughly 85 percent conventionally fed, and 15 percent grass fed, and 100 percent from the United States. Moreover, regulations, and the volatility of the market are the most important challenges in this sector. However, this is representing a very small portion of retailers and distributors in the U.S., so more research and survey responses are needed to fully represent the entirety of this sector. Consumer needs and expectations evolve with time. As a result, the lamb industry must continually adapt to meet consumer expectations. Since the 1960s, per capita consumption has dropped from nearly 2.5 kg to less than 1 kg (USDA ERS, 2020). Increasing the demand for lamb is a significant opportunity for industry to increase consumption.

Sustainability

Most respondents demonstrated a basic understanding of sustainability, which aligns with the definition of sustainability put forth by the United Nations Brundtland Commission in 1987: "meeting the needs of the present without compromising the ability of future generations to meet their own needs." Aligned with these thoughts, the responses revealed central themes, including environmental concerns, grazing management, the balance of economic, social, and environmental aspects, and productivity and profitability as definitions for sustainability. The sustainability responses provide valuable insights that should be used within the industry and

built upon by industry organizations. Advancing and promoting sustainable management practices will be critical to the U.S. sheep and lamb industry.

As consumer demands change, benchmarking, and monitoring industry progress of quality characteristics to maintain viability in the U.S. lamb industry is crucial. The NLQA collecting data through surveys and in-plant data can be beneficial to track progress. Previous studies have indicated that regular audits will promote consistency and improvement, aiming to improve the quality of U.S. lamb as a point of differentiation from imported product (Whaley et al., 2022). Over the past 30 years, three NLQAs have been completed in 1992, 2007, and 2015 (Hoffman et al., 2015). Past NLQAs were a starting place for the industry to identify these challenges. However, there is minimal data from past audits capturing the beginning of the supply chain. To enhance the industry, it is crucial to gain a comprehensive analysis through data collection to understand areas of improvement for each industry sector to meet evolving consumer needs.

Conclusion

The phase I supply chain survey of the NLQA helped capture current perceptions of the U.S. lamb industry. Although lamb represents less than one percent of the U.S. livestock industry, lamb operations are crucial parts of several state economies (USDA ERS, 2020). Respondents across the U.S. have similar viewpoints on the industry's most challenging aspects. Increased operation costs are widely problematic to producers and business operators. Still, by understanding the information presented in this survey, industry stakeholders can begin to use these perceptions in addition to the in-plant audit in Phase 2 of the NLQA to enhance the quality, consistency, and competitiveness of U.S. lamb. This can promote continuous viability in the face of challenges such as import pressure and consumer demand. The future inclusion of the second

survey, looking specifically at the foodservice and consumer perspectives, will align opportunities and compare progress for an industry comparison between 2015 to 2023.

Respondents across the supply chain emphasized lamb quality, animal welfare, and sustainability as the top important attributes of their respective operations and businesses. The current survey defined lamb quality as Prime (PR) and Choice (CH). However, 98 percent of all lambs are categorized as CH or PR (ASI, 2015), so there is currently no incentive for or between PR and CH for producers, as most lamb carcasses are primarily valued for HCW and YG (Brady et al., 2003). Producers' perceptions of lamb quality need to be investigated further. Further evaluation of interpreting what lamb quality means to each specific sector may be beneficial to understand and more rapidly progress the industry forward. The increasing social and scientific concern regarding animal welfare has been growing (De la Fuente et al., 2017).

The least important topics to most sectors were overfat lambs and no rolls/mutton. Results from phase II indicate there are a lot of excessively fat lambs identified by measured fat thickness. However, most producers are paid based on live weight or HCW. Increasing weight, whether fat or muscle, increases the net return for the producer. Though for the packer and processor, excessively fat lambs slow down fabrication time due to increasing trimming to meet specifications and reduce profit as fat is valued significantly less than red meat. Identifying a value-based grid system that benefits both the producer and the packer may be needed to increase the consistency and uniformity of carcasses going into the supply-chain. Overall, further research is needed to examine the cost of excessive fat in lambs and determine if leaving lambs on feed longer is a viable option for increasing profit margins in the lamb industry. This leads to why the next phase of the current study will provide insightful and valuable data for the industry and allow it to be used as a starting point to monitor progress.

Table 1. Breeding, show, and wool operations survey respondents ranking of eight challenges relevant to the breeding, show, and wool operations in the U.S. lamb industry from 1 = most important to 8 = least important

Challenges	Mean	Min	Max	Standard Deviation
Cost of operation	2.45	1.00	7.00	1.76
Volatility of market	3.61	1.00	8.00	1.88
Labor	3.69	1.00	8.00	2.17
Land	3.81	1.00	8.00	1.85
Water	4.66	1.00	8.00	2.17
Laws/Regulation	5.15	1.00	8.00	1.89
Transportation	5.36	2.00	8.00	1.48
Overfat/Overweight lambs	7.29	1.00	8.00	1.30

Table 2. Breeding, wool, and show operation survey respondents priorities of seven essential topics on a whole number line scale from 1= least important to 8 = most important

Topics	Mean	Min	Max	Standard Deviation
Animal welfare	8.76	1.00	10.00	2.07
Sustainability	8.53	1.00	10.00	1.99
Lamb quality	8.04	1.00	10.00	2.39
Ribeye area	6.77	1.00	10.00	2.73
Overfat lambs	4.64	1.00	10.00	2.83
No Rolls/Mutton	4.41	1.00	10.00	3.23
Grazing regulations	4.39	1.00	10.00	3.48

Table 3. Feeder lamb operation survey respondents ranking of nine challenges relevant to the feeder sector of the U.S. lamb industry from 1 = most important to 9 = least important

Topics	Mean	Minimum	Maximum	Standard Deviation
Cost of operation	2.94	1.00	5.00	1.60
Supply-chain issues	3.06	1.00	8.00	1.64
Consumer demand	3.94	1.00	7.00	1.71
Labor	4.63	1.00	9.00	3.06
Volatility of market	5.06	1.00	9.00	2.63
Water	5.06	1.00	9.00	2.75
Regulations	6.06	2.00	8.00	1.89
Overfat/overweight lambs	6.94	3.00	9.00	1.48
Contamination/food safety	7.31	3.00	9.00	1.65

Table 4. Feeder lamb operation survey respondents priorities of seven topics on a whole number line scale from 1= least important to 10 = most important

Topic	Mean	Min	Max	Standard Deviation
Animal welfare	9.57	6.00	10.00	1.05
Lamb quality	8.43	5.00	10.00	1.58
Sustainability	8.93	5.00	10.00	1.92
Loineye area	7.85	3.00	10.00	2.54
Grazing regulations	6.00	1.00	10.00	3.54
Overfat lambs	5.00	2.00	9.00	2.76
No Rolls/Mutton	4.43	1.00	10.00	2.50

Table 5. Percentage of the product types lamb processors sell to wholesalers and/or retailers

Product Type	Mean	Minimum	Maximum	Standard Deviation
Whole carcasses	69.20	46.00	100.00	19.86
Primals	25.50	10.00	47.00	13.54
Retail cuts	49.00	5.00	100.00	35.83

Table 6. Lamb processor survey respondent ranking of ten challenges relevant to the U.S. lamb industry in the last five years from 1 = most important to 10 = least important

Challenge	Mean	Min	Max	Standard Deviation
Cost of operation	3.71	1.00	9.00	1.75
Labor	3.86	1.00	9.00	2.85
Supply	4.00	2.00	7.00	1.51
Consumer demand	5.00	1.00	9.00	2.62
Volatility of market	5.43	2.00	9.00	2.56
USDA regulations	5.71	2.00	10.00	2.91
Overfat/overweight lambs	6.29	1.00	10.00	2.66
Contamination/food safety	6.29	1.00	10.00	3.15
Environmental regulations	6.43	3.00	9.00	2.06
Water	8.29	2.00	10.00	2.73

Table 7. Lamb processor survey respondent ranking of four pre-selected source types whole number line scale from 1 = least important to 10 = most important

Source Type	Mean	Min	Max	Standard Deviation
Antibiotic Free	8.80	7.00	10.00	1.17
Conventionally-Fed	7.83	6.00	10.00	1.34
Certified Source Verification Programs	5.25	1.00	9.00	2.86
Grass-Fed	4.00	1.00	9.00	3.10

Table 8. Lamb retail and distributor survey respondents priorities of eight topics on a continuous line scale from 1= least important to 8 = most important

Topics	Mean	Min	Max	Standard Deviation
Cost of Operation	3.13	2.00	5.00	1.05
Consumer Demand	3.63	1.00	5.00	1.22
Water	4.00	1.00	7.00	2.29
Labor	4.13	1.00	8.00	2.67
Supply	4.13	1.00	6.00	1.83
Regulations	4.25	1.00	7.00	2.33
Volatility of Market	6.00	2.00	7.00	1.66
Cost of Importing vs. American	6.75	2.00	8.00	2.22

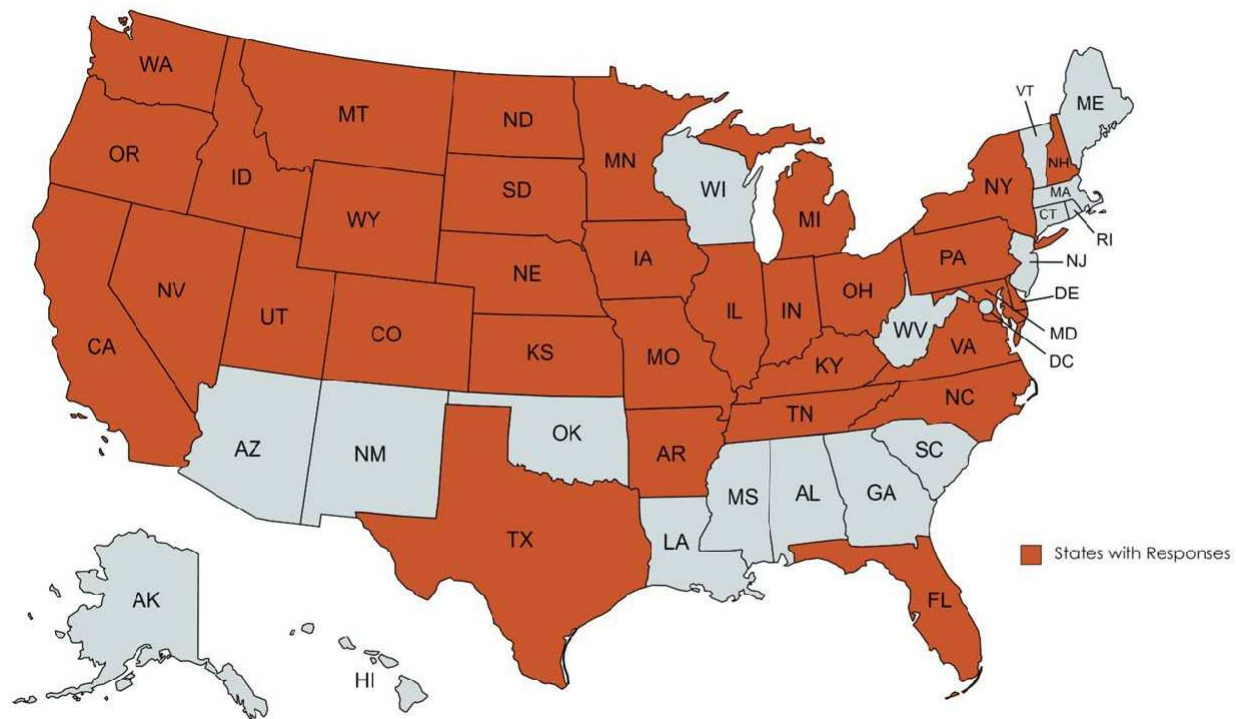


Figure 1. States represented in 2022-NLQA Phase I Survey

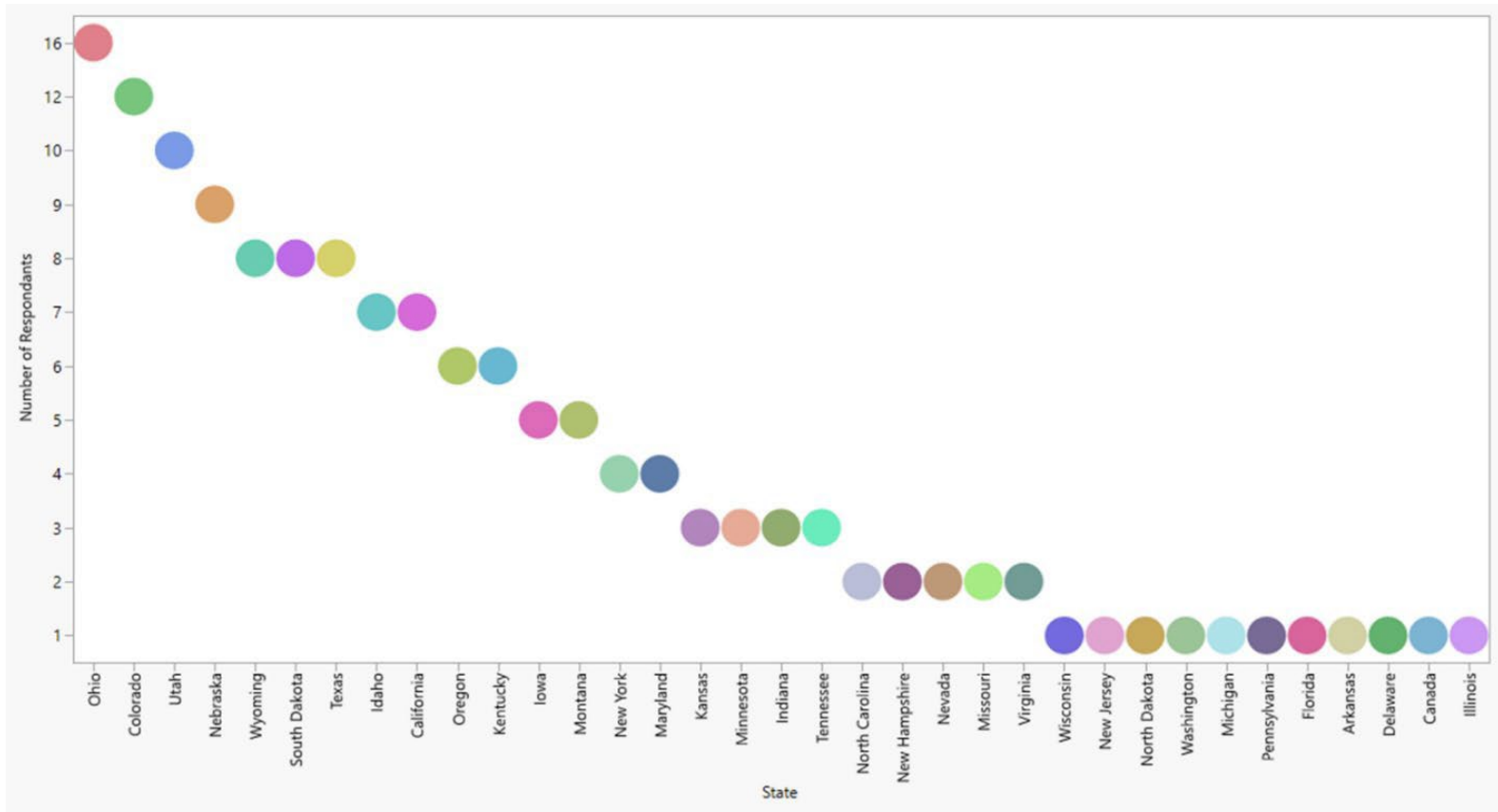


Figure 2. Number of respondents from each U.S. state and Canada in 2022-NLQA Phase I Survey

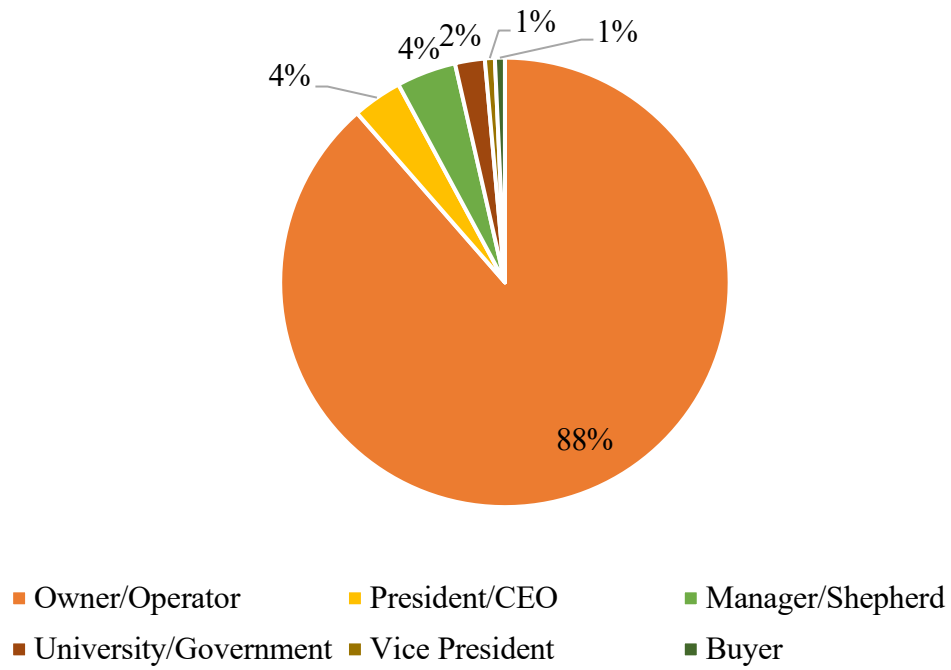


Figure 3. Job title of respondents in 2022 NLQA-Phase I Survey

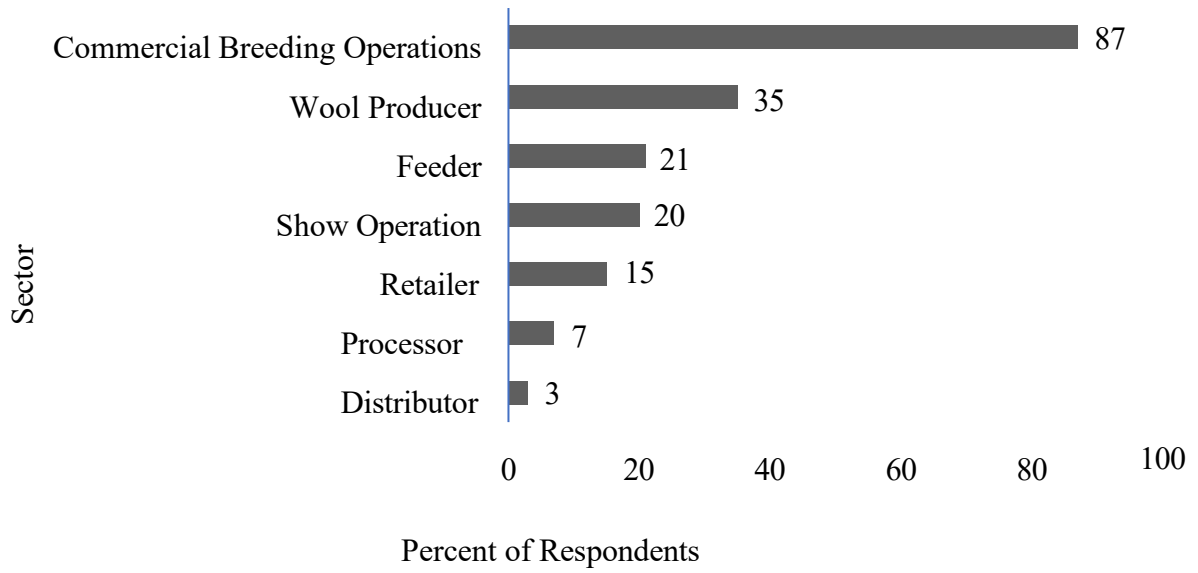


Figure 4. Distribution of sector representation in 2022-NLQA Phase 1 Survey

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CHAPTER 3: 2022 NLQA PHASE II: IN-PLANT AUDIT OF CARCASS
CHARACTERISTICS RELATED TO QUALITY AND VALUE OF FED LAMBS 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 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 II 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 2.54cm, 2.54 to 5.08 cm, 5.08 to 7.62cm, 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 number of permanent incisors and 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 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 carcasses 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 carcasses for skeletal maturity, degree of flank streaking, and adjusted fat thickness, and then assigned the carcasses 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 10. 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) The 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 11). The wool length was observed for 2,604 carcasses, 35 percent (n = 905) was 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 12). The largest category represented was the shorn or less than 2.54 cm of the wool group. There was low correlation between mud score and wool length (0.22, $P < 0.001$) (Figure 7). 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 13).

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 14). 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 15). There is a small relationship between dentition and spool joints ($R^2=0.31$, $P=<0.001$)(Figure 8) .

Carcass Assessment

Carcass data for n = 2,464 carcasses are presented for across plants (A, B, C, D). Across all plants the mean USDA YG was 2.71 ± 0.97 (Mean \pm SD), mean USDA QG was CH, mean HCW was 39.9 ± 9.08 kg., and mean MFT was 0.97 ± 0.38 cm (Table 16). The distribution of carcasses stratified by USDA QG and YG indicated as YG increased from one to five, the percentage of PR carcasses increased by almost 29 percent (Table 17). In contrast, as YG increased from one to five the percentage of CH carcasses decreased from 95 percent to 66 percent. 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 18). 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 ($P=<0.001$). For HCW, between groups, group 1 was different from group 2, group 1 = 38.00 ± 0.26 kg (Mean \pm SE) and group 2 = 41.40 ± 0.24 kg ($P=<0.001$). For MFT between groups, group 1 was different from group 2, group 1 = 0.86 ± 0.01 cm, and group 2 = 1.06 ± 0.01 cm ($P=<0.001$). Table 19 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) ($P < 0.001$). 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) ($P < 0.001$).

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). In a 100-person consumer study of lamb, they found that meat from castrated animals scored higher ($P < 0.05$) 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. From the survey portion of the audit every sector mentions animal welfare as a top three important factor to their operation or business. 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.

Wool length was evaluated on 2,604 carcasses (Table 12). 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 from lamb harvesting, so the industry should take action to ensure pelts are adding value to the industry. We evaluated the correlation between mud score and wool length (Figure 7). The correlation ($R^2= 0.22$, $P= < 0.001$) 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 (Table 13). Speckle-faced sheep are common as operations commonly cross a blackface sire on a whiteface ewe to produce terminal crosses. Blackface breeds tend to have increased growth and carcass traits, whereas whiteface breeds tend to have higher maternal and wool traits (Schoenian, 2021). Rambouillet (whiteface 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 which 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 (Table 14). However, dentition of the same carcasses audited resulted in 78 percent of carcasses displaying zero or one permanent incisors, indicating carcass maturity (Table 15). When the correlation between the number of permanent incisors and spool joints was evaluated ($R^2=0.31$, $P=<0.001$), there was significant relationship; however, the relationship would not be considered strong (Figure 8). 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.

Additionally, normally the front two cannon bones (trotter) are left attached to the 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. Based on the results of 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 suggests 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 in some cases provides the basis to assist consumers in selecting meat cuts to provide eating satisfaction (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 method 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 and others 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 (Tighe et al., 2017). 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 to further differentiate the value and consumer preference of the carcasses in the U.S. market. The mean HCW for all plants was 39.9 kg, and the mean fat thickness was 0.97 cm (Table 16). The average carcass weight from NASS 2022 data is 31.8 kg. 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 was higher than NASS data, which may be largely due to the smaller population size in the current study.

Additionally, in 2023, NASS reported the number of lambs under 29.5 kg decreased by 2.9 percent, carcasses that fell between 29.5-38.1 kg decreased by 2.1 percent, while lambs between 38.6 - 47.6 kg. rose 4.9 percent from 2021 (NASS, 2023). The current study may have captured larger carcasses due to this shift of larger lambs compared to the 2022 data. 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 are required to 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. 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 (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). The chilled carcass component 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, 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 is 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 using further implementation to measure YG had a higher USDA-reported YG but had a lower difference in calculated YG based on the lamb YG grade equation. 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. This indicates that probing and camera grading systems may significantly improve more 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 want 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 means to each sector is crucial to understand the best way to measure and incentivize and evaluate the current QG system.

Conclusion

The 2022 NLQA serves as a baseline to measure and report lamb carcass traits in the U.S. production system. Based on results from the current study the use of probes and camera

grading systems are the most accurate systems when determining YG. Additionally, further research evaluating if the current QG system is the best representation of characterizing differentiation of carcasses that are associated with consumer satisfaction. Future audits capturing shifts in seasonality challenges should be considered to evaluate the trends in quality, yield, and maturity indicators. Results from this audit will provide valuable information and data to the existing knowledge base of the lamb industry regarding carcass quality attributes. Due to the 98 percent of lamb qualifying for PR and CH and with no price spread between grades, lambs are primarily marketed on weight and YG. The inconsistency in YG measurement techniques found in the present study further complicates the marketing techniques of lamb. The YG technique varies across plants and showed that probe and camera grading measurement systems had a smaller difference between USDA YG and calculated YG. Future research evaluating lamb QG and YG systems may be important to maximize the percentage of boneless, closely trimmed retail cuts and develop more carcass consistency.

From Phase I of the present study, respondents identified animal welfare, lamb quality, and sustainability as the most important topics to supply chain operations or businesses. Phase II was able to collect data related to what the supply chain identified as important and challenging topics. As found in Phase II of the present study, mud score which is attributed to animal welfare concerns was not identified as a concern in the present audit. Though due to the audit being conducted in the summer months further research should be conducted to identify if seasonality differences exist between summer and winter months. Although, carcass characteristics showed further research for evaluation of USDA YG and QG systems in the U.S. YG measurement systems need further investigation to analyze if camera grading or probe measurements is more accurate. Excess fat is costly to all aspects of the supply chain. Though, in the present study

shows that the increase of YG indicates higher quality lamb. For producers it equates to extra time on feed past optimal endpoints. For processors it adds additional processing and fabrication time as more fat as to be trimmed to meet specification. All of these factors have a role in lamb quality and sustainability. For lamb quality, as indicated in the 2015 NLQA indicated that eating satisfaction was the most important quality factor attribute. Though management that influences fatness and flavor should be considered in lamb production system (Hoffman et al., 2015). To enhance the lamb industry, it is crucial to gain a comprehensive analysis of what needs to be improved at the plant level.

Table 9. Sex classed identified across all plants in the 2022-NLQA Phase II audit (n = 1,605).

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

Table 10. Mud score across all plants in the 2022-NLQA Phase II 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 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 (NBQA, 2016).

Table 11. Wool length across all plants of the 2022-NLQA Phase II 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 12. Breed type across all plants of the 2022-NLQA Phase II 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 13. Spool joints observed at all plants in the 2022-NLQA Phase II 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 14. Permanent incisors observed at all plants in the 2022-NLQA Phase II 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 15. Carcass characteristics of lamb and mutton carcasses across all plants in the 2022-NLQA Phase II 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 16. Distribution (%) of carcasses stratified by USDA quality and yield grades in the 2022-NLQA Phase II 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 17. 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 Phase II 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

² Plants B and D

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 18. 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 Phase II audit.

Group	n ¹	USDA Yield Grade	Calculated Yield Grade ²	t-Value	Standard Error ³	P-Value
Group 1 ⁴	970	2.80	3.71	-17.48	0.03	<0.001
Group 2 ⁵	1267	2.64	4.51	-35.87	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

⁵ Plants B and D

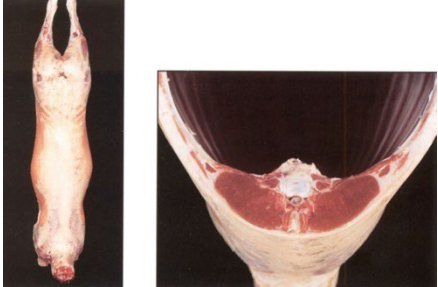
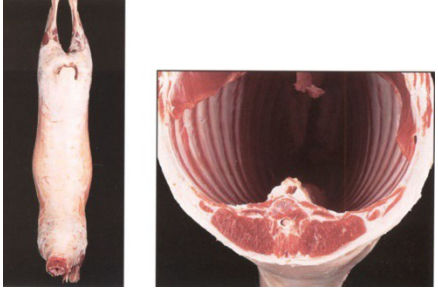
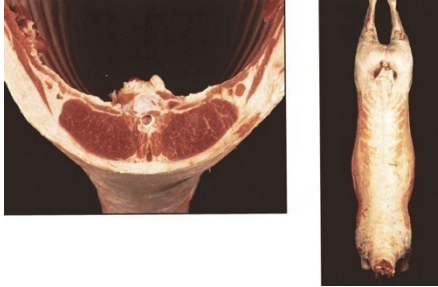
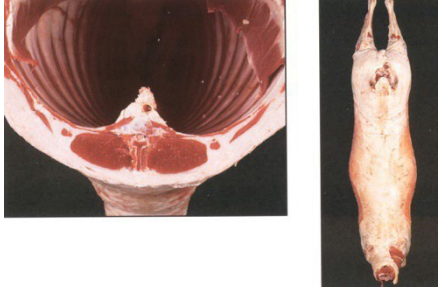
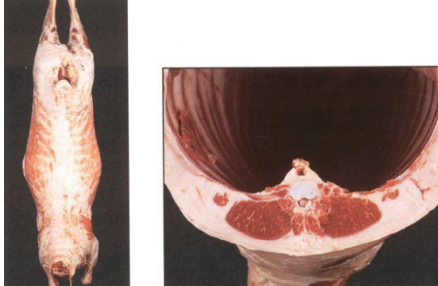
Yield Grade 1	A yield grade 1 has a thin layer of external fat over the back and loin and slight deposits of fat in the flanks and cod/udder. There is usually a thin layer of fat over the shoulders and outsides of the leg.	
Yield Grade 2	A yield grade 2 usually has a thin layer of fat over the back and 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 great than that of a yield grade 4.	

Figure 5. 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.

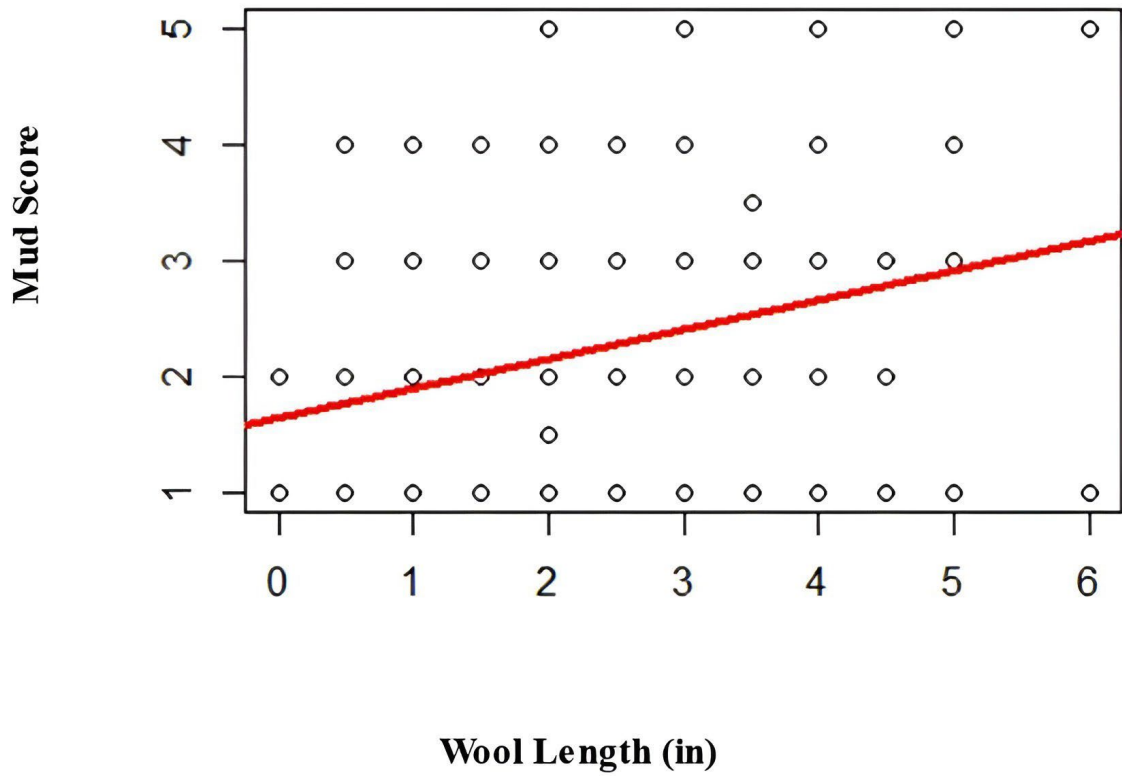


Figure 6. Correlation between wool length and mud score for lambs across all plants in the 2022-NLQA Phase II audit.

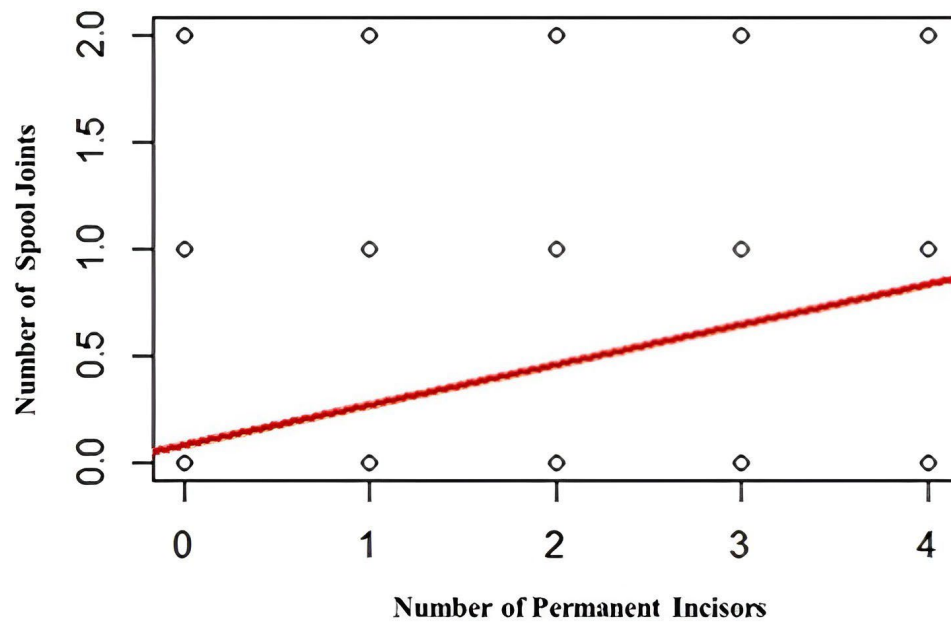


Figure 7. Correlation between permanent incisors and spool joints across all plants in the 2022-NLQA: Phase II audit.

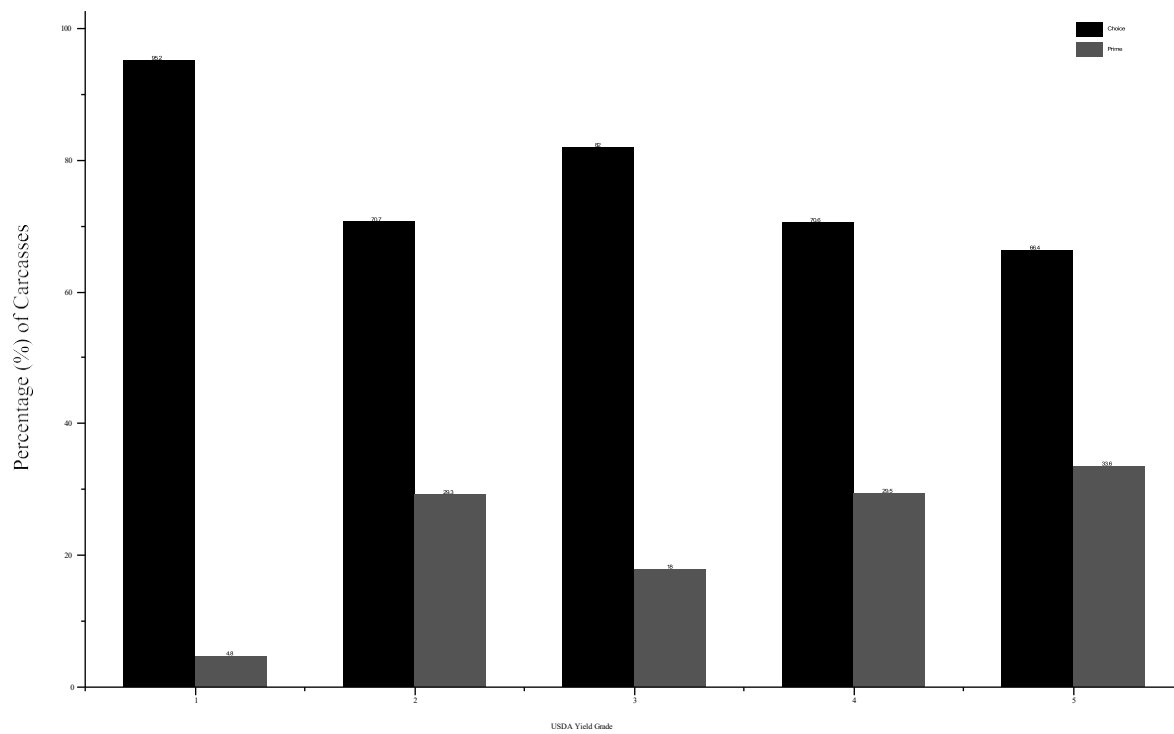


Figure 8. Distribution (percent) of carcasses stratified by USDA quality and yield across all plants in the 2022-NLQA Phase II audit (n=2,237)

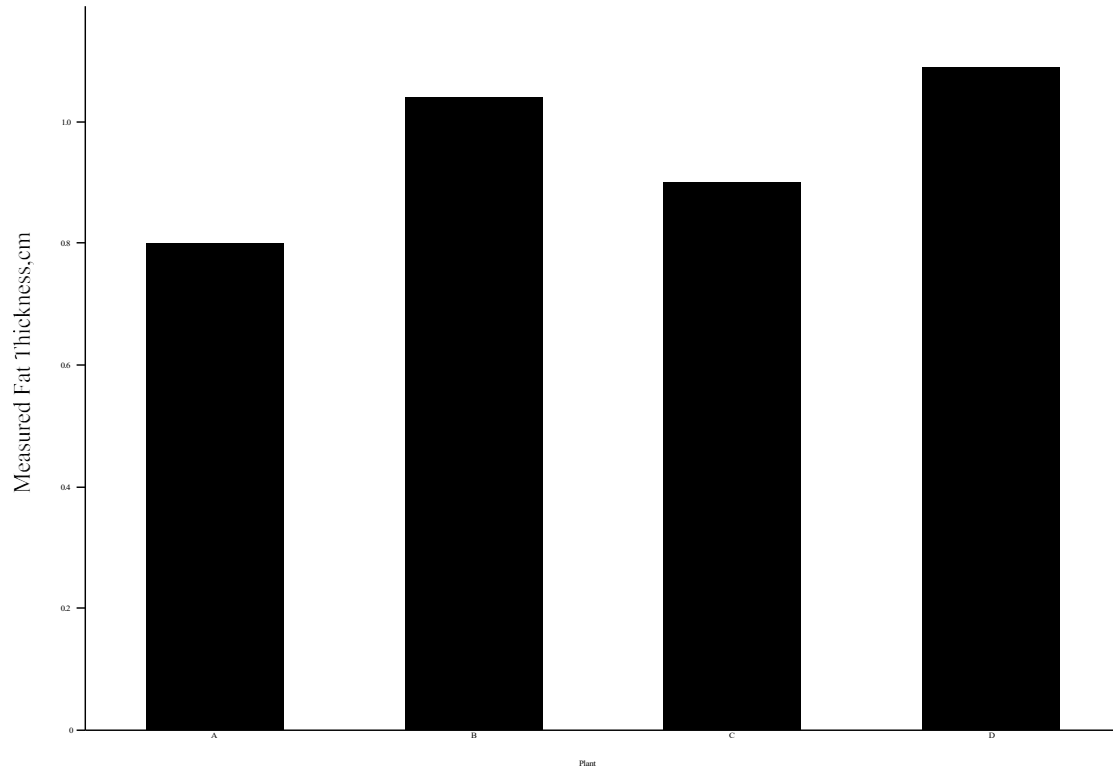


Figure 9. Measured fat thickness across all plants in the 2022-NLQA Phase II audit (n=2,237)

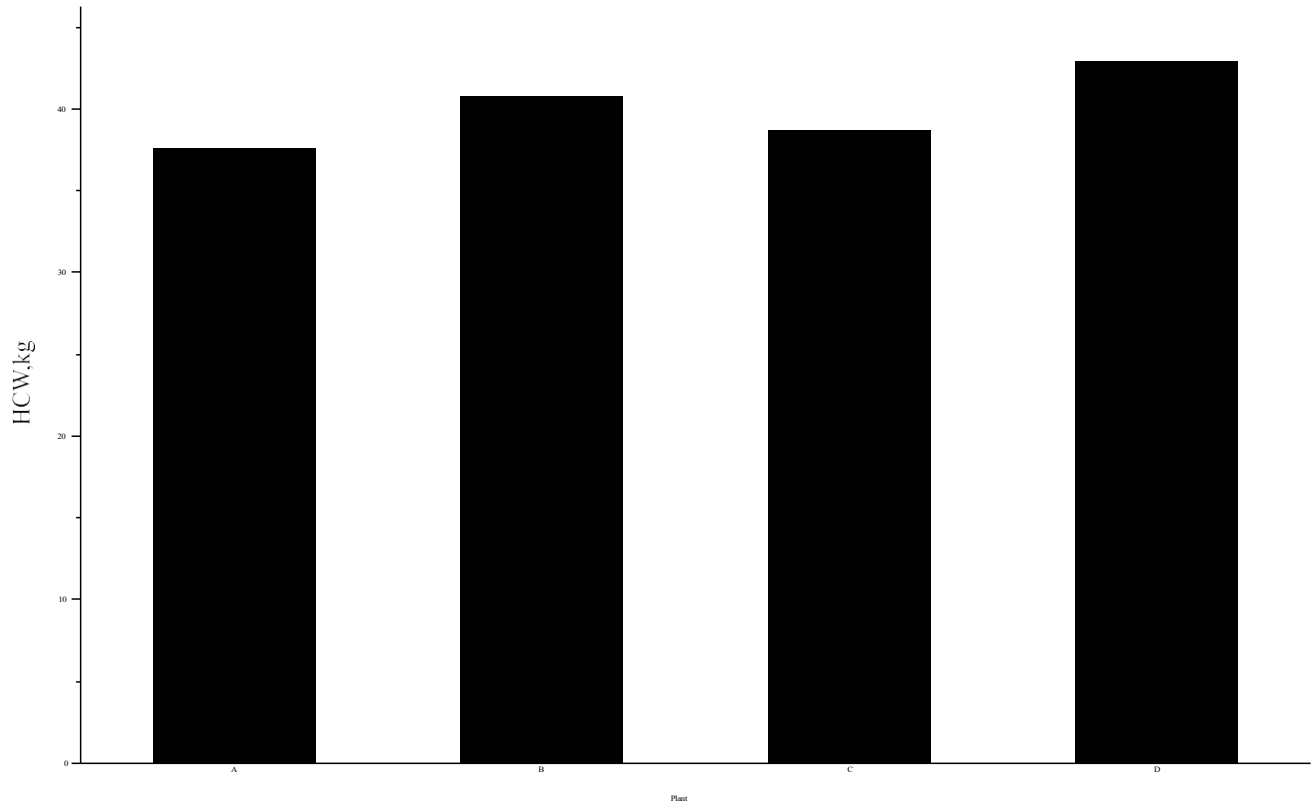


Figure 10. Hot carcass weight across all plants in the 2022-NLQA Phase II audit (n=2,237)

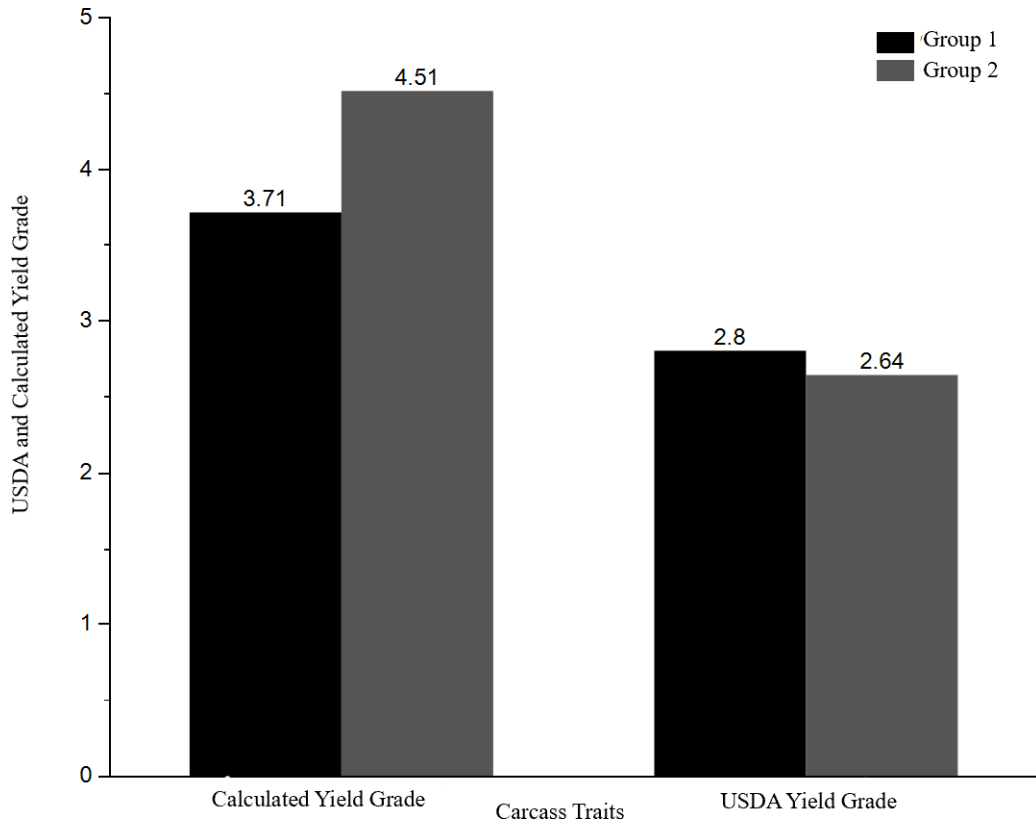


Figure 11. Estimated means between USDA yield grade and calculated yield grade of lamb and mutton carcasses compared between in-plant grading systems (Group 1- probe or camera grading and Group 2- visual assessment) in the 2022-NLQA Phase II audit

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APPENDIX 1: 2022 National Lamb Quality Audit Phase 1 Survey Questions

General (all) Questions

1. Where is the Business/Interviewee located (City/State)? (Fill-in-the-blank)
2. What is your title at your company? (Fill-in-the-blank)
3. What is the age of the interviewee? (Multiple choice)
 - a. 20-29
 - b. 30-39
 - c. 40-49
 - d. 50-59
 - e. 60-69
 - f. 70+
4. What category does your company or business fall into? (Select all that apply)
 - a. Processor/Packer
 - b. Seedstock/Breeding/Commercial Lamb Operation
 - c. Wool Production
 - d. Show Lamb
 - e. Feeder
 - f. Retailer
 - g. Distributor
5. What does sustainability mean to your operation or business? (Short answer)

Packer/Processor Questions

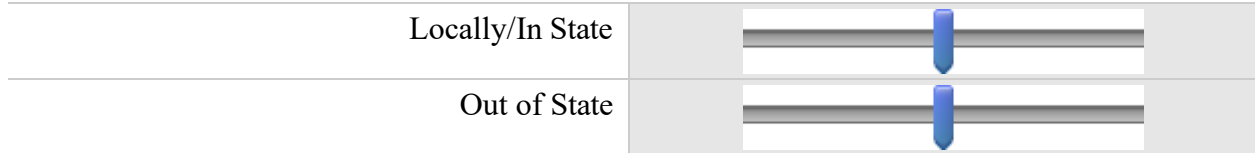
1. How long has your facility been in operation? (multiple-choice)
 - a. 0-5 years
 - b. 6-10 years
 - c. 10-20 years
 - d. 20 or more years
2. How many lambs on average do you process a week? (Multiple choice)
 - a. 1-500
 - b. 501-1,000
 - c. 1,001-1,500
 - d. 1,501-2,000
 - e. 2,001-2,500
 - f. 2,500+
3. How many employees do you have? (Multiple choice)
 - a. 0-10
 - b. 11-50
 - c. 51-100
 - d. 100+
4. What does your facility do? (Select all that apply)
 - a. Harvest
 - b. Fabrication
 - c. Case-Ready
5. Rank these challenges in order of importance referencing the last 5 years.
 - a. _____ Labor
 - b. _____ Supply issues (of lamb, equipment etc.)
 - c. _____ Water
 - d. _____ Consumer demand
 - e. _____ Cost of Operations
 - f. _____ Environmental Regulations
 - g. _____ Overfat/Overweight lambs
 - h. _____ Contamination/Food Safety
 - i. _____ Volatility of Market
 - j. _____ USDA Regulations
6. Rank these challenges in order of importance referencing the last 5 years.
 - a. _____ Labor
 - b. _____ Supply issues (of lamb, equipment etc.)
 - c. _____ Water
 - d. _____ Consumer demand
 - e. _____ Cost of Operations
 - f. _____ Regulations
 - g. _____ Overfat/Overweight lambs
 - h. _____ Contamination/Food Safety
 - i. _____ Volatility of Market

7. Where do you market your product? (Select all that apply)

- a. Locally (Within State)
- b. Regionally (Surrounding States)
- c. Nationally (Across U.S.)
- d. Internationally

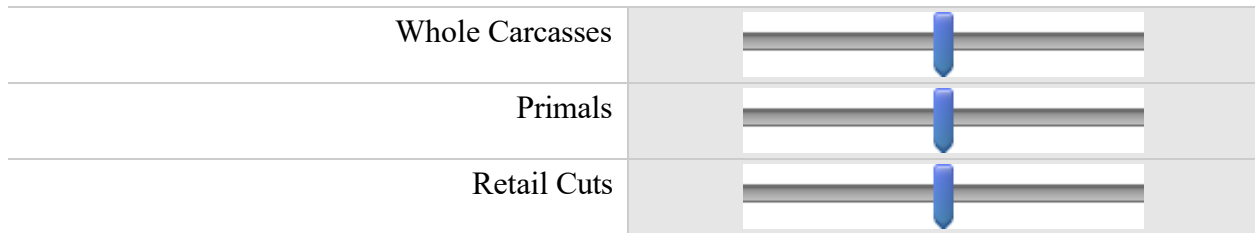
8. What percentage of your lambs come from these sources? (Continuous line scale, %)

0 10 20 30 40 50 60 70 80 90 100



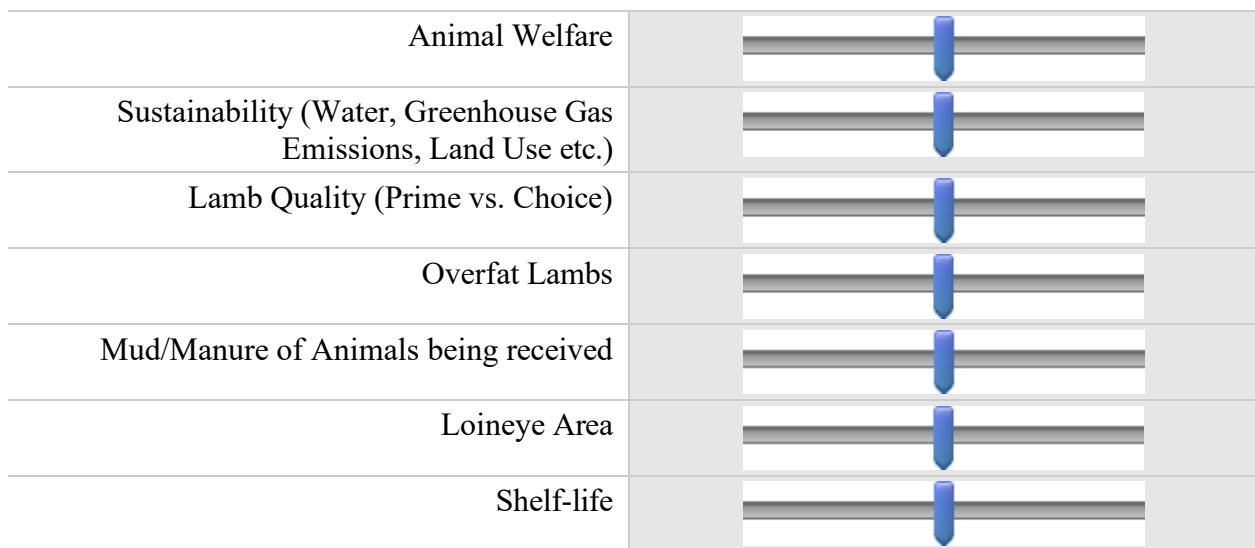
9. What percentage of your products fall into these categories? (Continuous line scale, %)

0 10 20 30 40 50 60 70 80 90 100



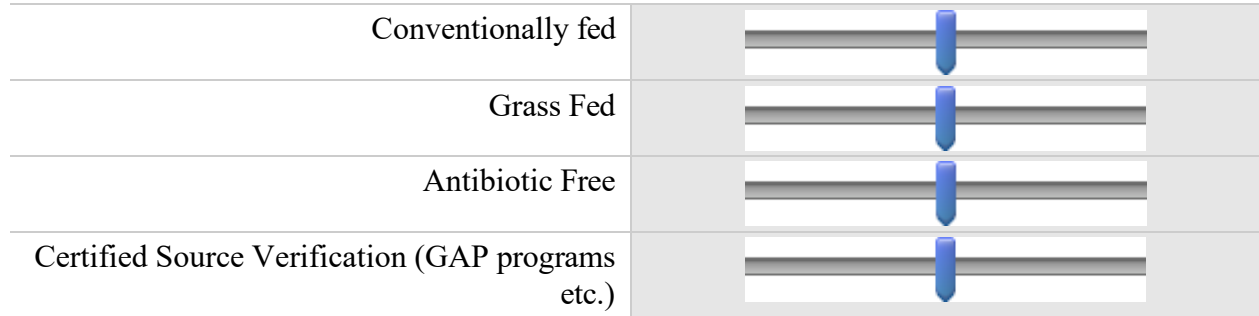
10. How important are these issues to your company, scale of 1-10?

1 2 3 4 5 6 6 7 8 9 10





11. On a scale of 1-10 how important are these characteristics when sourcing lamb?
 1 2 3 4 5 6 6 7 8 9 10



12. In the next five years, what do you foresee will be your biggest opportunities as a packer?
 (Short answer)

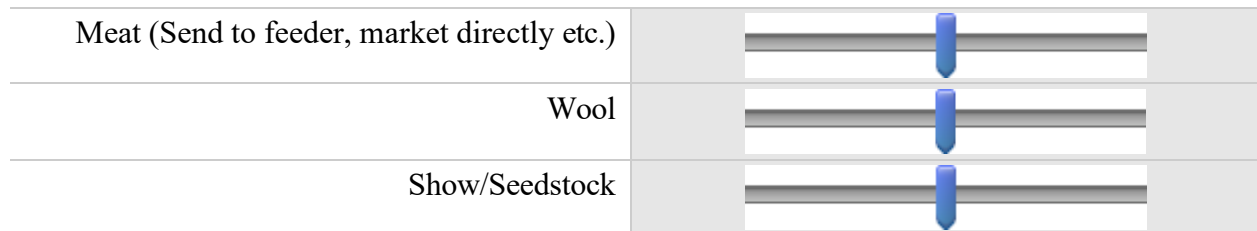
13. In the next five years, what do you foresee will be your biggest challenges as a packer?
 (Short Answer)

Seedstock/Breeding Operation, Wool Production, Show Lamb Operation Questions

1. How many years has your operation been in business? (Multiple choice)
 - a. 0-5 years
 - b. 5-10 years
 - c. 10-15 years
 - d. 15-20 years
 - e. 20+ years
2. How many lambs are residing at your operation? (Multiple choice)
 - a. 1-100
 - b. 101-500
 - c. 501-1000
 - d. 1001-1500
 - e. 1501-2000
 - f. 2000+
3. How many employees do you have at your operation? (Multiple choice)
 - a. 0-10
 - b. 11-50
 - c. 51-100
 - d. 100+

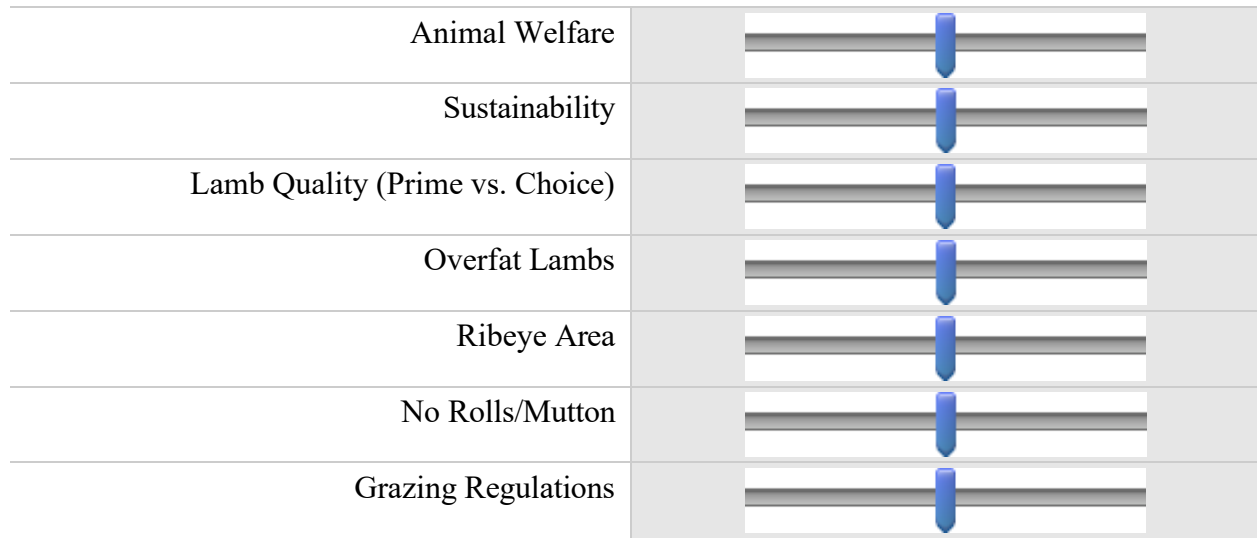
4. What percentage of your operation targets these markets? (Continuous line scale, %)

0 10 20 30 40 50 60 70 80 90 100



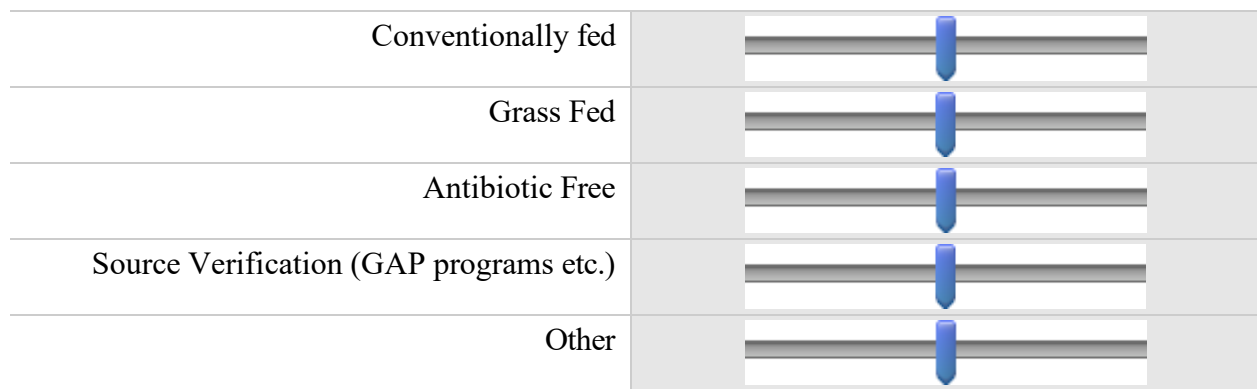
5. Rank these challenges in order of importance to your operation from the last 5 years specifically.
 - a. _____ Labor
 - b. _____ Water
 - c. _____ Land
 - d. _____ Laws/Regulation
 - e. _____ Transportation
 - f. _____ Volatility of Market
 - g. _____ Cost of Operation
 - h. _____ Overfat/Overweight Lambs
6. How important are these issues to your operation, scale of 1-10?

1 2 3 4 5 6 6 7 8 9 10



7. What percentage of your lambs fall into these categories?

0 10 20 30 40 50 60 70 80 90 100



8. In the next 5 years what do you foresee being the biggest challenges for your operation?
(Short answer)

9. In the next five years, what do you foresee will be your biggest opportunities as an
operation? (Short answer)

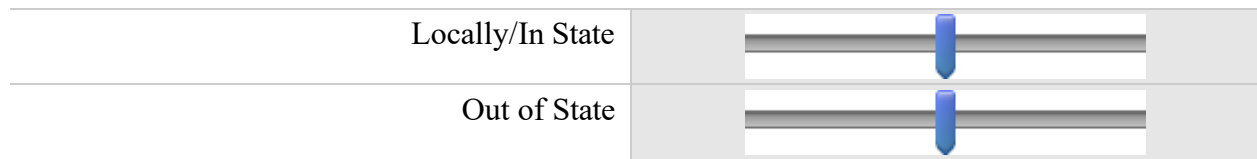
Feeder Questions

1. How long has your business been in operation? (Multiple choice)
 - a. 1-5 years
 - b. 5-10 years
 - c. 10-20 years
 - d. 20 years or more

2. How many lambs does your operation feed annually? (Multiple-choice)
 - a. 1-100
 - b. 101-999
 - c. 1000-1999
 - d. 2000-2999
 - e. 3000-3999
 - f. 4000-4999
 - g. 5000-5999
 - h. 6000-6999
 - i. 7000-7999
 - j. 8000-8999
 - k. 9000-9999
 - l. 10,000+

3. What percentage of your lambs come from these sources?

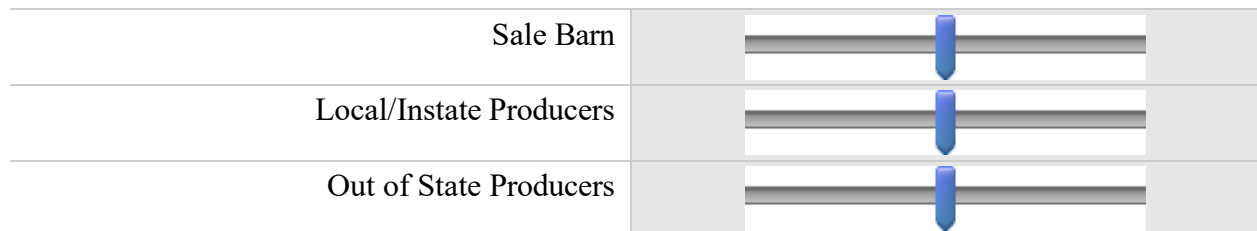
0 10 20 30 40 50 60 70 80 90 100



4. How far to you source lambs from? (Multiple choice)
 - a. 1-100 miles
 - b. 101-500 miles
 - c. 500+

5. Where do you source lambs from (purchased or raised)? (Continuous-line scale, %)

0 10 20 30 40 50 60 70 80 90 100



6. How many employees do you have? (Multiple choice)

- a. 0-10
- b. 11-50
- c. 51-100
- d. 100+

7. Rank these challenges in order of importance referencing the last 5 years.

- a. _____ Labor
- b. _____ Supply-chain issues (of lamb, equipment etc.)
- c. _____ Water
- d. _____ Consumer demand
- e. _____ Cost of Operations
- f. _____ Regulations
- g. _____ Overfat/Overweight lambs
- h. _____ Contamination/Food Safety
- i. _____ Volatility of Market

8. How important are these issues to your operation, scale of 1-10?

	1	2	3	4	5	6	6	7	8	9	10
Animal Welfare						6					
Sustainability						6					
Lamb Quality (Prime vs. Choice)						6					
Overfat Lambs						6					
Ribeye Area						6					
No Rolls/Mutton						6					
Grazing Regulations						6					

9. In the next 5 years what do you foresee being the biggest challenges for your operation? (Short answer)

10. In the next five years, what do you foresee will be your biggest opportunities in your operation? (Short answer)

Distributor Questions

1. What category does your company or business fall into?
 - a. Foodservice
 - b. Supermarket
 - c. Distributor/Purveyor
 - d. Direct/Farmer's Market
 - e. Chef

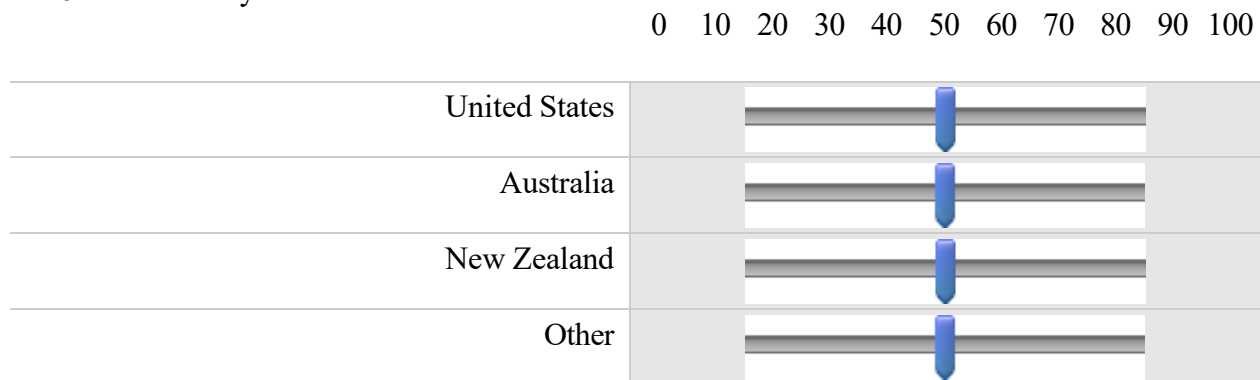
2. What category of foodservice does your company fall under?
 - a. Fine dining
 - b. Casual Dining
 - c. N/A Distributor
 - d. I am a chef in one of these categories.

3. How long as your business been in operation?
 - a. 0-5 years
 - b. 5-10 years
 - c. 10-20 years
 - d. 20 years or more

4. How many employees do you have?
 - a. 0-10
 - b. 11-50
 - c. 51-100
 - d. 100+

5. How many pounds of lamb does your company purchase per week?
 - a. <100lbs
 - b. 101 to 1000lbs
 - c. 1,000+ lbs. per week

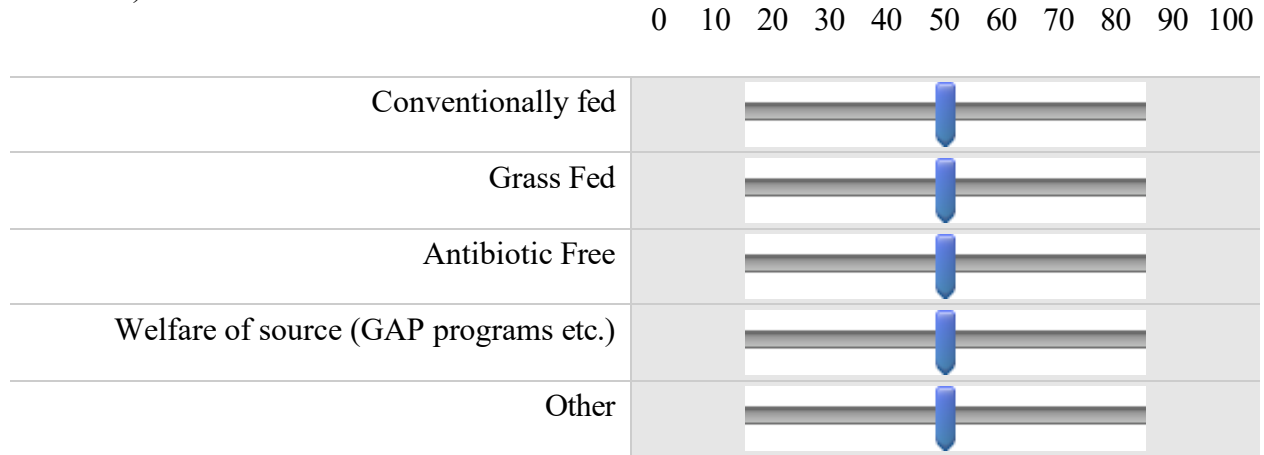
6. Where do you source lambs from?



7. How much would you pay more per pound, for American Lamb? (Multiple choice)
 - a. \$1.00 or less
 - b. \$1.01-\$2.00

- c. \$2.01-\$3.00
- d. \$3.01-\$4.00
- e. \$4.01-\$5.00
- f. \$5.00 or more

8. What percentage of lamb that you buy fall into these categories? (Continuous line scale, %)



9. Rank these challenges in order of importance referencing the last 5 years.

- a. _____ Labor
- b. _____ Supply
- c. _____ Water
- d. _____ Consumer demand
- e. _____ Cost of Operations
- f. _____ Regulations
- g. _____ Volatility of Market
- h. _____ Cost of importing vs. American

10. By most difficult to least difficult rank these issues you face when trying to purchase American Lamb?

- a. _____ Price
- b. _____ Consumer Demand
- c. _____ Supply
- d. _____ Quality
- e. _____ Variety of Cuts
- f. _____ Lack of Claims (Grass-Fed, Organic etc.)

11. What do you foresee being the biggest challenge in the next 5 years of supplying and purchasing American Lamb? (Short answer)

12. What do you foresee being the biggest opportunity in the next 5 years of supplying and purchasing American Lamb?

13. What is 'quality' and what quality factors drive the company's purchasing decisions?

14. When purchasing lamb products what is the most important quality attribute?
 - a. I don't purchase lamb.
 - b. Flavor
 - c. Origin
 - d. Sheep Raising Practices
 - e. Eating Satisfaction
 - f. Weight/Size of the Product
 - g. Product Appearance/Confirmation
 - h. Product Convenience
 - i. Nutrition/Wholesomeness
 - j. Sustainability of the product
15. Why is sustainability of the product the most important quality attribute to your company? (Short answer)
16. Why don't you purchase lamb for your company? (Short answer)
17. Why is flavor the most important quality attribute to your company when buying lamb? (Short answer)
18. Why is origin the most important quality attribute to your company when buying lamb? (Short answer)
19. Why is Sheep Raising Practices the most important quality attribute to your company when buying lamb? (Short answer)
20. Why is Eating Satisfaction the most important quality attribute to your company when buying lamb? (Short answer)
21. Why is Weight/Size of product the most important quality attribute to your company when buying lamb? (Short answer)
22. Why is product appearance/confirmation the most important quality attribute to your company when buying lamb? (Short answer)
23. Why is product convenience the most important quality attribute to your company when buying lamb? (Short answer)
24. Why is product nutrition/wholesomeness the most important quality attribute to your company when buying lamb? (Short answer)
25. If you are currently purchasing branded lamb products, what are certain cut/carcass specifications and requirements for purchasing? (Can select more than one) (select all that apply)
 - a. Local

- b. Grass-Fed
 - c. American
 - d. USDA Yield/Quality Grade
 - e. Animal Age
 - f. Organic
 - g. Cut weight/size.
 - h. Know the farmer.
 - i. Halal Slaughtered
 - j. Kosher Slaughtered
 - k. Imported
 - l. Breed Type
26. Out of what you selected in the previous question, what is MOST important cut/carass specification when purchasing lamb for your company? (Multiple choice)
- a. Local
 - b. Grass-Fed
 - c. American
 - d. USDA Yield/Quality Grade
 - e. Animal Age
 - f. Organic
 - g. Cut weight/size.
 - h. Know the farmer.
 - i. Halal Slaughtered
 - j. Kosher Slaughtered
 - k. Imported
 - l. Breed Type
27. Rank these challenges in order of importance referencing the last 5 years.
- a. _____ Labor
 - b. _____ Supply
 - c. _____ Water
 - d. _____ Consumer demand
 - e. _____ Cost of Operations
 - f. _____ Regulations
 - g. _____ Volatility of Market
 - h. _____ Cost of importing vs. American
28. Where do you market your lamb, you distribute?
- a. Locally (Within State)
 - b. Regionally (Surrounding States)
 - c. Nationally (Across U.S.)
 - d. Internationally
29. What percentage of your products you purchase fall into these categories?

0 10 20 30 40 50 60 70 80 90 100

Whole Carcasses	
Primals	
Retail Cuts	

30. How important are these issues to your company, scale of 1-10?

1 2 3 4 5 6 6 7 8 9 10

Animal Welfare	
Sustainability (Water, Greenhouse Gas Emissions, Land Use etc.)	
Lamb Quality (Prime vs. Choice)	
Loineye Area	
Shelf-life	
Fat on retail cuts or primals	

31. On a scale of 1-10 how important are these characteristics when sourcing lamb?

1 2 3 4 5 6 6 7 8 9 10

Conventionally fed	
Grass Fed	
Antibiotic Free	
Certified Source Verification (GAP programs etc.)	

APPENDIX 2. 2022 National Lamb Quality Audit Phase 1 Survey Questions: Open Ended

Responses

Question 1. What do you foresee in the next five years will be your most significant opportunities as a Packer?

1. Unless the American lamb industry commits to making a more consistent lamb, there will not be any opportunities to grow in this industry.
2. Retail
3. Hard to say; what the regulations will be for small operations.
4. In our case, we are moving away from selling carcasses to fabricating.
5. Local demand for lamb is growing for smaller carcass weights. Traceability back to farm and individual lamb even.
6. Demand

Question 2. What do you foresee in the next five years will be your biggest challenges as a Packer?

1. Keeping customers excited about buying American lamb.
2. Labor will continue to be a big factor.
3. Regulations and cost of operating.
4. Sourcing high-quality lambs 52 weeks a year.
5. Getting a supply of lambs that are consistent throughout the year.
6. Finding lambs.

Question 3. In the next five years, what will be your biggest opportunities for breeding, wool production, and show operation?

1. Direct sales
2. Growth in my area
3. Implementation of reproductive technologies
4. Expanding
5. Increased consumer demand for locally sourced, healthy options in food.
6. Local markets, farmers markets, processing own wool, small farm flocks.
7. Growing customer base
8. Market expansion
9. Genetic improvements, more direct marketing
10. Having a plan in place to keep the operation going.
11. Developing a good breeding program
12. Market influx
13. Cost of productions
14. Expanding numbers to stack lamb production with target grazing
15. Grass-fed demand
16. Different opportunities for marketing lamb.
17. Controlled market

18. Providing for a large ethnic group in our area as well as foodies

Question 4. What will be your biggest challenges for your breeding, wool production, and show operation in the next five years?

1. Labor shortage
2. Growth, cost of hay, water access
3. Breaking even
4. Aging
5. Expanding with only myself and one employee
6. Marketing show lambs
7. Labor
8. Labor
9. Buyer demand for frame sheep seedstock
10. Availability of USDA processing facilities
11. Markets
12. Predator control
13. Feed prices, feed availability, water, imports
14. Expanding flock
15. Rising input cost
16. Lower prices on the open market
17. Purchasing more land
18. Market Prices
19. Market Volatility
20. Imports
21. Slow wool trade
22. Drought
23. Regulations
24. Water, feed
25. Drought
26. The market influx
27. Volatility of market
28. Cost of doing business
29. Planning ground
30. Winter hay costs

Question 5. In the next five years, what do you foresee will be the biggest opportunities for your feeding operation?

1. Different ways to market lamb
2. Forage
3. Direct marketing
4. Market opportunities
5. Increasing demand
6. High lamb prices
7. Market
8. Growing flock
9. Being at the forefront to help supply a growing demand.

10. Growing flock
11. Non-traditional markets
12. Demand
13. Continuing to provide in a niche market.

Question 6. In the next five years, what do you foresee will be your biggest opportunities for your feeding operation?

1. Feed and operation costs
2. Changing operations
3. Regulations and cost
4. Labor, equipment, and facility
5. Feed cost, availability of lamb buyers and processors
6. Age/Retirement
7. Water
8. Gas and hay
9. Cost of operation and trying to generate as much income as possible, with land available to us.
10. Cost
11. Feeder lamb supply
12. Regulations
13. Finding available land and capital

Question 7. Producer Sustainability Definitions from Survey.

1. We work very hard to employ sustainable agricultural practices at our farm.
2. Not overgrazing pasture and keeping the correct number of sheep for our resources.
3. It means that I'm doing things right.
4. A balance of economics, time, environmental stewardship, and relationships that allows the farm to continue to the next generation.
5. Everything.
6. Producing high-quality animals in a way that has a low environmental impact and in a way that serves to continually do so with what we make without a huge pull-on resource available to use. Give back what you take.
7. Production with few inputs.
8. The ability to produce lamb and wool on the same ranch for generations to come.
9. Protecting and enhancing the resources we use, humanely and professionally managing our animals for long term health and productivity, being economically sustainable as well.
10. The sheep have to pay their bills.
11. Making money.
12. Being able to protect our bottom line.
13. Economic sustainability: the sheep and their wool pay their way (raw wool, processed yarns, sheepskin pelts and custom butchered lamb plus breeding stock sales).
Environmental sustainability: the sheep do not degrade but enhance the soil and vegetation in their pastures.
14. Being able to change with the times.
15. It's essential to nearly every aspect of our business. Environmental, Economic.

16. Important we sustain and reduce costs feed and fuel and optimize grass 2 acres.
17. Raising animals and building soil in best methods for the animals and the environment.
18. The way we take care of our land, our lambs and enables us to stay in business.
19. Being profitable for years to come.
20. Ability to get/grow grass/hay.
21. Growing good quality animals while being mindful of the effect on the environment and keeping costs as low as possible.
22. Using our land and resources to meet our needs today while protecting and nurturing them for future use.
23. Working with the space and resources available in a responsible way so as to not deplete what's readily available and to improve what was there when you got there.
24. Being mindful of the environment, economics, and management practices to ensure our business can continue and grow.
25. Rotational pastures all growing season.
26. We graze pastures in the warm season and harvest grasses mechanically to be utilized during the cool season.
27. Lower cost, better forage, healthier lambs.
28. Maintaining the sheep flock over a 5–10-year period.
29. Maintain a consistent product, with genetic advancements being put in place.
30. The ability to maintain a cost effective and profitable system overtime while capitalizing on outputs generated within the system rather than relying on external inputs.
31. That we figure out cheaper, alternative feed options.
32. Ability to stay in business and make a profit and leave resources as good or better than when we started.
33. Ability to make a profit and leave resources used in the same or better state than when started.
34. The ability to financially support the operation with funds generated by the operation.
35. Safe, Healthy, Profitable.
36. To raise enough lambs each year for show and for meat for the year.
37. Profitable.
38. Continuing.
39. We are continually trying to improve our pastures and animals.
40. Can the operation survive without the help of outside income.
41. To be clean and green.
42. Sustainability means leaving the land as good or better than we started, and that is how we ranch. We practice soil and rangeland health without multispecies grazing operation.
43. Able to stay profitable enough to pass along to the next generation.
44. GOOD PRICES.
45. Very important.
46. Producing animals with as few inputs as possible. When inputs are used, they should be reused.
47. It is what I strive for every day.
48. With the animal itself. Respectively harvest the animal. Make use of everything of the animal. Do it in a way that tries to limit use of inputs. So that we efficiently use inputs.
49. Being able to continue raising livestock year after year.

50. Education: continue to increase enrollment and provide high quality education.
Production: use methods that result in improvements in production and profit with an emphasis on sheep that provide a high quality of life.
51. Long term operational viability.
52. To be profitable and optimize production goals without being wasteful.
53. Using limited resources wisely.
54. Running sheep in such a manner that I can continue to produce a quality lamb product in a profitable manner on the same rangelands for years to come.
55. Management that improves the quality of life for family, livestock and desirable plants while utilizing inputs that minimize environmental impact.
56. Financially stable, improving soil health and productivity, building soil organic matter, minimal need for purchased fertilizer or ag chemicals, healthy livestock.
57. Operation is sustainable year over year, ongoing. Sufficient feed, shelter, etc.
58. Providing cutting edge genetics while profitable and enhancing our resources
59. Growing lamb in a way that ensures long term health of the ground (soil, native plants, wildlife, watershed) on which we graze. Additionally, raising our sheep in a way that preserves the culture of shepherding in our corner of the world.
60. Being able to stay in business over the long run.
61. To make a profit.
62. Ability to use or raise livestock on.
63. Keeping a quality product on pasture resources as long as possible before feeding hay and/or causing harm to the pasture.
64. Treading water.
65. Consistent prices that are over our breakeven point. Basically, higher than they are now. We could consistently be putting out a great product but that doesn't help us stay in business if we can't make a little profit from our sales.
66. We have always done what is best for the stock and the land. This is a continuous cycle for the best of all involved and our bottom line.
67. Raising lamb economically, while holistically managing our land to maximize our return on investment.
68. The ability to make a profit to continue operations.
69. Lamb production is a long-term business. I have to be able to predict, with some amount of confidence, what the market will be years from now.
70. Profitably operating in a manner that produces a quality product that satisfies consumers and responsibly utilizing resources.
71. Being able to pass this business/lifestyle on to my grandchildren and great grandchildren.
72. It means being self-sufficient, as green as possible, and delivering the best product possible to the consumer while supplying the animals with the best life possible.
73. Everything is balanced with the land resources.
74. Farming and conducting business in such a way so that the land is made better by it, my animals are better for it, and my business thrives because of it.
75. Being able to pay my operating costs with enough money to invest in new genetics.
76. Thriving with low input. The land is Number One.
77. Many things. We use the sheep for weed control, fire suppression, carbon sequestration, residue reduction, to clear crop residue. We feed our own grain and hay and support the local economy. We are generational farmers.

78. It means caring for and protecting the land that feeds our sheep/lambs.
79. Being able to turn a profit each year.
80. I believe it is our goal to continue to improve our operations each and every year. Increasing the pounds of lamb we produce, quality and making our operations more efficient.
81. Producing a quality product as natural as possible while not negatively impacting our soil, animals and being able to sell our products locally at a price point that positively affects our business.
82. Innovation, collaboration between different stakeholders within and out of the industry. Thinking and doing outside of the box.
83. Staying afloat.
84. It means a lot to our industry and to our operation. It starts with environmental and ends with economical sustainability for the livestock and producer as well as the packer.
85. Bring profitable and caring for the land and livestock.
86. A more predictable cost of product and expenses.
87. We want to maintain as a sustainable operation as we can. We practice rotational grazing and regenerative agriculture to preserve the land and bring back soil health and wildlife to create a flourishing ecosystem.
88. Knowing we have a future in the business.
89. To operate in a manner that is striving to improve the land and livestock so our operation will continue for future generations.
90. Being able to consistently produce replacement females at a low cost while still being productive.
91. Being able to reasonably produce lamb for years to come.
92. Quality product every year at a profit.
93. Conserving and utilizing available resources to the best of our ability to gain the most successful outcome. We pride ourselves on producing genetically and phenotypically superior breeding stock and provide Farm Fresh Lamb direct to the consumer.
94. We can be here again next year.
95. Profit.
96. Keep it running.
97. It means having a profit margin that can be counted on year after year instead of sold fluctuations.
98. Availability, price, and flavor consistency.
99. Sustainability is huge--for me it means lower input costs and of course, a healthy farm. "Sustainability" is thrown around a lot and sometimes isn't so feasible/doesn't make sense, but true sustainability is every farm's main goal to keep the operation going.
100. Long lasting recovery to land and livestock.
101. Regenerative age, improving your flock and productivity, using resources wisely.
102. It's extremely important to our company.
103. Living wage.