UNDERSTANDING CONSUMER ACCEPTANCE OF MULTIPLE RED MEAT PRODUCTS AND PERCEPTIONS OF THE AMERICAN MEAT SCIENCE ASSOCIATION'S INTERCOLLEGIATE MEAT JUDGING PROGRAM BENEFITS FROM PARTICIPANTS

A Dissertation
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Michaella Ann Fevold

In Partial Fulfillment of the Requirements
for the Degree of
DOCTOR OF PHILOSOPHY

Major Department:
Animal Sciences

May 2022

Fargo, North Dakota

North Dakota State University
Graduate School

Title

UNDERSTANDING CONSUMER ACCEPTANCE OF MULTIPLE RED MEAT PRODUCTS AND PERCEPTIONS OF THE AMERICAN MEAT SCIENCE ASSOCIATION'S INTERCOLLEGIATE MEAT JUDGING PROGRAM BENEFITS FROM PARTICIPANTS

By

Michaella Ann Fevold

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

DOCTOR OF PHILOSOPHY

SUPERVISORY COMMITTEE:

Dr. Robert Maddock
Chair

Dr. Kasey Maddock-Carlin

Dr. Larry Reynolds

Dr. Adam Marx

Approved:

06-29-2022
Date

Dr. Guillermo Scaglia
Department Chair

ABSTRACT

Per capita consumption of red meat products totaled 67 kg in 2017. Given the popularity of meat, it is important for meat scientists to monitor consumers acceptance of red meat products. Consumer acceptance of red meat products is driven by meat quality characteristics such as tenderness. The objectives of the second and third chapter was to investigate the influence of beef ribeye steak weight and thickness on purchasing behaviors of consumers and to better understand the effects of frozen storage on protein degradation, lipid oxidation, meat quality, and sensory characteristics of lamb.

As beef carcasses have grown over the time an unexpected consequence arose, an increase in ribeye size. Researchers have been studying these effects for several years to understand the influence on increasing ribeye size in relation to consumer acceptance of beef steaks. Our results indicate beef consumers are varied in their preference of beef ribeye steak size. However, beef consumers do discriminate against thin cut steaks regardless of steak size. These results indicate the beef industry is providing enough variation in steak types to meet consumer demands.

The lamb industry experiences lulls and surplus of fresh lamb due to breeding seasons of sheep, creating supply chain issues. Use of frozen lamb could alleviate some of these issues, however consumers discriminate against frozen lamb in the retail space. Our research indicates consumers discriminate against frozen loin chops due to tenderness and juiciness issues. However, consumers did not discriminate against frozen leg chops. Furthermore, we affirmed previous research which indicated the importance of allows lamb several days to age postmortem before freezing to improve protein degradation.

An important part of the meat industry is the AMSA intercollegiate meat judging program. This program allows for students to learn how to evaluate meat products and introduces students to the meat industry. Our objective of this study was to better understand the influence of the meat judging program on participants. Our results indicate judging programs provide participants with benefits such as skills development and introduction to the meat industry. Area of improvement included more community building and more applicability to the meat industry.

ACKNOWLEDGMENTS

I would like to thank my advisor, Dr. Robert Maddock, for his support through my degree. I've learned more from you about meat science than I ever thought I would know. Your guidance through research, and teaching has made a greater influence on me than I think you know.

To my committee, Dr. Kasey Maddock-Carlin, Dr. Larry Reynolds, Dr. Adam Marx, and Dr. Liza Gilblom, thank you for always being there to answer my questions and provide support.

To Wanda Keller, thank you for all your help and guidance during research collections and during lab experiments. I'm a better scientist and researcher because of your mentorship.

To Dr. Sherry Olsen who has served as an advisor, coach, and professor to me, you have taught me so much and I'm thankful to have to opportunity to work with you.

To the 2016 Iowa State Meat Judging Team, thank you for all the laughs and memories. I never would have gotten through the rough says of undergrad and graduate school without your support.

To Jerica Hall, thank you for all your help throughout research projects and always being willing to have research idea nights. I can't wait to see all you do in your career.

Finally, to my family, thank you for all the support you have given me all my life. I was always told I could do and be anything I wanted and I am here today because you all.

DEDICATION

To my dad, John, you gave me my passion for learning, science, and livestock agriculture by always encouraging me to ask questions.

To my mom, Linda, you always encouraged me to follow my dreams. I would have never had the courage to pursue the opportunities I have without your love and support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

kg..Kilograms

US ....United States

USDA..United States Department of Agriculture

FSIS..Food Safety Inspection Service

NBQA ....National Beef Quality Audit

LMA..Longissimus muscle area

cm^2 ....Squared centimeters

Ca^{2+} ....Calcium ion

pH...Potential for hydrogen

ATP ....Adenosine triphosphate

kDa...Kilodalton

WBSF..Warner-Bratzler shear force

C..Celsius

p*I* ....Isoelectric point

MDA ....Malondialdehyde

PUFA ....Polyunsaturated fatty acid

TBA...Thiobarbituric acids

TBARS..Thiobarbituric acid reactive substances

AMSA...American Meat Science Association

IMPS ....Institutional Meat Purchase Specifications

N/A..Not applicable

NDSU..North Dakota State University

LRG...Large

INT ....Intermediate

SMA .... Small

THK .... Thick

THN .... Thin

LL .... Longissimus lumborum

SM .... Semimembranosus

FRSH .... Fresh

FRZN .... Frozen

h .... Hour

cm .... Centimeters

g .... Grams

oz .... Ounces

d .... Day

mL .... Milliliters

m*M* .... Millimolar

SDS .... Sodium dodecyl sulfate

vol .... Volume

µL .... Microliter

g .... Gravitational force equivalent

nm .... Nanometers

µg .... Microgram

EDTA .... Ethylenediamine tetraacetic acid

wt .... Weight

AMPER .... Ammonium persulfate

TEMED .... Tetramethylethylene diamine

SDS-PAGE .... Sodium dodecyl sulfate-polyacrylamide gel electrophoresis

V..Volts

m ....Minutes

PVDF ....Polyvinylidene difluoride

A..Amps

PBS ....Phosphate buffered saline

TnT..Troponin-T

GPA..Grade point average

CHAPTER 1. LITERATURE REVIEW

United States Beef Industry and Beef Consumption

The United States (US) beef industry is quite massive in scale compared to other countries and is quite varied. The high level of consumption of beef products by the average American consumer (37 kg per year) (Smith et al., 2018) contributes to the size and breadth of the industry. Contrary to popular belief, the majority of beef production in the US is pastoral due to the conditions of the traditional cow-calf herd. Given the size and varied climates in the US, beef production across the US looks different dependent upon the region. In 2016, the US had a cow herd of 30 million head and had 10.5 million head of cattle in feedlot systems (Smith et al., 2018). In 2015, 29 million head of cattle were harvested to produce over 10 million tons of beef (Smith et al., 2018). The US beef industry is not only a large volume industry, but also a large source of receipts for US farms, totaling $88 billion in 2015 (Smith et al., 2018).

However, the magnitude of the US beef industry is not the only factor that is important in order to understand how the industry affects the beef products produced. It is also important to understand the general structure of the US beef industry. In general, the US beef industry structure is comprised of four main sectors for live animal production: seedstock, commercial cow/calf, stocker/backgrounders, and feedlot. Seedstock operators control the genetics and genetic improvement of the US beef herd by producing the breeding lines that filter down into the cow/calf herds. The cow/calf herd is comprised of breeding cows which produce a calf. Most US calves are born in the spring and then are weaned between the ages of three and seven months (USDA, 2022). Most cow/calf herds are grazed on forage year around. After weaning, the calves may be used as breeding stock or they will be placed on the terminal track for the feedlot. Some terminal animals may be sent to a stocker/backgrounder to allow for additional growth for a few months before being sent to the feedlot. Calves in a stocker/backgrounder may eat both forage and grain depending on the operator, region, and economics at the time. Lastly, cattle will enter a feedlot system to be fed for slaughter. The majority of feed yards in the US are confinement operations where a high-energy, grain-based diet is fed to cattle to increase weight prior to slaughter. Feedlots in the US use grain-based diets to increase intramuscular fat deposition to achieve a high-quality product that is sought after is the US marketplace (Smith et al., 2018, USDA, 2022). Furthermore, the USDA quality grading standards are heavily influenced by intramuscular fat. Therefore, most feedlot operators that will be harvesting animals at commercial packers want to maximize intramuscular deposition to increase their profit margins as much as possible (USDA, 2022).

Most US beef consumers consider several factors when purchased whole muscle beef products, including color, marbling, thickness (Leick et al., 2012, Miller, 2020). However, after preparation, US beef consumers judge beef quality on the factors of flavor, juiciness, and tenderness (Smith et al., 2018) which is where majority of research on beef quality has been focused for several decades. These parameters for defining quality will be discussed more completely in following sections.

United States Lamb Industry and Lamb Consumption

In the past several decades, the US sheep and lamb industry has suffered massive contraction, from 56 million head in 1942 to just over 5 million head in 2020 (Thorne et al., 2021). Decline in numbers are attributed to several reasons including, changes to public grazing laws, changes to laws providing price support and stabilization for wool, increased predation, and less interest in consumption of lamb from US consumers (Feuz and Kim, 2019, Thorne et al., 2021). Most researchers do not view any of these reasons as being the top reason for the decline in the US sheep herd but rather as compounding effects that have has a cumulative effect over the past several decades. Even with the decline in numbers in the sheep herd, it is still important to understand how the US lamb industry functions, especially due to some market signals which suggest an increase in interest in lamb as a protein source (Thorne et al, 2021).

Similar to the US beef industry, the US lamb industry is primarily pastoral in nature (Thorne et al., 2021). Most breeding ewes are kept on forage year around and lambs that are designated for terminal production are weaned and placed in concentrated feedlots where they are fed high energy, grain-based diets to increase weight. However, a complication to the US lamb industry is the fact that sheep are short day breeders. This means that majority of breeding ewes in the US lamb during the first 5 months of the year (Redden et al., 2018). This creates an inconsistency of supply in fresh lamb in the retail space which can become problematic during spikes of lamb demand around the Christmas and Easter holidays. However, a potentially larger issue to the US lamb industry is the lack of interest and consumption in the general US population.

On a per capita basis, US consumers eat less than 0.5 kg of lamb per year, with approximately 65% of Americans eating no lamb (Jones, 2004, Feuz and Kim, 2019). The lack of interest in lamb may be attributed to a few different reasons. First, lamb and mutton meat was first considered a by-product of wool production in the US, meaning sheep and lambs were not raised for express reason to produce meat, rather they were raised as a fiber source (Jones, 2004). After the introduction of synthetic fibers in the 1960's, which were considerably less expensive than wool, the US herd began to constrict and therefore less lamb and mutton was available for consumption. Furthermore, mutton was a common meal for US soldiers in World War II and folklore tells us the soldiers developed adverse feelings to mutton and avoided consumption after they returned home in the mid-1940's (Jones, 2004). Lastly, many US consumers simply do not like the flavor of lamb or rather, are not accustomed to the taste at a young age. Lamb flavor will be discussed in more depth in following sections.

United States Meat Grading Standards

History of United States Grading Standards

The idea to utilize grading in the US to segregate beef animals into different market classes is credited to Herbert Mumford from the University of Illinois who published a series entitled in "Market Classes and Grades of Cattle with Suggestions for Interpreting Market Quotations" in 1902 (Mumford, 1902). After this publication, the United States Department of Agriculture (USDA) established a tentative grading standard in 1916 (USDA, 2017). After public hearings in 1925, the USDA grading service began the official process of grading beef carcasses in 1927. While the USDA grading standards were originally designed to be used for the purpose of segregation and market reporting, the standards were soon used for many other purposes, such as serving as the basis for beef selection for Allied troops and in private industry. In 1931, the USDA grading service began the official process of grading lamb and mutton carcasses (USDA, 1992). USDA grading standards use yield and quality grading to segregate carcasses. USDA yield grades are used to estimate the amount of salable product which may be obtained from a carcass. USDA quality grades are used to estimate the palatability of meat products.

Beef Yield Grading

USDA beef yield grades are determined using the following regression equation:

$$2.50 + (2.50 \times fat\ thickness, inches) + (0.20 \times kidney, pelvic, and\ heart\ fat) + (0.0038 \times hot\ carcass\ weight, pounds) - (0.32 \times area\ of\ ribeye, square\ inches)$$

(USDA, 2017). Fat thickness is the measurement of fat over the ribeye muscle at the 12th and 13th rib. This measurement is taken three-fourths of the way up the exposed ribeye muscle. This measurement may be adjusted to reflect fatness of over areas of the beef carcass (USDA, 2017). Kidney, pelvic, and heart fat is evaluated as a percentage of the carcass weight. This characteristic includes the fat surrounding the kidneys, the fat in the pelvic area of the loin and round, and any fat associated with the heart (USDA, 2017). The ribeye area is determined between the 12th and 13th rib and is expressed in square inches (USDA, 2017). Lastly, the hot carcass weight is expressed in pounds (USDA, 2017). USDA beef yield grades are expressed in whole numbers from 1 to 5. A Yield Grade 1 beef carcass has very little fat, with the muscle being visible through the fat, in contrast, a Yield Grade 5 beef carcass is completely covered in fat, with almost no muscle being visible through the fat (USDA, 2017).

Beef Quality Grading

USDA beef quality grades are assigned by evaluating the maturity and marbling of a beef carcass. Maturity may be evaluated in three ways, dentition by USDA-Food Safety and Inspection Service (FSIS), age verification through approved USDA programs, or evaluation of the split chine bones and lean color/texture (USDA, 2017). Any carcass determined to be less than 30 months of age and exhibiting physiological characteristics of a C-maturity carcass and younger will be evaluated as an A-maturity carcass. Any carcass determined to be less than 30 months of age and exhibiting physiological characteristics of a D-maturity carcass and older will be evaluated based on their lean color and texture (USDA, 2017). Marbling is the exposed intramuscular fat and is evaluated using set USDA standards. Figure 1.1 below shows the relationship between maturity and marbling in the assignment of USDA beef quality grades (USDA, 2017).

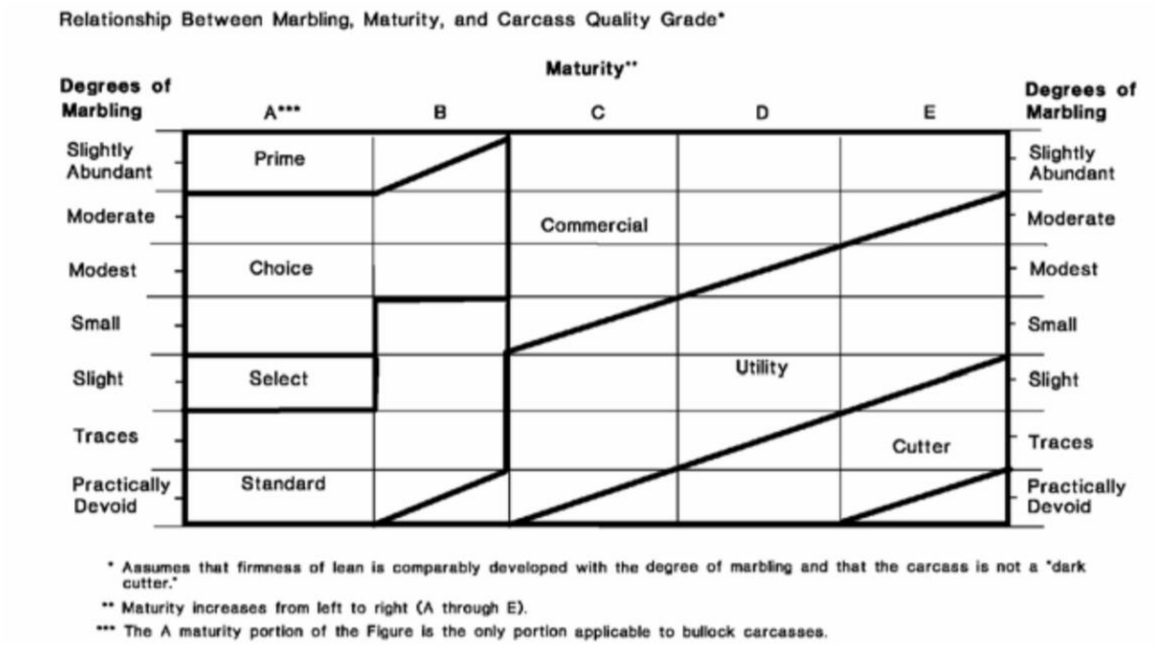


Figure 1.1. Relationship between marbling and maturity in assigning USDA beef quality grades (USDA, 2017)

Lamb Yield Grading

USDA lamb yield grades are determined using the following equation: $0.4 + (10 \times fat\ thickess, inches)$ (USDA, 1992). The fat thickness is evaluated at the 12th and 13th rib. When lamb carcasses are ribbed, the fat thickness is measured in the same manner as beef carcasses. When lamb carcasses are not ribbed (i.e. intact) a USDA-approved fat probe must be used for fat thickness evaluation (USDA, 1992). Fat thickness may be adjusted to reflect overall carcass fatness. USDA lamb yield grades are expressed in whole numbers from 1 to 5. A Yield Grade 1 lamb carcass has very little fat, with the muscle being visible through the fat, in contrast, a Yield Grade 5 lamb carcass is completely covered in fat, with almost no muscle being visible through the fat (USDA, 1992).

Lamb Quality Grading

USDA lamb quality grading is based on maturity and degree of flank streaking. Maturity of carcasses are determined to be lamb, yearling lamb, or mutton based on evidence of maturation such as rib color/shape and presence of break joints on the front trotter (USDA, 1992). Flank streaking is the observed as the fat steaking through the inside flank muscle and serves as a general indicator of the intramuscular fat deposition in the rest of the carcass (USDA, 1992). Figure 1.2 below shows the relationship between maturity and flank steaking in the assignment of USDA lamb quality grades (USDA, 1992).

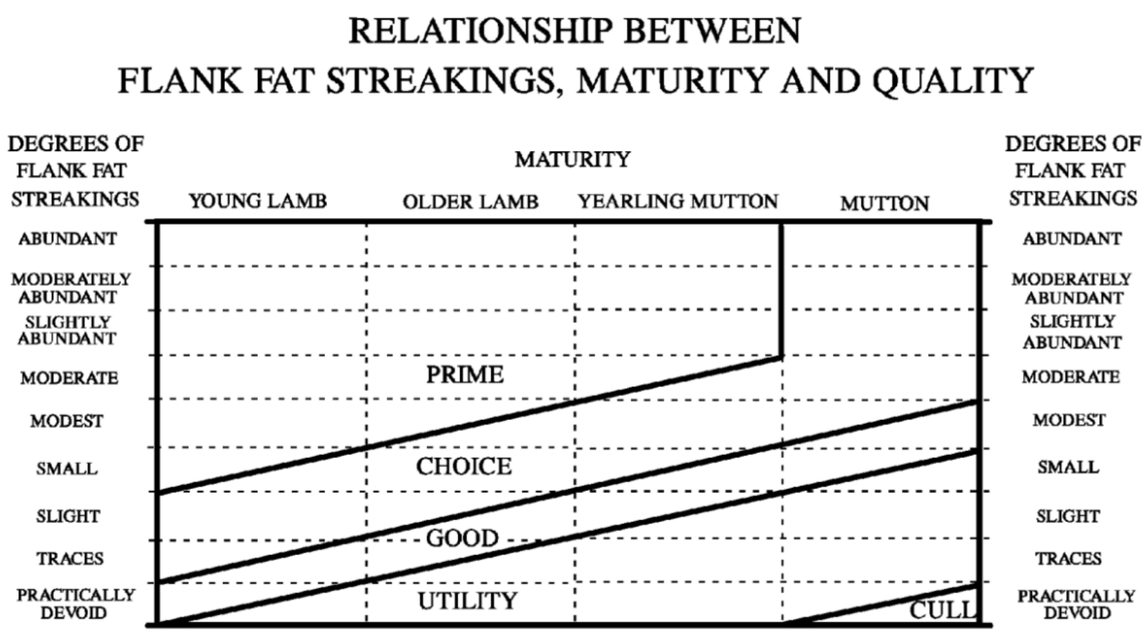


Figure 1.2. Relationship between flank streaking and maturity in assigning USDA lamb quality grade (USDA, 1992)

Meat Quality

Thickness of Whole Muscle Beef Steaks

The average hot carcass weight has increased by 45 kg since 1991 (NBQA, 2016). The increase in weight is likely attributed to the increase in longissimus muscle area (LMA) due to the lack of significant increase in external fat thickness during the same time period.

Longissimus muscle area has increased by 6.45 cm^2 since 1991 from 83.2 cm^2 to 89.7 cm^2 (NBQA, 2016). While an argument can certainly be made the increase in carcass size and therefore increase in pounds per lean produced with a lower number of cattle is a sign of increased efficiency in the US beef industry, we also must consider the influence of increasing muscle size on consumer satisfaction. This is especially important because the US beef industry must keep aligned with market signals from consumers due to the time needed to make changes to the US beef herd to grow cattle that better fit the demands of our consumers.

There is conflicting evidence in the literature in relation to how beef consumers perceive larger steaks. Research has shown that there is a wide range of beef consumers in the US and their preferences are varied for steak size, indicating increase in LMA size may not be an issue (Sweeter et al., 2005). Furthermore, consumers discriminate against steaks with a small LMA more so than those with a large LMA due to dislike of the small surface area seen in steaks with a small LMA (Leick et al., 2011). These observations seem to show US beef consumers have a preference for larger whole muscle beef cuts compared to smaller whole muscle beef cuts. Furthermore, research (Sweeter et al., 2005) showed consumers preferred larger steaks and discriminated against large steaks which had been cut in half to reduce portion size. While consumers were willing to purchase halved steaks, they were only willing to do so if the steak was discounted compared to their whole steak counterparts. However, this observation is complicated more when consideration for not only size of LMA and surface area of cuts but thickness of beef cuts is also taken into account. Maples et al., (2018) found consumers have a wide range of acceptance of steaks from varying size, however most consumers discriminate against thin cuts of steak. However other research has determined the preference for steak size and thickness is dependent upon individual consumers and there is likely a customer for every steak the US beef industry may produce. This a vitally important observation for the US beef industry to understand. While consumers may prefer a larger surface area, is that preference altered based on steak thickness? More research is needed in this area of study to better understand if US beef consumers are more willing to sacrifice thickness or surface area for their whole muscle beef products. Furthermore, more research is needed to elucidate whether the adage “a steak for everyone” is correct.

Lastly, the previous section covered research, which was conducted for the retail space, meaning these were steaks where customers were choosing them for themselves. However, there is another a sector of the US beef industry that needs to be considered in the debate over size and thickness. The food service sector is a massive industry and outlet for a lot of beef steaks. Research determined the optimum range for steaks in the food service sector came from beef carcasses with measured LMAs between 77 – 97 cm^2 (Dunn et al., 2000). This was the optimum LMA range due to the combination of cooking time and tenderness. With these steaks, the food service sector was able to cook steaks in a shorter time while maintain demanded thickness of their customers while also meeting customer demands for palatability and satisfaction (Dunn et al., 2000). Furthermore, it was recognized that the food service sector likely would prefer their supply of steaks be as consistent in size and thickness as possible to reduce errors of cooking steaks in the fast-paced restaurant environment (Dunn et al., 2000).

In summary, in the retail case, the US beef industry seems to have little issue with providing steaks for all consumers due to the range is desirability seen with US beef consumers (Sweeter et al., 2005, Leick et al., 2011, Leick et al., 2012, Maples et al., 2018). However, in the food service sector, the US beef industry may need to monitor the range in LMA sizes to ensure a consistent supply of product is available to this vital sector (Dunn et al., 2000).

Meat Tenderness

Meat tenderness is an important component of meat quality, consumer satisfaction, and consumer repurchase (Boleman et al., 1997, Maltin et al., 2003). Variation in meat quality is often a major determinant in consumer repurchase with overall eating quality and tenderness being ranked highly (Tarrant, 1998, Bindon and Jones, 2001, Maltin et al., 2003). Furthermore, the most common reason for consumers to report dissatisfaction with fresh meat products is toughness (Jeremiah, 1982). Therefore, much research has been conducted to better understanding how meat tenderness may be affected. Research has included antemortem, postmortem, and post-processing conditions to better understand how to control tenderness to maximize consumer satisfaction.

Antemortem Conditions

A common detriment to tenderness in fresh meat products in the abundance of connective tissue. In general, as an animal ages, they will develop more connective tissue in their muscle. Connective tissue common in animal muscle includes collagen and elastin in the endomysium and perimysium (Lepetit, 2007). The increase in connective tissue may come from a thickening of the perimysium, as well as the formation of non-reducible intermolecular cross links in collagen (Robins et al., 1973, Purslow, 2017). It has been specifically noted that as the perimysium around the muscle fiber thickens a marked increase in toughness is correlated (Fang et al., 1999, Purslow, 2014). It has been generally accepted that the main reasons connective tissues contributes to background toughness of meat products is due to the shrinkage of the crosslinks which occur during heating and the general insolubility of connective tissue (Light et al., 1985).

In the past, nutrition has been a key research point to attempt to manipulate tenderness in the antemortem or immediate postmortem period. Manipulation of Ca^{2+} levels have been the center of this research topic, with an attempt at early and sustained activation of the calpain system (discussed later) being the goal. Some studies (Kerth et al., 1995, Harris et al., 2001) injected meat with calcium in the immediate postmortem period with some improvements of tenderness identified. However, other studies (Wiegand et al., 2001, Scanga et al., 2001) fed cattle calcium to a supranutritional level in an attempt to increase serum calcium levels. While serum calcium levels were increased in both studies, both studies failed to see an improvement in tenderness of meat products. These results likely indicate that the regulation of cellular Ca^{2+} levels are tightly controlled and not easily manipulated.

It has also been suggested that growth rate and protein turnover may have some effect on tenderness of fresh meat products. This theory arose from observations that double-muscled cattle breeds, such as Belgian Blues and Piedmontese exhibited accelerated lean growth rates and lower Warner-Bratzler shear force values (Hornick et al., 1998). However, other studies that modeled accelerated growth rates compared to the growth rate seen in a commercial operation did not influence tenderness (Allingham et al., 2001, Sinclair et al., 2001). These results seem to suggest that growth rate may not have a significant effect on tenderness of meat products.

Lastly, breeding and genetics may play an important role in meat tenderness. It has been found that up to 30% of the variability in beef tenderness may be explained with genetics with about 70% of the variation being explained by other factors (Koch et al., 1982). There may be some variation in tenderness between beef breeds, however the majority of variation between breeds comes between the 2 larger groups, *Bos taurus* and *Bos indicus*. *Bos taurus* cattle breed examples are Angus, Hereford, and Charolais, otherwise commonly known as British or

Continental breeds in the US. *Bos indicus* cattle breed examples are Nellore and Brahman, otherwise commonly known as Exotic breeds in the US. Beef from *Bos taurus* cattle are more tender than *Bos indicus* on average. This variation in tenderness arises from two main different between these two groups. *Bos indicus* have a higher amount of calpastain activity in the early postmortem period which leads to decreased calpain activity, and therefore less protein degradation resulting in tougher meat (O'Connor et al., 1997). Furthermore, *Bos indicus* cattle have less marbling compared to *Bos taurus* cattle which may lead to increased acceptance by consumers for *Bos taurus* meat (Wheeler et al., 1994).

As previously discussed, calpastain activity is highly correlated to the development of tough meat. The callipyge gene in lambs in another excellent example of when high calpastain activity results in increased toughness of meat. In lambs which carry the callipyge gene, the muscle experiences relatively uncontrolled hypertrophy of myofibrils, seen mostly in the rear leg (Cockett et al., 1996). While this observation may seem like a useful gene to exploit for improved muscle growth in lambs, this gene increases the activity of calpastatin (Duckett et al., 2000), therefore leading to tougher cuts of lamb, especially in the hindsaddle.

Postmortem Conditions

In the early postmortem period, muscle undergoes significant changes which have an effect on final tenderness of fresh meat products. During this period, muscle attempts to maintain homeostasis via anerobic glycolysis due to lack of oxygen in the system following clinical death. From this attempt, muscle pH is driven down due to accumulation of lactic acid (lactate) in the muscle (Maltin et al., 2003). Concurrently, ATP is being depleted and Ca^+ levels are increasing creating an environment of permanent cross-bridges between myosin and actin proteins leading to irreversible muscle contraction, or rigor mortis (Bate-Smith and Bendall, 1949, Bendall, 1951, Jeacocke, 1982, Maltin, et al., 2003), which caused toughening due to sarcomere shortening (Locker and Hagyard, 1963, Huff-Lonergan et al., 2010). Rigor mortis is referred to as irreversible muscle contraction because the myosin-actin crossbridge bond is never fully resolved, rather the increase in tenderness in the late postmortem period is due to eventual proteolysis (Taylor et al., 1995, Koohmaraie et al., 1996, Maltin et al., 2003).

Postmortem proteolysis affecting meat tenderness is accepted to primarily be caused by the calcium-dependent calpain system (Boehm et al., 1998, Wheeler et al., 2000, Huff-Lonergan et al., 2010). The calpain system is comprised of three calpains: m-calpain, μ-calpain, p94, as well as an inhibitor, calpastatin. There is a general consensus in the literature that μ-calpain plays the primary role in postmortem protein degradation (Boehm et al., 1998, Kanawa et al., 2002, Maltin et al., 2003). However, this not mean that m-calpain does not play a role in postmortem protein degradation. Some research seems to indicate μ-calpain is not active in the 3-14 d window postmortem when a significant portion of protein degradation occurs (Maltin et al., 2003). This may suggest μ-calpain is activated during postmortem storage and protein degradation during this time is accomplished via m-calpain or proteases (Delgado et al., 2001). It would seem the likely scenario of postmortem protein degradation is μ-calpain being activated in the early postmortem period (1-2 d postmortem). Evidence suggests μ-calpain degrades the costameres, sarcolemma, and some intermediate filaments. As levels of Ca^{2+} rise as the muscle enters the rigor mortis phase, m-calpain is activated. Literature seems to suggest m-calpain acts on cytoskeletal proteins, such as desmin and titin several days into the postmortem period (Koohmaraie et al., 1991, Taylor et al., 1995).

For this dissertation, the understanding of troponin-T degradation is important for interpretation of results. Troponin-T is a protein in the myofibril which plays a structural role by bind the troponin-I and troponin-C to tropomyosin and actin (Penny and Dransfield, 1979). μ-calpain has been shown both in vitro and in situ to degrade troponin-T at the ten times the rate compared to m-calpain (Di Lisa et al., 1995). The relationships between troponin-T degradation and improvement of tenderness has been investigated for several decades (Hay et al., 1973, Penny, 1976, Olson et al., 1977). Furthermore, the 30 kDa the degradation component of troponin-T has been highly positively correlated with an increase in meat deemed tender by both instrumental evaluation and sensory evaluation. Conversely, meat deemed tough by instrumental and sensory evaluation often lacks the 30 kDa degradation product of troponin-T (MacBride and Parrish, 1977). Therefore, it can be concluded the evaluation of troponin-T degradation can serve as an indicator of tenderness in meat products.

Evaluation of Tenderness

Several methods can be used to evaluate tenderness of meat products. Arguably, the most utilized in meat science research is the Warner-Bratzler shear force test (WBSF). This procedure was originally defined by Bratzler and Warner (Bratzler, 1949, Warner, 1952). The equipment and devices used may vary depending on location and laboratory, however, the basic principle applies across all variations. A meat sample is cooked to an internal temperature of 71° C and allowed to cool to room temperate. The cooked meat sample is used to obtain a core with muscle fibers running parallel to each other. The core is sheared with a blade attached to a force meter which records the amount of force needed for the blade to shear through the core (Liu and Zhang, 2020) It is strongly recommended at least six cores are obtained from each sample to be averaged for analysis. Force may be reported in either kilograms of force or Newtons (Honikel, 1998).

Another method to evaluate meat tenderness is the star probe. In the star probe evaluation, cooked meat samples are punctured and compressed to 80% their original height with a 5-point star-shaped probe. The value reported in the peak force needed for the probe to puncture and compress the cooked meat sample. The star probe measurement has been correlated to WBSF values and is viable alternative to WBSF evaluation (Liu and Zhang, 2020).

Texture profile analysis is sometimes used due to ability to simulate mastication or chewing. Texture profile analysis is able to simulate chewing because it utilized the force-deformation curve which analyses parameters such as hardness, springiness, chewiness, and adhesiveness of meat products (Rosenthal, 2010). Furthermore, texture profile analysis has been shown to explain more variation in tenderness compared to WBSF, making it likely a better measurement to evaluate tenderness (Caine et al., 2003). However, texture profile analysis does require more training and more specialized equipment to conduct, so it may not be available at every institution.

Water Holding Capacity

Water holding capacity is the ability for meat to retain moisture through the conversion of muscle to meat, ageing, and cooking processes. Further, it is the ability of meat to retain water during pressing, grinding, cutting, heating, during storage, and cooking. Reduced capacity to hold water costs the US meat industry millions of dollars annually due to both loss of product weight and consumer rejection (Den Hertog-Meischke et al., 1997). Muscle contains several components, including protein, lipid, carbohydrates, and vitamins and minerals. However, water is the largest component and makes up about 75% of lean muscle tissue (Huff-Lonergan and Lonergan, 2005). However, water is not the only important component loss due to inferior water holding capacity, water-soluble sarcoplasmic proteins may also be lost during water loss of fresh meat products (Savage et al., 1990).

The majority of water is muscle is held in three places in muscle and meat: 1) within the myofibrils; 2) between the myofibrils and sarcolemma; and 3) between muscle bundles (Offer and Cousins, 1992). Furthermore, water is found in three different “types” in muscle and meat. Bound water is water that is tightly bound to the protein and is not free to move. Binding of water and protein occurs due to the dipolar nature of water being attracted to the charged nature of proteins in muscle and meat (Huff-Lonergan and Lonergan, 2005). The second type of water in muscle and meat is known as immobile water. Immobile water is water that is held in the muscle by either steric forces or an attraction to bound water. However, an important distinction between bound water and immobile water is immobile water is not held by an attraction to proteins in meat and muscle (Huff-Lonergan and Lonergan, 2005). Immobile water will be most affected by the muscle conversion to meat process and will escape muscle and meat as purge. The third and last type of water in meat is known as free water. Free water is mostly seen on the surface of meat and can easily flow out with little resistance due to very weak van Der Waals forces (Puolanne and Halonen, 2010). Many factors may affect the ability of muscle and meat to hold water in the early postmortem period and throughout aging. These factors are known as the net charge effect, steric effect, and “sponge effect”.

Net Charge Effect

When muscle is converted into meat, the pH lowers from the neutral pH of living muscle to the slightly acidic pH of meat due to the build up lactic acid from anaerobic metabolism. As the pH of meat approaches the isoelectric point (p*I*) of major proteins, the net charge of the protein converts to nearly zero. This means the protein is no longer charged and will not be able to bind the dipolar water molecules in the meat, which may allow for some of the water to leak out (Huff-Lonergan and Lonergan, 2005). Furthermore, as the net charge of the proteins approach zero, the myofibrils may pack closer together due to the loss of repulsion forces between myofibrils (Huff-Lonergan and Lonergan, 2005; Puolanne and Halonen, 2010) which can lead to less space for water to reside between and in myofibrils).

Steric Effect

As previously discussed, a significant proportion of water in muscle is contained with the myofibrils. This water is held in the myofibrils by capillary forces which are created from the arrangement of myosin and actin. Interestingly, research has shown the isovolumetric capacity of muscle sarcomere do not change during muscle contraction and relaxation (Millman et al., 1983). However, in contrast to living muscle, the isovolumetric capacity changes as postmortem muscle undergoes changes due to rigor mortis because of the actomyosin cross-bridge formation. With the formation of theses cross-bridges, the amount of space for water to reside inside the myofibril decreases (Huff-Lonergan and Lonergan, 2005). The decline in space forces water out of the myofibril and into extramyofibrillar space. Furthermore, the space for water in the myofibrillar space may be further compromised due to the shortening of sarcomeres during the onset of rigor mortis. Research has shown a direct relationship between an increase in drip loss related to a decrease in sarcomere length (Honikel et al., 1986). Thus, as space for water decreases within the myofibril, the water must go somewhere. The expelled water may be able to drip out of meat in the postmortem period due to the formation of drip channels which are formed when muscle cells constrict during rigor mortis. The theory of drip channels is further explained in the sponge effect hypothesis.

Sponge Effect Hypothesis

At one time, increased water-holding capacity of aged meat was explained by the meat having less water to lose during the aging process due to moisture loss in the early postmortem period (Joo et al., 1999). However, this hypothesis is challenged by observations of Farouk et al. (2012) where there were not significant changes in moisture content in the early postmortem period and during aging. Therefore, another explanation for this phenomenon is needed. One such explanation is the "sponge effect" hypothesis (Farouk et al., 2012). After a series of other studies (Farouk et al., 2007; Farouk et al., 2009) it was observed water-holding capacity increased with longer ageing periods. In this hypothesis, it is explained that during the conversion of muscle to meat, channels may be formed due to the decrease in pH and muscle contraction due to rigor and these channels may allow for water to more easily drip out of meat. However, as postmortem aging occurs, the structure of these channels may be disrupted due to proteolysis of various structural proteins. The breakdown of structural proteins is pivotal to the increased water-holding capacity of aged meat due to the ability of water to be physically trapped in the meat, leading to more immobile water. Furthermore, there is the potential that the increased viscosity of water in meat (due to soluble protein in the water from proteolysis) may further reduce the ability of water to drip out of meat (Farouk et al., 2012).

Water Holding Capacity and Consumer Acceptance

Water holding capacity and consumer acceptance are highly correlated (Troy and Kerry, 2010). Water holding capacity of meat related to consumer acceptance is generally broken out in to two types: drip loss of raw meat products and water loss during the cooking process. Drip loss of fresh, raw meat products is unavoidable, however use of interventions to avoid enhanced drip loss is important. Consumers are known to discriminate against packages of meat with visible water loss (Troy and Kerry, 2010). Furthermore, water loss in raw meat may result in loss of visual color characteristics (Hughes et al., 2014). Water loss in raw product is also positively correlated with increased dryness in final cooked product.

However, water loss during the cooking process is arguably more important to consumer acceptance than drip loss of raw meat (Hughes et al., 2014). This is mostly attributed to the fact that consumer associate the juiciness of a cooked meat product to the perception of tenderness, thereby increasing the overall enjoyment of a cooked meat product. Sensory studies have shown there is a positive correlation between consumer assessment of tenderness and juiciness and measured water loss during cooking (Hughes et al., 2014). This phenomenon of associated acceptance has sometimes been referred to as the halo effect, where an increase in either perception of tenderness or juiciness generally increases the perception of the other factor (Roeber et al., 2005, Jenkins et al., 2011).

Evaluation of Water Holding Capacity

Water holding capacity is typically measured in meat science research in two different phases, the ability of raw meat to hold water and the amount of water lost during the cooking process. Water holding capacity of raw product is most often described as the measurement of drip loss. Drip loss may be evaluated in several ways including: Honikel drip loss, EZ DripLoss, and tampon/absorption (Oswell et al., 2021). Honikel drip loss (Honikel, 1998) describes a method where a sample of meat is suspended by a hook in a plastic bag and allowed to sit for a certain amount of time, often 24-48 hours. The sample is weighed before and after suspension and the difference is weight is considered the amount of water loss. EZ DripLoss (Rasmussen and Andersson, 1996) is a similar concept to Honikel drip loss, however, samples are placed in a cup with a base that allows for drip to be collected over a period of time. This method is considered more efficient than Honikel drip loss. Lasty, the tampon/absorption method was proposed by Walukonis et al. (2002) to attempt to allow for rapid collection of drip loss data. In this method, an absorbent tampon is inserted into an incision in a meat sample and removed every 15 minutes for 105 minutes. It was found that this method correlated relatively well to other methods of measuring drip loss and allowed for much more rapid collection of data.

Marbling Effects on Perception of Meat Quality

A somewhat common misconception is that marbling in meat products guarantees a product will be a satisfying product for consumers. While marbling certainly plays a role in fresh meat quality, there are some theories that explain how marbling effect the perception of meat quality. There theories include: the insurance theory, the lubrication theory, and the bulk density theory.

The insurance theory proposes fresh meat products with higher amounts of marbling are more resistant to cooking abuse (Savell and Cross, 1988). Recent research showed that beef strip loin steaks from higher quality grades (USDA Prime) were able to maintain relatively high levels of consumer acceptance even with increasing end point cooking temperatures, while other quality grades (USDA Choice and USDA Select) had steep drop offs of consumer acceptance with increasing end point cooking temperatures. (Drey et al., 2018). These conclusions suggest the insurance theory likely contributes to marbling effects on perception of meat quality.

The lubrication theory suggests that an increase in marbling allows for more fat breakdown during the cooking process due to the addition of heat. The breakdown of fat increases the lubrication in the mouth and may stimulate saliva production which leads to a perception of increased juiciness of the meat product (Smith and Carpenter, 1974). With the perception of increased juiciness, there is likely also a perception of increased tenderness due to the consumer connection of juiciness and tenderness.

The bulk density theory suggests that after cooking, intramuscular fat is less dense compared to lean and is therefore it would be easier to bite through a piece of meat with an increased amount of marbling. The fat becomes less dense due to gelatinization from heat (Savell and Cross, 1988). However, this theory has not been widely researched and may have the least effect on perception of meat quality.

Lipid Oxidation

Lipids are essential compounds in meat products for several reasons. First, they provide energy for biological processed to occur in the body. Second, they provide needed nutritional components such as essential fatty acids and fat-soluble vitamins. Lastly, lipids are often associated with important meat quality characteristics such as different flavor profiles of meat products and increased perceived tenderness from due to intramuscular fat (Dominguez et al., 2018). However, while lipids are an integral part of fresh meat products they are prone to degradation and oxidation which can have devastating consequences on the quality of fresh meat products.

Lipid oxidation has been identified as the main cause of deterioration in quality of fresh meat products, excluding microbial causes (Min and Ahn, 2005). Lipid oxidation may begin at the time of slaughter and continue until meat products are prepared and consumer, so it is important to understand how lipid oxidation may occur and interventions to slow lipid oxidation progress. Simply, lipid oxidation occurs when unsaturated fatty acids react with reactive oxygen species, which eventually degrade into secondary compounds such as aldehydes, ketones, alcohols, and hydrocarbons. These secondary compounds are the triggers for the development of off-flavors, aromas, and loss of desirable color (Dominguez et al., 2018). In meat, the secondary compound we are most generally most concerned with is the aldehyde called malondialdehyde (MDA). In meat products, the most common lipid oxidation process is known as lipid autoxidation. This lipid autoxidation occurs in three distinct phases: initiation, propagation, and termination.

In the initiation phase, an unsaturated fatty acid reacts with an oxygen molecule. However, it is nearly impossible for this reaction to occur spontaneously in the natural state of the unsaturated fatty acid (singlet electronic state) and the oxygen molecule (triplet electronic state) because of the differing spin states of the electrons (Min and Ahn, 2005). Thus, before the initiation reaction of lipid oxidation can occur, the oxygen must be converted to singlet oxygen or another reaction oxygen species such as hydrogen peroxide or a hydroxyl radical (Dominguez et al., 2018). This conversion must be activated by some sort of energy or the presence of a transition metal. After conversion, reactive radicals will begin to "attack" unsaturated fatty acids to begin lipid autoxidation. There may be an observed lag in the progression of oxidation as oxidative products begin to accumulate in the meat product. As lipid oxidation continues, it will progress into the propagation phase. Figure 1.3 shows a simple representation of the initiation phase (Dominguez et al., 2018).

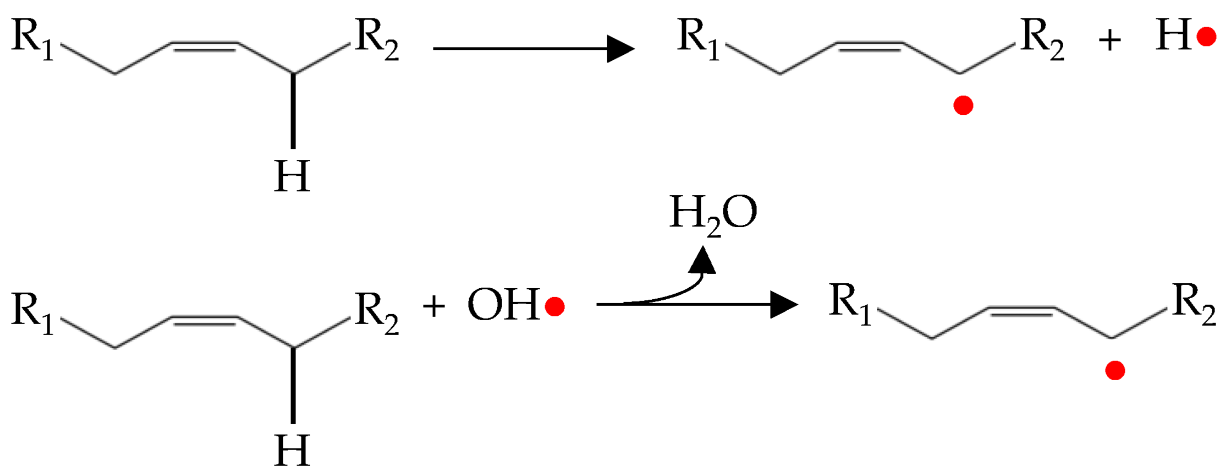


Figure 1.3. Representation of the initiation stage of lipid autoxidation (Dominguez et al., 2018)

In the propagation phase, the reactive radicals form a peroxy radical which is capable of a much more efficient abstraction of hydrogen from the unsaturated fatty acids. This reaction results in another radical forming and the previous reaction is repeated over and over, hence the same “propagation”. However, not only was a radical formed in the previous reaction, hydroperoxide was also formed. Hydroperoxide may also be degraded into reactive radicals via two different pathways. The first pathway relies on transition metals, such as iron, to donate an electron to the hydroperoxide to degrade into radicals. Due to the high levels of iron in meat, this is likely a common cause of lipid autoxidation. The second pathway is the interaction between two different hydroperoxides. In this interaction, the hydroperoxides associate together and degrade into radicals (Ghnimi et al., 2017). Figure 1.4 shows a simple representation of the propagation phase (Dominguez et al., 2018).

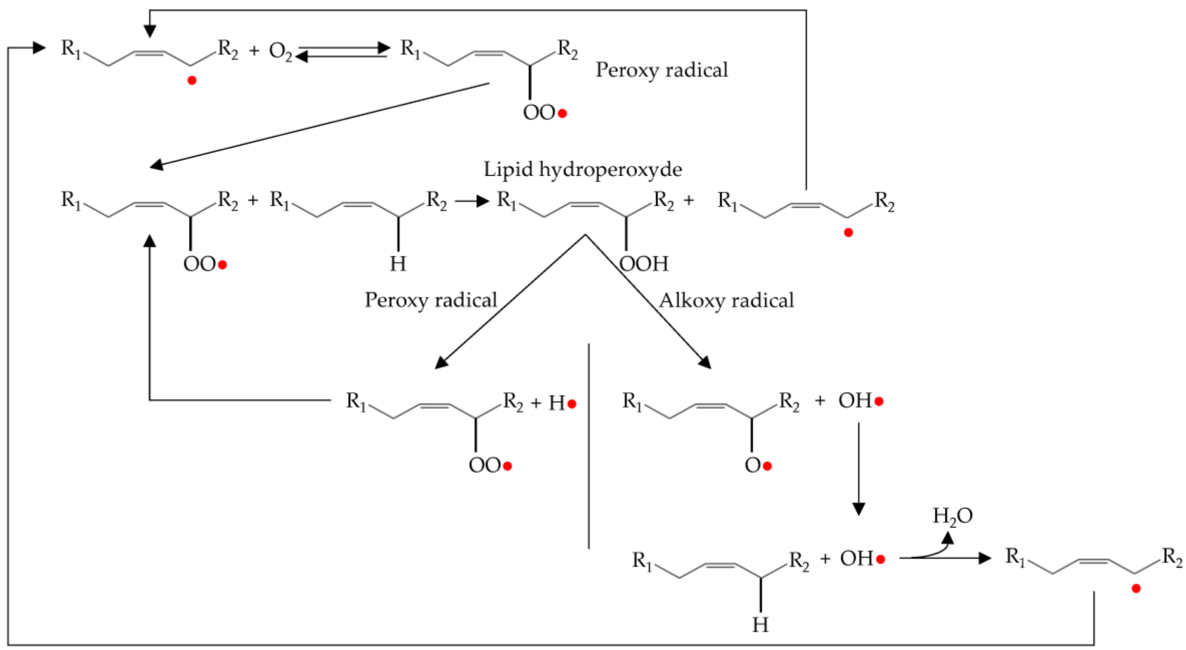


Figure 1.4. Representation of the propagation stage of lipid autoxidation (Dominguez et al., 2018)

Termination of lipid autoxidation may occur from two different reactions, radical associating with other radicals or radicals associating with antioxidants. In both of these reactions, the radical species are essentially neutralized and become much less reactive (Dominguez et al., 2018). However, in term of meat quality, the termination phase is not a highly important step due to the fact that by the time lipid autoxidation terminates in this phase, the damage to product quality has already occurred in the initiation and propagation phases. However, it should be noted some lipid oxidation is favored in some meat products due to the development of wanted aromas or flavors which may develop from the oxidation of certain fatty acids. Examples of controlled lipid oxidation include ripening and curing of processed meat products (Lorenzo, 2014; Paterio et al., 2015).

Several factors may be associated with rate and extent of lipid oxidation in fresh meat products. One factor is composition of the meat product, specifically the types of lipids present in the meat product. In meat products, lipids may be present in several forms, including triglycerides, phospholipids, and, to some extent, free fatty acids. Triglycerides represent the majority of lipids in meat products due to the high prevalence of triglycerides in intramuscular fat. Phospholipids are generally contained only in the membranes of cells in meat. This means that the amount of triglycerides in meat may be highly variable with changes in the amount of marbling in different meat cuts, while the amount of phospholipids will remain relatively constant (Christie, 1978).

However, while triglycerides account for the majority of lipid content in meat, there is evidence which suggests phospholipids contribute heavily to lipid oxidation in meat products. The first theory of why this phenomenon may occur is due to the arrangement of phospholipids in membranes which allows for highly reactive oxidation sites to be readily exposed during the propagation phase of lipid autoxidation (Dominguez et al., 2018). Secondly, phospholipids have a higher amount of polyunsaturated fatty acids (PUFAs) compared to triglycerides (Amaral et al., 2018). This is important because it has been well established in the literature that an increase in double bonds leads to less oxidative stability due to increase in potential oxidative sites for lipid oxidation to occur in either the initiation or propagation phase of lipid autoxidation (Barden and Decker, 2016, Dominguez et al., 2018). Furthermore, research has suggested that phospholipids contribute more than 90% of the MDA formation in meat products (Pikul et al., 1984).

Another factor that may affect lipid oxidation is the presence of heme proteins or transition metals. While lipid oxidation is often contributed to exposure to light or increased temperature, some research argues the presence of metals such as iron can actually accelerate lipid oxidation onset faster than light or temperature (Dominguez et al., 2018). Unfortunately for meat scientists, heme proteins such as myoglobin are in abundance in red meat products and carry an abundance of iron with them.

It is also important to mention how lipid oxidation may be evaluated in meat products. In meat science, MDA is often evaluated as a marker of lipid oxidation in meat products. MDA is quantified in meat products via the thiobarbituric acid (TBA) test due to the color reaction that is created when MDA and TBA associate with each other. Figure 1.5 shows an example of the color reaction from MDA and TBA association. However, it should be noted that MDA is not the only oxidation product that can create the color reaction seen in the TBA test, so the test is often referred to as the thiobarbituric acid reactive substances (TBARS) test (Dominguez et al., 2018).

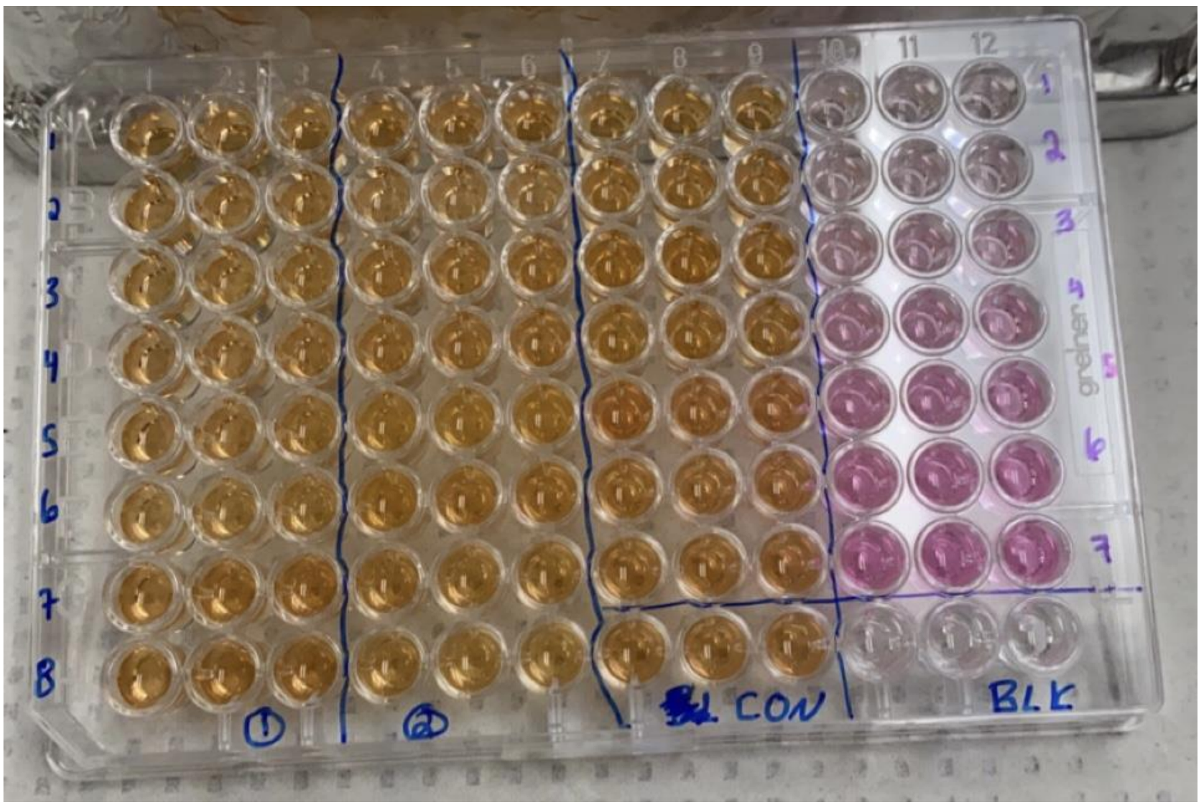


Figure 1.5. Color reaction from MDA and TBA association (Picture from Carlin Lab at North Dakota State University)

Freezing Effects on Lamb Quality

As previously discussed, a major product problem for the US lamb industry is the production cycle of breeding ewes. Ewes cycle as short-day breeders who experience a cycle of sexual inactivity which can last for several months (Redden et al., 2018). This creates a lag in the supply of lamb during certain time periods and a surplus supply of lamb during other time periods. The inconsistency in the supply of lamb could be resolved using frozen storage supplies, however, many retailers, food service providers, and consumers discriminate against frozen lamb, and frozen products in general. Therefore, an important area of research is to better understand how the US lamb industry may utilize frozen storage of lamb to achieve a consistent supply without sacrificing quality and palatability.

There has been a stigma for several decades regarding the quality of frozen red meat products (Smith et al., 1968, Jasper and Placzek, 1980, Wheeler et al., 1990). The loss of quality in frozen meat has mostly been attributed to the formation of ice crystals during freezing which may cause structural damage to the meat leading to increased water loss. Generally, meat which is frozen slower and experience fluctuation in temperature during storage produce larger ice crystals which appear to cause more damage to the ultrastructure of meat products (Devine et al., 1995, Ballin and Lametsch, 2008). Prevention of large ice crystal formation may be solved in the industry as they employ larger, faster freezers. However, it may be difficult to solve lamb quality issues which arise from consumer freezing of purchased fresh meat due to the slow freezing rate of most at-home, still air freezers (Bannister et al., 1971). Furthermore, some quality deterioration occurs due to chemical reactions that may continue to occur in frozen products, such as lipid oxidation (Zhang et al., 2005). However, recent research on Spanish-raised lamb showed little difference in meat quality and consumer acceptability of fresh vs. frozen lamb (Muela et al., 2010, Muela et al., 2012). In both studies, lamb was frozen in differing methods and times, as well as amount of time in storage. These results suggest that frozen storage of lamb products may be a viable option, assuming careful consideration is taken to ensure lamb in frozen quickly and stays frozen while in storage. However, it should be mentioned both studies only stored frozen lamb to a maximum of 6 months, therefore it may be crucial for further research to be conducted to gain a better understanding of how long lamb may remain in frozen storage before quality deterioration becomes an issue with consumer acceptance. Interestingly, despite lamb flavor often being considered a main driver for consumer acceptance or rejection of lamb products, there is a gap in the literature on the effects of freezing on lamb flavor. Most research has centered around the occurrence of lipid oxidation, which may explain some variation in flavor.

Lastly, careful consideration is needed on the timing of freezing lamb in the postmortem period. In general, most processors allow for meat to age before freezing due to the benefits in meat quality (Crouse and Koohmaraie, 1990, Kim et al., 2018). However, it is currently unknown if this precaution is being taken in the US lamb processing industry due to gaps in the literature and general knowledge of the US lamb processing. It is likely these gaps exist due to general neglect of the industry in meat science research for several decades.

Lamb Flavor

Lamb flavor has an interesting dichotomy to consumer acceptance of lamb products. For some consumers, the unique and intense flavor of lamb is the main draw for consumption. On the other side of the spectrum, the same flavor profile, is often viewed as the impediment to consumer acceptance (Watkins et al., 2014). In general, lamb flavor can be altered based on diet. Globally, lambs are raised on forage, but the United States differs from other countries such as Australia and New Zealand who generally produce lamb that has only been raised on the forage while the United States often finishes lambs on a concentrate diet in a feedlot. Lambs fed a concentrate diet generally have higher marbling scores compared to lamb with on forage-based diet, indicating concentrate fed-lamb have a higher lipid content.

Lamb raised primarily on forage generally have a more rancid and liver flavor compared to lambs fed concentrates. This difference may be due to an increase in linolenic acid present in forage-fed lambs due to the propensity of linolenic acid to undergo lipid oxidation and develop off-flavors associated with lipid oxidation (Miller, 2020). Furthermore, some research has suggested forage-fed lambs have a higher concentration of skatole, which is the same compound associated with the development of boar taint in pork (Young et al., 2002). The presence of skatole increased the intensity of lamb flavor, lamb off-odor, and increases the perception of the "barnyard" flavor sometimes associated with lamb (Miller, 2020). Lastly, forage-fed sheep over one year of age are often associated with flavors that are termed "pastoral" or "grassy" (Miller, 2020). It is likely these flavors arise from the presence of branched chain fatty acids such as 4-methyloctanoic acid and 4-ethyloctanoic acid. In a project with Australian lamb consumers, lamb samples with less 4-methyloctanoic acid and 4-ethyloctanoic acid present were more highly rated for overall like and flavor like compared to those with more presence of 4-methyloctanoic acid and 4-ethyloctanoic acid (Watkins et al., 2014).

Due to the variation in lamb flavors based on diet, there has been significant amount of research investigating how consumers perceive lamb from varying diets. Several studies conducted research asking consumers to evaluate lamb from three different production systems: only forage-fed, forage-fed with concentrate supplementation, and concentrate-fed. Most consumers preferred to concentrate-fed lamb regardless of the type of lamb they were accustomed to. Furthermore, an interesting dichotomy was discovered between consumers who frequently ate lamb and those who rarely consumed lamb. Consumers who self-identified as frequent consumers of lamb preferred forage-fed lamb with concentrate supplementation. In contrast, consumers who self-identified as infrequent consumers of lamb vastly preferred concentrate-fed lamb (Fonti-Furnols et al., 2006, Fonti-Furnols et al., 2009). These conclusions seem to point to an overall conclusion that lamb flavor is extremely reliant on personal preference and it may be difficult to pinpoint exact measures the industry can take to improve consumer acceptance of lamb products.

Sensory Evaluation

Sensory evaluation has long been used in the food industry to determine acceptance by consumers, it involves the evaluation of food characteristics which can be perceived by the human senses, taste, sight, smell, and touch. Sensory science evolved into a hard science after the start of World War II when countries were rapidly making rations for soldiers but were looking for ways to make sure they were palatable (Ruiz-Capillas et al., 2021). Sensory analysis is simultaneously a subjective and objective field of research, due to the data being analyzed in an objective method while the data itself is considered subjective due to the involvement of humans in data collection (Ruiz-Capillas et al., 2021). Furthermore, there is considerable variation between individuals in how they score and perceive meat products, leading to further variation in sensory data (Brown et al., 1996). However, the subjectivity of collected data may be marginalized with careful consideration of panelist selection, project design, and panel conduction. Traditional sensory analysis for most food products can be divided into two separate testing categories, analytical testing and affective testing. Table 1.1 outlines types of sensory testing below.

Table 1.1. Description of types of sensory tests employed in sensory evaluation of foods[1]

Sensory Test Type	Subtype of Sensory Test	Examples	Type of Panelists
Analytical	Discrimination	Paired Comparison Triangle	Trained or Consumer
	Descriptive	Texture Profile Flavor Profile	Trained
Affective	Preference	Preference test	Consumer
	Hedonic/Line	Like-dislike scales	

[1]Table adapted from Ruiz-Capillas et al., 2021

Analytical Testing

Analytical testing involves discrimination and descriptive testing which attempt to describe products or differentiate products. Discrimination testing is a simple test to determine if panelists are able to detect differences between samples. Generally, in discrimination testing panelists are not asked to assign a value to any sample or sample characteristics, rather they are simply asked if they can detect a difference between samples. In this type of test, either consumers or trained panelists may be used depending on project design and objectives. Types of discrimination tests include: paired-comparison and triangle tests. In a paired comparison test, two samples are paired together and panelists are asked to determine if there is a difference between samples (Ruiz and Capillas et al., 2021). In a simple example of a paired comparison tests, a panelist may be presented with two samples of pork loin from the same carcass. However, one loin sample has been enhanced and one loin has not. Meanwhile, a triangle test utilizes three samples, where two samples are the same and one sample is different (Ruiz-Capillas, et al., 2021). In a simple example of a triangle test, consumers may be asked to identify which sample is different where they are presented with two samples of USDA Prime ribeye steak and one sample is USDA Select ribeye steak.

Descriptive testing employs sensory description of food products and generally requires a fully trained panel to be considered usable data. This type of sensory evaluation is considered the most objective due to use of defined attributes which panelists are trained on in order to best describe products researchers are interested in. Furthermore, this type of analysis is considered the to be the "gold standard" of sensory evaluation due to the amount of information provided to researchers, as well as the amount of objectivity employed in the gathering of said data. An example of a descriptive test is a flavor profile or texture profile. In a flavor profile test, trained panelists may be asked to identify different flavor categories in food products. (Ruiz-Capillas et al., 2021). An example might be asking panelists to report all flavors they are able to identify in grass-fed beef compared to grain-fed beef. It is important to remember with descriptive testing, panelists are trained to detect characteristics before research begins, with panelists often being eliminated if they are unable to identify characteristics in a satisfactory manner.

Affective Testing

Affective testing involves acceptance tests and employs the use of preference or hedonic testing. In general, naïve panelists are used in affective testing to garner a better outlook on potential purchasing attitudes of all consumers or the acceptance of products by all consumers. In preference testing, panelists are given two samples of a food product and are asked to choose which one they prefer. This is a common method used if the research team only wants to answer the question "Which product will customers prefer?". While preference testing is easy to employ, it provides very little information to the researchers which may be a downfall to this method. In fact, this method rarely even answers a question related to the magnitude of like or dislike on sample products (Ruiz-Capillas et al., 2021). An example of a preference test is presenting panelists with two samples of a pork sausage using different levels of fat and asking them to simply indicate which sample they prefer.

If researchers would like more information but still want to perform affective testing, a hedonic scale or continuous line scale may be employed. With a hedonic scale, a 9-point scale is used to gauge the magnitude of like and dislike of a product. Often the scale will begin at 1 (extremely dislike) and end on 9 (extremely like). A continuous line scale may also be used which allows for a wider range of answers from panelists. Preference testing and hedonic/line scale testing may be employed together to gather as much information as possible from panelists while maintaining simplicity in the panel (Ruiz-Capillas et al., 2021). An example of a hedonic sensory test is presenting panelists with a sample of cooked lamb and asking panelist to use a scale to evaluate overall like, like of tenderness, like of juiciness, and like of flavor.

Student Involvement in Collegiate Activities

A popular theory to explain both student involvement and the importance of that involvement is Astin's theory of student involvement. In order to understand Astin's theory, a definition for student involvement is needed. Student involvement is defined as the amount of physical, mental, and emotional energy a student devotes to the academic experience (Astin, 1984). An example of a student who is highly involved is a student who participates in classes, spends significant amount of time on campus with faculty and peers, and involved in extracurriculars. In contract, a student who is uninvolved is a student who may be absent from classes, does not participate in the campus community, and is relatively uninvolved with extracurriculars.

Astin's theory of student involvement contains five postulates (Astin, 1984):

1) Student involvement includes investment of energy by the student in various experiences. These experiences could be: studying for their biochemistry exam or organizing a sorority philanthropy project.
2) Student involvement occurs on a continuum, meaning all students will invest differing amounts of energy into different experiences.
3) Evaluation of student involvement can be both qualitative and quantitative in nature. Qualitative evaluation may be evaluating the soft skills developed by a student after serving as an officer in a campus organization, whereas a quantitative evaluation may be the number of hours the student dedicated to the campus organization fulfilling their official duties.
4) The amount of learning and development a student experiences is directly proportional to the amount of energy the student expends in pursuit of the experience (You get out, what you put in).
5) The effectiveness of any experience is directly proportional to the ability of that experience to increase student involvement.

While these postulates are important to understanding Astin's theory, the underlying importance of student involvement becomes a bit lost. Ultimately, what Astin's theory postulates is a student who is involved is a student who learns (Wyrick, 1998). Put more simply, a student who is involved in the campus community and extracurriculars learns more both inside and outside the classroom. However, it is important to frame what exactly student are learning from their involvement in campus activities. Significant research has been performed to show the benefits of participation in extracurriculars on college campuses. Research across multiple extracurricular activities indicate a major benefit of student involvement is the ability to develop and hone multiple professional skills, such as organization and leadership skills (Birkenholz and Schumacher, 1994; Foreman and Retallick, 2012; Buckley and Lee, 2021). Furthermore, involvement in extracurriculars often lead to improved classroom performance and retention of learned material (Wyrick, 1998). Moreover, students who are highly involved in their undergraduate careers are more likely to graduate, pursue advanced degrees, or participate in continued education programs in the workforce (Stoecker et al., 1988). Lastly, students with high level of involvement also has a higher job placement rate after graduation, especially in positions they deemed as in their desired fields (Wyrick, 1998). Given the brief summary of benefits of undergraduate student involvement on students, it is important that extracurriculars activities provided to students are continually monitored and evaluated by their governing bodies to ensure all student participants are gaining as many benefits as possible from their programming.

Another aspect which must be considered in relation to student involvement in campus activities is that students who are motivated to learn and to be involved, will be. Motivation can be broken down into two types, extrinsic motivation and intrinsic motivation. Extrinsic motivation is motivation that occurs outside of oneself, meaning this motivation is spurred by a force other than the student. Examples of this type of motivation include grade-seeking behavior or studying for a driver’s exam. On the other hand, intrinsic motivation is motivation that occurs from within oneself, meaning this motivation is spurred by the student. Examples of intrinsic motivation include natural curiosity about a subject. In order to encourage students to be more involved in extracurriculars, it would be important to find a way to encourage the natural intrinsic motivation in the student (Wolfgang and Dowling, 1981).

American Meat Science Association Intercollegiate Meat Judging Program

History

The intercollegiate meat judging program began in 1926 at the International Livestock Exposition in Chicago, Illinois and was hosted by the National Livestock and Meat Board. In the first year, ten teams representing state universities (Colorado, Illinois, Iowa, Minnesota, Missouri, Nebraska, Oklahoma, Pennsylvania, South Dakota, and Wyoming) competed (Bray, 1948). Meat judging was started in order to train college students about the evaluation of carcasses and cuts of meat, as the USDA needed carcass graders due to the establishment of the meat grading service in the 1920's. Since 1926, intercollegiate meat judging contests have been held every year except for three years during World War II, with contest formats being changed to virtual competitions during the judging seasons affected by the COVID-19 pandemic. Programming responsibility was passed to the American Meat Science Association (AMSA) from the National Live Stock and Meat Board in 1996 where it has remained since that time. At this time, the intercollegiate meat judging program is the only judging program with a defined entity which oversees most contests, making this program unique in the ability to be evaluated for effectiveness. However, at this time, goals and missions of the AMSA intercollegiate meat judging program are not readily available to be viewed, creating an issue to provide a relevant framework to evaluate the program.

Contest Structure

Currently, the intercollegiate meat judging program is divided into two divisions, A-division and Senior-division. The A-division is mostly composed of community colleges and smaller universities, with the Senior-division being composed of larger universities. Description of classes in a standard intercollegiate meat judging contest are outlined in Table 1.2. The structure of intercollegiate meat judging contests between the two divisions are shown in Table 1.3. The main differences between A-division and Senior-division are as follows: A-division answers questions over classes while Senior-division writes reasons and A-division does not evaluate specifications. In general, the contest structure of intercollegiate meat judging contests has not changed significantly since the inception in 1926.

Previous Evaluations

The first evaluation of the intercollegiate meat judging program (on record) occurred as a questionnaire sent to all colleges and universities with meat judging teams in the 1940's (Bray, 1948). The main objective of this survey was to better understand the main reasons why institutions supported meat judging programs on their campuses. Several key themes were identified through the responses which included, promoting the US meat industry to college students, providing networking opportunities to participants, development of decision-making skills, and developing future leaders of the meat and livestock industries (Bray, 1948). These discoveries have been a common thread among other studies conducted over the past several decades. In several evaluations of the intercollegiate meat judging program, it was found that program participants rated development of decision-making skills and the exposure to the meat industry as the most important traits of the program to them (Fields et al., 1998, Davis et al., 1991, Mefford, 2011). Furthermore, participation in the intercollegiate meat judging program has been associated with increased development of critical thinking skills (Miller et al., 2011).

However, there has been some disagreement in the literature about how well intercollegiate contests (both livestock and meat) represent the actual industry. In one evaluation (Mello, Jr., et al, 1973), respondents indicated they felt meat and livestock judging contests did a fair job at representing the respective industries accurately. However, other research (Bray, 1948, Field et al., 1998) have suggested meat and livestock judging do not always reflect the commercial industry as accurately as they should. However, it should be noted this observation was more heavily placed on livestock judging compared to meat judging.

Table 1.2. Description of classes in a standard American Meat Science Association intercollegiate meat judging contest for both A-division and Senior-division

Class Type	**Description**	**Classes Available for Evaluation**
Placings Classes	Contestants place 4 exhibits on the basis of cutability and quality. Highest possible score is 50 points.	Beef carcasses, beef cuts, pork carcasses, pork cuts, lamb carcasses, veal carcasses
Reasons/Questions Classes	Contestants place 4 exhibits on the basis of cutability and quality and record detailed notes. Highest possible score is 50 points.	Beef carcasses, beef cuts, pork carcasses, pork cuts, lamb carcasses
Reasons	Contestants use notes to write a 4-paragraph defense of their reasons class placing. Highest possible score is 50 points.	N/A
Questions	Contestants answer 10 questions about the questions class. Highest possible score is 50 points.	N/A
Specifications	Contestants evaluate 10 cuts based on their accuracy to prescribed USDA Institutional Meat Purchasing Specifications (IMPS)	Beef: IMPS 107, 112A, 120, 170, 174, 180, 184 Lamb: IMPS 204, 207, 232, 233A Pork: IMPS 401, 406, 408, 412
Beef Yield Grading	Contestants evaluate and assign USDA yield grades to 15 beef carcasses	Beef carcasses
Beef Quality Grading	Contestants evaluate and assign USDA quality grades to 15 beef carcasses	Beef carcasses

Table 1.3. Classes and point available in an American Meat Science Association standard intercollegiate meat judging contest for A-division and Senior-division

	A-Division		**Senior-division**	
	Number of Classes	**Total Points**	**Number of Classes**	**Total Points**
Placing Classes	5	250	5	250
Reasons/Questions Classes	5	250	5	250
Reasons	N/A	N/A	5	250
Questions	5	250	N/A	N/A
Specifications	N/A	N/A	1	100
Beef Yield Grading	1	150	1	150
Beef Quality Grading	1	150	1	150
Total Contest Points	**1050**		**1150**	

References

Allingham, P.G., G.S. Harper, D.W. Hennessey, V.H. Oddy. 2001. The influence of pre-weaning nutrition on biochemical and myofiber characteristics of bovine semitendinosus. Aust. J. Agric. Res. 52, 891-902.

Amaral, A.B., M.V. da Silva, S.C.S. da Lannes. 2018. Lipid oxidation in meat: Mechanisms and protective factors – A review. Food Sci. Technol. 38, 1-15.

Astin, A.W. 1984. Student involvement: A developmental theory for higher education. J. Coll. St. Personnel. 25, 297-308.

Ballin, N.Z. and R. Lametsch. 2008. Analytical methods for authentication of fresh vs. thawed meat – A review. Meat Sci. 80(2), 151-158.

Bannister, M.A., D.L. Harrison, A.D. Dayton, D.H. Kropf, H.J. Tuma. 1971. Effects of a cryogenic and three home freezing methods on selected characteristics of pork loin chops. J. Food Sci. 36(6) 951-954.

Barden, L. and E.A. Decker. 2016. Lipid oxidation in low-moisture food – A review. Crit. Rev. Food Sci. Nutr. 56, 2467-2482.

Bate-Smith, E.C., Bendall, J.R. 1949. Factors determining the time course of rigor mortis. J. Physiol. 110, 47-65.

Bendall, J.R. 1951. The shortening of rabbit muscles during rigor mortis: its relation to the breakdown of adenosine triphosphate and creatine phosphate and to muscular contraction. J. Physiol. 114, 71-88.

Bindon, B.M. and N.M. Jones. 2001. Cattle supply, production systems, and markets for Australian beef. Aust. J. Exp. Agr. 41, 861-877.

Birkenholz, R.J. and L.G. Schumacher. 1994. Leaderships skills of college of agriculture graduates. J. Agr. Educ. 35(4), 1-8.

Boehm, M.L., T.L. Kendall, V.F. Thompson, D.E. Goll. 1998. Changes in the calpains and calpastatin during postmortem storage of bovine muscle. J. Anim. Sci. 76, 2415-2434.

Boleman, S.J., S.L. Boleman, R.K. Miller, J.F. Taylor, H.R. Cross, T.L. Wheeler, M. Koohmaraie, S.D. Shackleford, M.F. Miller, R.L. West, D.D. Johnson, J.W. Savell. 1997. Consumer evaluation of beef of known tenderness categories. J. Anim. Sci. 75, 1521-1524.

Bray, R.W. 1948. Meat judging contests and their place in education. 1st Recip. Meat Conf. Proc., Chicago, IL.

Brown, W.E., K.R. Langley, L. Mioche, S. Marie, S. Gerault, D. Braxton. 1996. Individuality of understanding and assessment of sensory attributes in foods, in particular, tenderness of meat. Food Qual. Pref. 7(3) 205-216.

Buckley, P. and P. Lee. 2021. The impact of extracurricular activity on the student experience. Act. Learn. High Educ. 22(1), 37-48.

Caine, W.R., J.L. Aalhus, D.R. Best, M.E.R. Dugan, L.E. Jeremiah. 2003. Relationship of texture profile analysis and Warner-Bratzler shear force with sensory characteristics of beef rib steaks. Meat Sci. 64(4), 333-339.

Christie, W.W. 1978. The composition, structure, and function of lipids in the tissues of ruminant animals. Prog. Lipid. Res. 17, 111-205.

Cockett, N.E., S.P. Jackson, T.L. Shay, F. Farnir, S. Berghmans, G.D. Snowder, D.M. Nielsen, M. Georges. 1996. Polar overdominance at the ovine callipyge locus. Science. 273(5272), 236-238.

Crouse, J.D. and M. Koohmaraie. 1990. Effect of freezing on beef on subsequent postmortem ageing and shear force. J. Food Sci. 55(2) 573-574.

Davis, G.W., M.F. Miller, D.M. Allen, K.L. Dunn. 1991. An assessment of intercollegiate meat judging from 1926 to 1989. NACTA J. 35(4), 28-31.

Delgado, E.F., G.H. Geesink, J.A. Marchello, D.E. Goll, M. Koohmarie. 2001. Properties of myofibril-bound calpain activity in longissimus muscle of callipyge and normal sheep. J. Anim. Sci. 79, 2097-2107.

Den Hertog-Meischke, M.J.A., R.J.L.M. Van Laack, F.J.M. Smulders. 1997. The water holding capacity of fresh meat. Vet. Quat. 19, 175-181.

Di Lisa, F., R. De Tullio, F. Salamino, R. Barbato, E. Melloni, N. Silipriadni, S. Schiaffino, S. Pontremoli. 1995. Specific degradation of troponin-T and I by μ-calpain and its modulation by substrate phosphorylation. Biochem. J. 308, 57-61.

Drey, L.N., K.R. Vierck, L.L. Prill, J.M. Gonzalez, T.A. Houser, E.A.E. Boyle, J.L. Vipham, T.G. O'Quinn. 2018. Consumer juiciness acceptability supports the beef marbling insurance theory. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. 68-70.

Dominguez, R., M. Pateiro, M. Gagaoua, F.J. Barba, W. Zhang, J.M. Lorenzo. A comprehensive review on lipid oxidation in meat and meat products. Antioxidants 8, 1-31.

Duckett, S.K., G.D. Snowder, N.E. Cockett. 2000. Effect of the callipyge gene on muscle growth, calpastatin activity, and tenderness of the three muscles across the growth curve. J. Anim. Sci. 78(11), 2836-2841.

Dunn, J. L., S. E. Williams, J. D. Tatum J. K. Bertrand, and T. D. Pringle. 2000. Identification of optimal ranges in ribeye area for portion cutting of beef steaks. J. Anim. Sci. 78:966- 975.

Fang, S-H., T. Nishimura, K. Takahashi. 1999. Relationship between development of intramuscular connective tissue and toughness of pork during growth of pigs. J. Anim. Sci. 77, 120-130.

Farouk, M.M., M. Beggan, S. Hurst, A. Stuart, P.M. Dobbie, A.E.D. Bekhit. 2007. Meat quality attributes of chilled venison and beef. J. Food Quality 30 1023-1039.

Farouk, M.M., E. Wiklund, A. Stuart, P.M. Dobbie. 2009. Ageing prior to freezing improves water-holding capacity in beef and venison. 55th International Congress on Meat Science and Technology, Copenhagen, Denmark. 16-21 August.

Farouk, M.M., N.M. Mustafa, G. Wu, G. Krsinic. 2012. The “sponge effect” hypothesis: An alternative explanation of the improvement in the water-holding capacity of meat with ageing. Meat Sci. 90(3) 670-677.

Feuz, R. and Kim, M-K. 2019. US sheep industry and the public grazing fee. Rangeland Ecol. Manag. 72(3) 415-424.

Field, T.G., R.D. Green, J.A. Gosey, H.D. Ritchie. 1998. A summary of intercollegiate judging activity, funding, and philosophy. NACTA J. 42(3), 27-31.

Fonti-Funrols, M., C.E. Realini, L. Guerrero, M.A. Oliver, C. Sanudo, M.M. Campo, G.R. Nute, V. Caneque, I. Alvarez, R. San Julian, S. Luzardo, G. Brito, F. Montossi. 2009. Acceptability of lamb fed on pasture, concentrate or combinations of both systems by European consumers. Meat Sci. 81, 196-202.

Fonti-Furnols, M., R. San Julian, L. Guerro, C. Sanudo, M.M. Campo, J.L. Oletta, M.A. Oliver, V. Caneque, I. Alvarez, M.T. Diaz, W. Branscheid, M. Wicke, G.R. Nute, F. Montossi. 2006. Acceptability of lamb meat from different producing systems and ageing time to German, Spanish, British consumers. Meat Sci. 72(3) 545-554.

Foreman, E.A. and M.S. Retallick. 2012. Undergraduate involvement in extracurricular activities and leadership development in College of Agriculture and Life Sciences students. J. Agr. Educ. 53(3), 111-123.

Ghnimi, S., E. Budilarto, A. Kamal-Eldin. 2017. The new paradigm for lipid oxidation and insights microencapsulation of omega-3 fatty acids. Compr. Rev. Food Sci. Food Saf. 16, 1206-1218.

Harris, S.E., Huff-Lonergan, E., Lonergan, S.M., Jones, W.R., Rankins, D. 2001. Antioxidant status affects color stability and tenderness of calcium chloride injected beef. J. Anim. Sci. 79, 666-677.

Hay, J.D., R.W. Currie, F.H. Wolfe. 1973. Polyacrylamide disc gel electrophoresis of fresh and aged chicken muscle proteins in sodium dodecylsulfate. J. Food. Sci. 38(6), 987-990.

Hnasko, T.S. and R.M. Hnasko. 2015. The western blot. ELISA 87-96.

Honikel, K.O. 1998. Reference methods for the assessment of physical characteristics of meat. Meat Sci. 49 447-457.

Honikel, K.O., C.J. Kim, R. Hamm, P. Roncales. 1986. Sarcomere shortening of pre-rigor muscles and its influence on drip loss. Meat Sci. 16, 267-282.

Hornick, J.L., C. Van Eneaeme, A. Clinquart, M. Diez, L. Istasse. 1998. Different periods of feed restriction before compensatory growth in Belgian Blue bulls: Animal performance, nitrogen balance, meat characteristics, and fat composition. Anim. Sci. 69. 563-572.

Huff-Lonergan, E. and S.M. Lonergan. 2005. Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. Meat Sci. 71 194-204.

Huff-Lonergan, E., W. Zhang, S.M. Lonergan. 2010. Biochemistry of postmortem muscle – lesson on mechanisms of meat tenderization. Meat Sci. 86, 184-195.

Hughes, J.M., S.K. Oiseth, P.P. Purlow, R.D. Warner. A structural approach to understanding the interactions between colour, water—holding capacity, and tenderness. Meat Sci. 98 520-532.

Jeacocke, R.E. 1993. The concentration of free magnesium and calcium ions both increase in muscle fibers entering rigor mortis. Meat Sci. 35, 27-45.

Jenkins, K.H., J.T. Vasconcelos, J.B. Hinkle, S.A. Furman, A.S. de Mello, L.S. Senaratne, C.R. Calkins. Evaluation of performance, carcass characteristics, and sensory attributes of beef from finishing steers fed field peas. J. Anim. Sci. 89(4), 1167-1172.

Jeremiah, L.E., Martin, A.H. 1982. Effects of prerigor chilling and freezing and subcutaneous fat cover upon the histological and shear properties of bovine longissimus dorsi muscle. C. J. Anim. Sci. 62(2), 353-361.

Jones, K.G. 2004. Trends in the US sheep industry. USDA-ERS Agriculture Information Bulletin Number 787.

Joo, S.T., R.G. Kauffman, B.C. Kim, G.B. Park. 1999. The relationship of sarcoplasmic and myofibrillar protein solubility to color and water-holding capacity in porcine longissimus muscle. Meat Sci. 52 291-297.

Kanawa, R. and K. Takashashi. 2002. Inactivity of mu-calpain throughout postmortem aging of meat. J. Anim. Sci. 67, 635-638.

Kerth, C.R., Miller, M.F., Ramsey, C.B. 1995. Improvement of beef tenderness and quality traits with calcium chloride injection with beef loins 48 hours postmortem. J. Anim. Sci.73, 750-756.

Kim, H-W., J-H. Kim, J-K. Seu, D. Setyabrata, Y.H.B. Kim. 2018. Effects of aging/freezing sequence and freezing rate on meat quality and oxidative stability of pork loins. Meat Sci. 139, 162-170.

Koch, R.M., L.V. Cundiff, K.E. Gregory. 1982. Heritabilities and genetic, environmental, and phenotypic correlations of carcass traits in a population of diverse biological types and their implication in selection programs. J. Anim. Sci. 55, 1319.

Koohmaraie, M. 1996. Biochemical factors regulating the toughness and tenderization processes of meat. Meat Sci. 43 193-201.

Leick, C.M., J.M. Behrends, T.B. Schmidt, M.W. Schilling. 2011. Consumer selection of constant weight ribeye, sirloin, and top loin steaks. Meat Sci. 87(1). 66-72.

Leick, C.M., J.M. Behrends, T.B. Schmidt, M.W. Schilling. 2012. Impact of price and thickness on consumer selection of ribeye, sirloin, and top loin steaks. Meat Sci. 91(1). 8-13.

Lepetit, J. 2007. A theoretical approach of the relationships between collagen content, collagen crosslinks and meat tenderness. Meat Sci.76, 147-159.

Light, N., Champion, A.E., Voyle, C., Bailey, A.J. 1985. The role of epimysial, perimysial and endomysial collagen in determing texture in six bovine muscles. Meat Sci. 13, 137- 149.

Liu, R. and W. Zhang. 2020. Chapter 4 – Detection techniques of meat tenderness: State of the art. In *Meat Quality Analysis*, Elsevier, London, UK.

Locker, R.H. and Hagyard, C.J. 1963. A cold shortening effect in beef muscles. Journal of the Science of Food and Agriculture. 14, 787-793.

Lorenzo, J.M. 2014. Changes on physico-chemical, textural, lipolysis, and volatile compounds during the manufacture of dry-cured foal cecina. Meat Sci. 96, 256-263.

MacBride, M.A. and F.C. Parrish, Jr. 1977. The 30,000 dalton component of tender bovine longissimus muscle. J. Food Sci. 42(6), 1627-1629.

Maltin, C., D. Balcerzak, R. Tilley, M. Delday. 2003. Determinants of meat quality: Tenderness. Proc. Nutri. Soc. 62, 337-347.

Maples, J.G., J.L. Lusk, D.S. Peel. 2018. Unintended consequences of the quest for increased efficiency in beef cattle: When bigger isn't better. Food Policy. 74. 65-73.

Mefford, C.S. 2011. Interpersonal and career skills gained from competing on an Oklahoma State University judging team. M.S. thesis, Oklahoma State Univ., Stillwater, OK. (https://shareok.org/bitstream/handle/11244/15005/Mefford_okstate_0664M_13141.pdf?sequence=1)

Mello, Jr., F.C., D.I. Davis, D.D. Didley. 1973. An analysis of intercollegiate meat and livestock evaluation contests. NACTA J. 17(1) 13-16.

Miller, C.C., C.C. Carr, J.H. Brendemuhl, J.C. Ricketts, B.E. Meyers, T.G. Roberts. 2011. Quantifying the critical thinking skills of students who receive instruction in meat-animal or meat product evaluation. NACTA J. 55(1), 50-54.\

Miller. R. 2020. Drivers of consumer liking for beef, pork, and lamb: A review. Foods. 9, 1-25.

Millman, B.M., K. Wakabayashi, T.J. Racey. Lateral forces in the filament lattice of vertebrae striated muscle in the rigor state. Biophys. J. 41, 259-267.

Min, B. and D.U. Ahn. 2005. Mechanism of lipid peroxidation in meat and meat products – A review. Food. Sci. Biotechnol. 14, 153-163.

Muela, E., C. Sanudo, M.M. Campo, I. Medel, J.A. Beltran. 2010. Effect of freezing method and frozen storage duration on instrumental quality of lamb throughout display. Meat Sci. 84(4), 662-669.

Muela, E., C. Sanudo, M.M. Campo, I. Medel, J.A. Beltran. 2012. Effect of freezing method and frozen storage duration on lamb sensory quality. Meat Sci. 90(1), 209-215.

Mumford, H.W. 1902. Market classes and grades of cattle with suggestions for interpreting market quotations. University of Illinois Agricultural Experiment Station. Bulletin No.78.

National Beef Quality Audit (NBQA), 2016. Executive Summary: The 2016 National Beef Quality Audit. National Cattleman’s Beef Association

O'Connor, S.F., J.D. Tatum, D.W. Wulf, R.D. Green, G.C. Smith. 1997. Genetic effects on beef tenderness in *Bos indicus* and *Bos taurus* cattle. J. Anim. Sci. 75(7), 1822-1830.

Offer, G. and T. Cousins. 1992. The mechanism of drip production – formation of 2 compartments of extracellular space in muscle postmortem. J Food Sci. Agric. 58 107-116.

Olson, D.G., F.C. Parrish, M.H. Stromer. 1976. Myofibrillar fragmentation and shear resistance of three bovine muscles during postmortem storage. J. Food. Sci. 41, 1036.

Oswell, N.L., O.P. Gilstrap, R.B. Begg. 2021. Variation in terminology and methodologies applied to the analysis of water holding capacity in meat research. Meat Sci. 178.

Pateiro, M., D. Franco, J.A. Carril, J.M. Lorenzo. 2015. Changes in physico-chemical properties, lipid oxidation, and volatile compounds during the manufacture of celta dry-cured loin. J. Food Sci. Technol. 52, 4808-4818.

Penny, I.F. and E. Dransfield. 1979. Relationship between toughness and troponin-T in conditioned beef. Meat Sci. 3, 135-141.

Pikul, J., D.E. Leszczynski, F.A. Kummerow. 1984. Relative role of phospholipids, triacylglycerols, and cholesterol esters on malonaldehyde formation in fat extracted from chicken meat. J. Food Sci. 49, 704–708.

Poulanne, E. and M. Halonen. 2010. Theoretical aspects of water-holding in meat. Meat Sci. 86 151-165.

Purslow, P.P. 2014. New development on the role of intramuscular connective tissue in meat toughness. Annu. Rev. Food Sci. T. 5, 133-153.

Rasmussen, A.J. and M. Andersson. 1996. New methods for determination of drip loss in pork muscles. 42nd International Congress on Meat Science and Technology. September 1-6. Lillehammer, Norway.

Redden, R., E. Sanko, R. Ehrhardt, C. Hiemke. 2018. Seasonality of the US Lamb Industry. American Lamb Board. 1-17.

Robins, S.P., S. Shimokamaki, A.J. Bailey. 1973. The chemistry of the collagen cross-links: Age related changes in the reducible components of intact collagen fibers. Biochem. J. 131, 771-780.

Roeber, D.L., R.K. Gill, Discostanzo, A. 2005. Meat quality responses to feeding distiller's grains to finishing Holstein steers. J. Anim. Sci. 83 2455-2460.

Rosenthal, A.J. 2010. Texture profile analysis – How important are the parameters. J. Text. Stud. 41(5), 672-684.

Ruiz-Capillas, C., A.M. Herrero, T. Pintado, G. Delgado-Pando. 2021. Sensory analysis and consumer research in new meat products development. Foods. 10, 1-15.

Savage, A.W.J., P.D. Warriss, P.D. Jolley. 1990. The amount and composition of the protein in drip from stored pig meat. Meat Sci. 27 289-303.

Savell, J. W., and H. R. Cross. 1988. The role of fat in the palatability of beef, pork, and lamb. In 'Designing foods: Animal product options in the marketplace. NRC Committee on Technological Options to Improve the Nutritional Attributes of Animal Products. 345–355.

Scanga, J.A., K.E. Belk, J.D. Tatum, G.C. Smith. 2001. Supranutritional oral supplementation with vitamin D_3 and calcium and the effects on beef tenderness. J. Anim. Sci. 79, 912-918.

Sinclair, K.D., G.E. Lobley, G.W. Horgan, D.J. Kyle, A.D. Porter, K.R. Matthews, C.C. Warkup, C.A. Maltin. 2001. Factors influencing beef eating quality: Effects of nutritional regimen and genotype on organoleptic and instrumental texture. Anim. Sci. 72, 268-277.

Smith, G. C., and Z. L. Carpenter. 1974. Eating quality of animal products and their fat content. Proc. Symposium on changing the fat content and composition of animal products. National Research Council, Washington DC, USA: Natl Academy of Sciences.

Smith, G.C., C.W. Spareth, Z.L. Carpenter, G.T. King, K.E. Hoke. 1968. The effects of freezing, frozen storage conditions, and degree of doneness on lamb palatability characteristics. J. Food Sci. 33, 19-24.

Smith, S.B., T. Gotoh, P.L. Greenwood. 2018. Current situation and future prospects for global beef production: Overview of special issue. Asian-Australas. J. Anim. Sci. 31(7) 927-932.

Sweeter, K.K., D.M. Wulf, R.J. Maddock. 2005. Determining the optimum beef longissimus muscle size for retail consumers. J. Anim. Sci. 83(11) 2598-2604.

Stoecker, J., E. Pascarella, L. Wolfe, 1988. Persistence in higher education: A nine-year test of a theoretical model. J. Coll. Student Dev. 29 196-209.

Tarrant, P.V. 1998. Some recent advances in and future priorities for the meat industry. Meat Sci. 49. 1-16.

Taylor, S.C. and A. Posch. 2014. The design of a quantitative western blot experiment. Biomed. Res. Int. 1-8.

Taylor, R.G., G.H. Geesink, V.F. Thompson, M. Koohmaraie, D.E. Goll. 1995. Is Z-disk degradation responsible for postmortem tenderization? J. Anim. Sci. 73, 1351-1367.

Thorne, J.W., B.M. Murdoch, B.A. Freking, R.R. Redden, T.W. Murphy, J.B. Taylor, D.H. Blackburn. 2021. Evolution of the sheep industry and genetic research in the United Stated: Opportunities for convergence in the twenty-first century. Anim. Genet. 52 395-408.

Troy, D.J. and J.P. Kerry. 2010. Consumer perception and the role of science in the meat industry. Meat Sci. 86, 214-226.

USDA. 1992. United States standards for grades of carcass beef. Livest. Seed Program, Agric. Market. Serv., Washington, D.C.

USDA. 2017. United States standards for grades of lamb, yearling mutton, and mutton carcasses. Livest. Seed Program, Agric. Market. Serv., Washington, D.C.

USDA. 2022. Cattle and beef sector at a glance. Econ. Res. Serv., Washington, D.C.

Walukonis, C.J., M.T. Morgan, D.E. Gerrard, J.C. Forrest. 2002. A technique for predicting water holding capacity in early postmortem muscle. Purdue University Swine Research Report. 110-117.

Watkins, P.J., D. Frank, T.K. Singh, O.A. Young, R.D. Warner. 2013. Sheepmeat flavor and the effect of different feeding systems – A review. J. Agric. Food Chem. 61, 3561-3579.

Watkins, P.J., G. Kearney, G. Rose, D. Allen, A.J. Ball, D.W. Pethick, R.D. Warner. 2014. Effect of branched chain fatty acids, 3-methylindole and 4-methylphenol on consumer sensory scores of grilled lamb meat. Meat Sci. 96(2), 1088-1094.

Wheeler, T,L., L.V. Cundiff, R.M. Koch. 1994. Effect or marbling degree on palatability in *Bos taurus* and *Bos indicus* cattle. J. Anim. Sci. 72(2), 3145-3151.

Wheeler, T.L., R.K. Miller, J.W. Savell, H.R. Cross. 1990. Palatability of chilled and frozen beef steaks. J. Food Sci. 55(2) 301-303.

Wheeler, T.L., S.D. Shackleford, M. Koohmaraie. 2000. Variation in proteolysis, sarcomere length, collagen content, and tenderness among pork muscles. J. Anim. Sci. 78, 958-965.

Wiegand, B.R., F.C. Parrish, D.G. Morrical, E. Huff-Lonergan. 2001. Feeding high levels of vitamin D_3 does not improve tenderness of callipyge lamb loin chops. J. Anim. Sci. 79, 2086-2091.

Wolfgang, M.E. and W.D. Dowling. Differences in motivation of adult and younger undergraduates. J. Higher Educ. 52(6) 640-648.

Wyrick, J. 1998. Why involvement matters: A review of research on student involvement in the collegiate setting. Coll. Stud. Aff. J. 17(2) 4-17.

Young, O.A., G.A. Lane, A. Priolo, K. Fraser. 2002. Pastoral and species flavor in lambs raised on pasture, lucerne, or maize. J. Sci. Food Agric. 83, 93-104.

Zhang, S.X., M.M. Farouk, O.A. Young, K.J. Wieliczjo, C. Podmore. 2005. Functional stability of frozen normal and high pH beef. Meat Sci. 69(4), 765-772.

CHAPTER 2. EVALUATION OF FARGO-MOORHEAD BEEF CONSUMERS PURCHASING DECISIONS BASED ON BEEF RIBEYE STEAK SIZE AND THICKNESS

Introduction

Since 1977 the United States has produced more beef each year with fewer cattle on feed (Maples et al., 2018). This achievement was reached by improving management of beef cattle, as well as increasing live animal size and carcass size (Maples et al., 2018). The average hot carcass weight has increased by 45 kg since 1991 from 345 kg to 390 kg (NBQA, 2016). While it may be easy to assume the increase in weight is occurring due to an increase in external fat, external fat thickness has actually decreased by 0.08 cm on average since 1991 from 1.5 cm to 1.42 cm (NBQA, 2016). Therefore, the increase in weight is likely attributed to the increase in longissimus muscle area (LMA). Longissimus muscle area has increased by 6.45 cm^2 since 1991 from 83.2 cm^2 to 89.7 cm^2 (NBQA, 2016). While an argument can certainly be made the increase in carcass size and therefore increase in pounds per lean produced with a lower number of cattle is a sign of increased efficiency in the US beef industry, we also must consider the influence of increasing muscle size on consumer satisfaction.

There is conflicting evidence in the literature in relation to how beef consumers perceive larger steaks. Research has shown that there is a wide range of beef consumers in the US and their preferences are varied for steak size, indicating increase in LMA size may not be an issue (Sweeter et al., 2005). Furthermore, consumers discriminate against steaks with a small LMA more so than those with a large LMA due to dislike of the small surface area seen in steaks with a small LMA (Leick et al., 2011). However, this observation is complicated more when consideration for not only size of steaks but thickness of steaks is also taken into account.

Maples et al. (2018) found consumers have a wide range of acceptance of steaks from varying size, however most consumers discriminate against thin cuts of steak. Therefore, an increase in LMA size becomes a significant issue for portioning of steaks due to a large LMA forcing portioned steaks to be cut thinner. Furthermore, the aforementioned studies did not evaluate retail sales of differing steaks, rather they were conducted as surveys or auctions which may contain skewed data of how consumers would actually purchase steaks with their own money and without knowledge of research being conducted at the time of steak selection. Therefore, the objective of the present study was to evaluate ribeye steak purchasing behaviors of Fargo-Moorhead beef consumers based on LMA size and thickness of beef ribeye steaks using retail intercept.

Materials and Methods

USDA Low Choice beef carcasses (n=50) were selected at a commercial abattoir based on 3 LMA size categories over 2 collections. Carcasses with a LMA size between 113 – 100 cm^2 were assigned to the large size (LRG) treatment, 99 – 84 cm^2 were assigned to the intermediate size (INT) treatment, and 83 – 64.5 cm^2 were assigned to the small size (SMA) treatment. Carcass data was collected by trained personnel from North Dakota State University (NDSU). Boneless ribeye rolls (IMPS 112A) were collected and transported back to the NDSU Meat Laboratory where they were aged for 14 days.

After aging, ribeye rolls were fabricated into boneless ribeye steaks (IMPS 1112C) (n=600) with varying thicknesses over 2 collections. Steaks with a thickness of 3.8 cm were assigned to the thick thickness (THK) treatment, 2.5 cm were assigned to the intermediate thickness (INT) treatment, and 1.9 cm were assigned to the thin thickness (THN) treatment. In order to eliminate location bias, steaks were fabricated in a pattern of THK, INT, THN starting on the cranial end, with four repetitions of the pattern on each ribeye roll. Simply, 12 steaks were fabricated from each ribeye roll, with a total of four steaks from each thickness treatment being collected. After fabrication, steaks were packaged in retail foam trays with oxygen-permeable overwrap and affixed with one of two labels. The first label was a three-digit code on the bottom of the package to track individual steaks through the study. The second label was a standard retail label with price per pound, weight, and total price. Figure 2.1 displays a representative package below. Steak weight, anatomical location, and steak price were all recorded for each individual steak fabricated.

Figure 2.1. Representative steak package with price per pound, steak weight, and steak price included on label

Packaged steaks were placed in a coffin-style, self-service cooler to conduct a retail intercept survey at the NDSU Meat Laboratory retail store. A ribeye steak sale was advertised to increase foot traffic to the retail store; however, customers were not made aware a study was being conducted until the time of purchase. Customers were not provided funds to purchase steaks. It is important to note; the research team took care to ensure all customers were able to choose from all treatment combinations at all times. Furthermore, the study was terminated when a single treatment was no longer available. At the time of purchase, customers were asked if they would participate in a study evaluating their purchasing decisions of their chosen steaks. Customers were awarded a free beef ribeye steak as compensation for their time. If customers agreed, they were asked to move to an office to eliminate bias for other customers purchasing steaks. Participants were given a Qualtrics survey which included demographic questions and purchasing decision questions for individual steaks. Options for purchasing decisions included: price, quality, thickness, weight, locally produced, trusted brand, country of origin labeling, antibiotic free labeling, hormone free labeling, and organic/natural labeling. Survey ballot is included in Table 2.1 below. This survey project was approved by the NDSU Institutional Review Board, #0003828. Data were analyzed using the PROC FREQ procedure of SAS Studio® (SAS Institute, Cary, NC). Chi square analysis was performed on steak disappearance data and was considered significant when $P \leq 0.05$.

Table 2.1. Survey ballot used by participants to evaluate Fargo-Moorhead beef consumers purchasing behaviors of steaks of varying longissimus muscle area and thickness

Demographics	
	What is your gender?
	What is your age?
	What is your current working status?
	What is your household income?
	How often do you consume beef products?
Purchasing Behavior	
	Please select **all** factors you consider when purchasing beef steaks.
	Please select the **most important** factor you consider when purchasing beef steaks.
	Please select the most important factor you considered to purchase this steak.

Results and Discussion

Individual Steak Data

Averaged individual steak data (n = 408) for each treatment is displayed below in Table 2.2. Data includes average weight and number of steaks sold for each of the nine treatments. Steaks from the INT × INT were the most popular among survey participants, with all three INT size treatments were the most popular among survey participants. Furthermore, chi squares goodness of fit tests are located in Table 2.3 to better understand purchasing behaviors of respondents. Based on these results, respondents preferred intermediate sized steaks compared to large and small steaks and discriminated most heavily against small steaks (P = 0.0052). Furthermore, there was a tendency for intermediate steaks of all thicknesses to be purchased more frequently compared to other steak size and thickness combinations (P = 0.0877). However, there were no significant differences (P = 0.3788) in purchasing frequency between varying thicknesses. This observation is in slight disagreement with previous research which indicated there was no significant differences in consumer preference between steak sizes (Sweeter et al., 2005). However, it should be noted that given the design of this study, this data can also be interpreted that Fargo-Moorhead beef consumers are varied in their preferences for steak size. This observation is in agreement with several other studies which suggested the varied nature of the supply of beef steaks in the US is a positive due to the varied preferences of US beef consumers (Sweeter et al., 2005, Leick et al., 2011, Leick et al., 2012, Maples et al., 2018). Furthermore, data from the current study does support findings in previous research which indicates consumers may discriminate against thin steaks (Maples et al., 2018).

Table 2.2. Number and average weight of boneless beef ribeye steaks sold (n = 408) to Fargo-Moorhead beef consumers

	Numbers of Steaks Sold	**Steak Weight (g)**
Steak Treatment[1]		
Small × Thin	32	303.91
Small × Intermediate	34	371.95
Small × Thick	46	521.63
Intermediate × Thin	53	308.44
Intermediate × Intermediate	57	390.09
Intermediate × Thick	55	589.67
Large × Thin	40	317.52
Large × Intermediate	44	444.52
Large × Thick	47	635.03

[1] Treatment names are [longissimus muscle area] × [thickness]

Table 2.3. Chi square goodness of fit test for purchasing trends of beef ribeye steaks (n = 408) from varying LMA[1] size and thickness by Fargo-Moorhead beef consumers

Treatment	**Observed Frequency[2]**	**Expected Frequency[2]**	χ^2	***P*-value**
LMA Size				
Small	112	136		
Intermediate	165	136	10.51	0.0052
Large	132	136		
Thickness				
Thin	125	136		
Intermediate	136	136	1.94	0.3788
Thick	148	136		
LMA Size × Thickness[3]				
Small × Thin	32	45		
Small × Intermediate	34	45		
Small × Thick	46	45		
Intermediate × Thin	53	45		
Intermediate × Intermediate	57	45	13.78	0.0877
Intermediate × Thick	55	45		
Large × Thin	40	45		
Large × Intermediate	45	45		
Large × Thick	47	45		

[1]Longissimus muscle area
[2]Observed frequency is the amount of test steaks purchases; expected frequency is the number of steaks expected to be purchased if all steak types were purchased at the same frequency
[3]Treatment names are [longissimus muscle area] × [thickness]

Demographics

Demographic data for survey respondents (n=114) is below in Table 2.4. Respondents were asked to provide their gender, age, working status, household income, and beef consumptions habits. Respondents were also asked to provide further insights into their personal beef purchasing behaviors. First, respondents were asked to select all factors which may affect their decision to purchase a beef steak. Then, respondents were asked to select the most important factor when purchasing a beef steak. Purchasing decision data for all respondents is below (Table 2.5 and 2.6). Results for purchasing decisions are in slight agreement with other research which indicates factors such as steak quality and thickness drive consumer purchasing decisions with price driving purchasing decisions to a lesser extent (Leick et al., 2012).

Table 2.4. Demographic data of Fargo-Moorhead beef consumers (n = 114) who purchased boneless beef ribeye steaks

	Count	**Percentage**
Gender		
Male	61	53.51
Female	50	43.86
Prefer Not to Say	3	2.63
Age		
<20	1	0.88
20-29	11	9.65
30-39	14	12.28
40-49	28	24.56
50-59	31	27.19
Over 60	29	25.44
Working Status		
Student	6	5.31
Part-Time	2	1.77
Full-Time	99	87.61
Retired	4	3.54
Not Employed	2	1.77
Household Income		
<$25,000	7	6.09
$25,000 - $49,999	13	11.30
$50,000 - $74,999	14	12.17
$75,000 - $99,999	32	27.83
>$100,000	49	42.61
Beef Consumption		
Daily	8	7.02
2-3 times/week	77	67.54
2-5 times/month	27	23.68
Less than once/month	2	1.75

Table 2.5. All[1] factors affecting respondents (n = 114) purchasing decisions of beef ribeye steaks

	Count
Steak Price	95
Steak Quality	96
Steak Thickness	85
Steak Weight	64
Produced Locally	73
Trusted Brand	38
County of Origin Labeling	36
Antibiotic Free Labeling	14
Hormone Free Labeling	18
Organic/Natural Labeling	11

[1]Respondents could select any factor they consider while purchasing beef steaks

Table 2.6. Most important[1] factor affecting respondents purchasing decisions of boneless beef ribeye steaks

	Count	**Percentage**
Price	22	19.13
Steak Quality	46	40.00
Steak Thickness	8	6.96
Steak Weight	9	7.83
Produced Locally	16	13.91
Trusted Brand	7	6.09
County of Origin Labeling	3	2.61
Antibiotic Free Labeling	1	0.87
Hormone Free Labeling	2	1.74
Organic/Natural Labeling	1	0.87

[1]Respondents were restricted to the most important factor they consider while purchasing beef steaks

Steak Purchasing

Respondents were asked to indicate the most important factor to their purchasing decision of each individual test steak they purchased. Steak purchasing data for all steaks sold is below in Table 2.7.

Our results strongly support previous research which suggests thickness of steaks is a major determinant for US beef consumers purchasing behaviors and that they discriminate more heavily against thin cut steaks (Leick et al., 2012, Maples et al., 2018). Previous research has not included an option for consumers to choose a thickness and weight combination option for purchasing decisions. Given the high frequency of this option in the current study, further research is warranted to better understand how steak size and steak thickness combinations influence beef purchasing decisions. More research is needed in this area of study to better understand if US beef consumers are more willing to sacrifice thickness or surface area for their beef steaks.

Table 2.7. Purchasing[1] decisions of Fargo-Moorhead beef consumers (n = 114) of boneless beef ribeye steaks (n = 408) across all treatments[2]

	Count	**Percentage**
Price	39	9.5
Steak Thickness	81	19.9
Steak Weight	51	12.5
Steak Thickness × Weight	136	33.3
Random	31	7.6
Other[3]	70	17.2

[1]Respondents were provided a list of purchasing decisions for test steaks
[2]Treatments include every combination of longissimus muscle area size (small, intermediate, large) and thickness (thin, intermediate, thick)
[3]All text responses for "other" were regarding steak quality

Conclusions

Our results indicate Fargo-Moorhead beef consumers do not have a strong preference for individual steak size. Furthermore, our results show that Fargo-Moorhead beef consumers choose steaks whose quality and thickness appeal to them more than price or steak size. These results are in agreement with previous literature which suggests that beef consumers have varied wants and needs from their beef steaks and the US beef industry provides them with varied options. Therefore, it can be included the US beef industry is currently producing and offering steaks which fit the needs of US beef consumers.

However, it should be noted this research and the literature referenced focuses on the retail sector. While the retail sector is a vitally important part of the US beef industry, is not the only sector. The food service sector is a massive industry and outlet for many beef steaks produced in the US beef industry. Previous research determined the optimum range for steaks in the food service sector came from beef carcasses with measured LMAs between 77 – 97 cm^2 (Dunn et al., 2000). This was the optimum LMA range due to the combination of cooking time and perceived tenderness. With these steaks, the food service sector was able to cook steaks in a faster time while maintaining demanded thickness of their customers while also meeting customer demands for palatability and satisfaction (Dunn et al., 2000). Furthermore, it was recognized that the food service sector likely would prefer their supply of steaks be as consistent in size and thickness as possible to reduce errors of cooking steaks in the fast-paced restaurant environment (Dunn et al., 2000). Given the differences in requirement for the retail and food service sector demands, further research is needed to fully understand the influence of increasing LMA size on acceptance of beef steaks across all sectors.

References

Dunn, J. L., S. E. Williams, J. D. Tatum, J. K. Bertrand, and T. D. Pringle. 2000. Identification of optimal ranges in ribeye area for portion cutting of beef steaks. J. Anim. Sci. 78:966-975.

Leick, C.M., J.M. Behrends, T.B. Schmidt, M.W. Schilling. 2011. Consumer selection of constant weight ribeye, sirloin, and top loin steaks. Meat Sci. 87(1). 66-72.

Leick, C.M., J.M. Behrends, T.B. Schmidt, M.W. Schilling. 2012. Impact of price and thickness on consumer selection of ribeye, sirloin, and top loin steaks. Meat Sci. 91(1). 8-13.

Maples, J.G., J.L. Lusk, D.S. Peel. 2018. Unintended consequences of the quest for increased efficiency in beef cattle: When bigger isn't better. Food Policy. 74. 65-73.

National Beef Quality Audit (NBQA), 2016. Executive Summary: The 2016 National Beef Quality Audit. National Cattleman's Beef Association.

Sweeter, K.K., D.M. Wulf, R.J. Maddock. 2005. Determining the optimum beef longissimus muscle size for retail consumers. J. Anim. Sci. 83(11) 2598-2604.

CHAPTER 3. EEFFECTS OF FRESH AND FROZEN STORAGE ON MEAT AND SENOSRY QUALITY CHARACTERISTICS, PROTEIN DEGRADATION, AND LIPID OXIDATION OF AMERICAN LAMB LONGISSMUS LUMBORUM AND SEMIMEMBRANOSUS

Introduction

A common challenge in the US lamb industry is inconsistencies in the supply of fresh lamb related to lambing time and rates in the traditional US lamb system, with about 80% of the US lamb crop being born in the first five months of the year (Redden et al., 2018). Use of frozen lamb could resolve some of these issues during spikes in lamb demand around the Christmas and Easter holidays. However, consumers heavily discriminate against frozen meat in the retail space (Bueno et al., 2013; Lambooij et al., 2019) due to perceived issues with product quality. There is general acceptance among research that freezing of meat products leads to a degradation of ultrastructure due to formation of ice crystals during the freezing process. The degradation of the ultrastructure may lead to palatability issues due to loss of water during the thawing process (Devine et al., 1995, Ballin and Lametch, 2008). Additionally, some research suggests freezing of meat products allows for continued deterioration due to chemical reactions, such as lipid oxidation, continuing to occur even in frozen products (Zhang et al., 2005). Some research has been performed on meat quality and sensory attributes of frozen lamb, however there are inconsistent conclusions on whether frozen lamb is a viable option for US retailers (Smith et al., 1968, Muela et al., 2016, Kim et al., 2011, Kim et al., 2013).

Furthermore, the US lamb processing industry is less organized compared to other US red meat processing industries, meaning that some processing techniques may be employed which reduce lamb meat quality. Therefore, it is important that research is conducted to understand exactly how freezing affects meat quality and sensory attributes of American lamb to provide better research-based guidance to processors, retailers, foodservice on the consumer perceptions of frozen lamb and whether frozen lamb is a viable option for US consumers.

Our objectives for this research were to evaluate differences in meat quality and sensory attributes of fresh and frozen lamb using the *longissimus lumborum* (LL) and *semimembranosus* (SM) muscles, evaluate differences in protein degradation and lipid oxidation of fresh and frozen LL and SM samples, and provide recommendations to US processors on best procedures of storage of the LL and SM muscles.

Materials and Methods

Experimental Design

North Dakota State University (NDSU) raised lambs (n=12) were slaughtered at the NDSU Meats Laboratory using standard slaughter and dressing procedure under USDA-FSIS inspection. After a 24 h chill, USDA yield grading and quality grading were performed by trained NDSU personnel. After grading, loin and leg subprimals were collected from each carcass. Subprimals were split in half and each side was assigned to either fresh (FRSH) or frozen (FRZN) treatment. Each half was weighed before being vacuum sealed. Subprimals assigned to FRSH treatment were stored in a cooler at 3° C for 14 days while subprimals assigned to FRZN treatment were stored in a freezer at -18° C for 13 days + 1 day of thawing at 3° C. FRNZ treatment samples were frozen at ~30 h postmortem.

Sample Preparation

Before fabrication, subprimals were removed from bags and reweighed for primal weight loss. LL sample collection began at the cranial end of the half with the following samples removed in sequential order: ~1.27 cm chop for protein degradation and lipid oxidation analysis, a ~1.27 cm chop for drip loss analysis, a ~2.54 cm chop for Warner-Bratzler shear force (WBSF) and cook loss analysis, with all over remaining chops being used for sensory analysis. The SM was removed from leg subprimal with sample collection beginning at the distal end of the muscle with samples being removed in the same manner as the LL. Samples destined for WBSF and cook loss analysis and sensory evaluation were vacuum-sealed and stored at 4° C until analysis was performed.

Meat Quality Analyses

Drip loss analysis was conducted immediately after sample collection. Samples weight ~25g from the LL and SM were suspended from a large paperclip in a wire closure bag to collect water drip for 24 h. Before suspension, samples were weighed with weight recorded as the beginning sample weight. After 24 h, samples were reweighed to determine ending weight. Drip loss was determined using the following equation: $[1 - \frac{(beginning\ weight - ending\ weight)}{beginning\ weight}]$. Chops for WBSF and cook loss analysis were allowed to equilibrate to approximately 20° C prior to cooking. Chops were weighed to determine raw weight before inserting a thermocouple [Omega Engineering Inc., Stamford, CT] into the geometric center of the chop. Chops were cooked on clamshell style grills [George Foreman Model No. GRP99, Columbia, MO] to an internal temperature of 71° C. Chops were allowed to cool to room temperature before being reweighed to determine cooked weight. Cook loss was determined using the following equation: $[1 - \frac{(raw\ weight - cooked\ weight)}{raw\ weight}]$. Three 1.27 cm cores were removed from the center of each chop being careful to keep muscle fibers parallel (AMSA, 2016). Cores were sheared perpendicular to the muscle fibers using a shear force machine [United-Smart 1 Test System SSTM500, United Calibration Corporation, Huntington Beach, CA]. The average of the three cores was used for statistical analysis.

Sensory Analysis

Sensory analysis was conducted 24 hours after sample collection. Longissimus lumborum and SM chops were cooked in the same manner as described above with the endpoint temperature of 60° C (AMSA, 2016). Consumer panelists were recruited via email lists of the NDSU campus faculty and staff. Consumer panelists (n=84) were served five 1.27 cm cubed samples. All samples were presented in 2 oz covered plastic cups which were labeled with a three-digit code. The first sample presented was a warm-up sample which was not used in analysis. The subsequent samples were paired SM and LL samples. Panelists were instructed to taste bite of a sample, and then a second bite before recording their scores. Furthermore, panelists were provided with unsalted crackers and distilled water to cleanse their palate between samples. Panelists were asked to evaluate each sample for overall like, flavor like, tenderness like, and juiciness like on a 0-100 continuous line scale. Demographic and sensory ballots provided to panelists are included Appendix A and B.

Protein Extraction and Protein Concentration for Lipid Oxidation Analysis

Sarcoplasmic protein fractions were extracted from samples collected and frozen after 14 d of storage. Briefly, ~1 g of muscle tissue was minced and homogenized in 4 mL of extraction buffer [20m*M* sodium phosphate, monobasic monohydrate; 20m*M* sodium phosphate, dibasic; Sodium dodecyl sulfate (SDS); 10% (vol/vol)] and 40 µL of 100X butylated hydroxytoluene] using a Polytron Kinematica [10/35 with controller and PTA 10S generator; Brinkmann, Westbury, NY] on wet ice until the sample was completely ground. The homogenate was clarified by centrifugation (15,000 x *g*) at 10° C for 15 minutes [Allegra 25R Centrifuge with TA-5.1-5000 swinging bucket rotor, Beckman Coulter, Fullerton, CA]. The clear supernatant was then transferred to 1.5 mL microtubes and stored at -80° C for further analysis. The protein concentration of each extract was determined using the Pierce Detergent Compatible Bradford Assay [Thermo-Fisher 23246; Rockford, IL].

Lipid Oxidation Analysis

Lipid oxidation analysis was performed using the OxiSelect TBARS Assay (Catalog No. STA-330, Cell Biolabs Inc., San Diego, CA) on 96-well flat bottom plates using a Synergy H1 microplate reader (Biotek, Winooski, VT) reading at 532 nm. Manufacturer procedures were followed except for the following modifications, samples were incubated in dry heating blocks at 95° C for 45 minutes. After cooling, samples were clarified by centrifugation (10,000 x *g*) at 12° C for 12 minutes.

Protein Extraction and Protein Concentration of Western Blotting Analysis

Sarcoplasmic protein fractions were extracted from samples collected and frozen at 14 d of aging. Briefly, ~1 g of muscle tissue was minced and homogenized in 10 mL of extraction buffer [20m*M* sodium phosphate, monobasic monohydrate; 20m*M* sodium phosphate, dibasic; Sodium dodecyl phosphate; 10% (vol/vol)] using a Polytron Kinematica [10/35 with controller and PTA 10S generator; Brinkmann, Westbury, NY] on wet ice until the sample is completely ground. The homogenate was clarified by centrifugation (3,000 x *g*) at 10° C for 20 minutes [Allegra 25R Centrifuge with TA-5.1-5000 swinging bucket rotor, Beckman Coulter, Fullerton, CA]. The clear supernatant was then transferred to 1.5 mL microtubes and stored at -80° C for further analysis. The protein concentration of each extract was determined using the Pierce Detergent Compatible Bradford Assay [Thermo-Fisher 23246; Rockford, IL].

Gel Sample Preparation

Protein extracts were diluted with water for a final concentration of 0.64 µg /µL. Two hundrend and fifty µL of sample gel buffer/tracking dye solution [3 m*M* ethylenediamine tetraacetic acid (EDTA); 3% (wt/vol) SDS; 30% (vol/vol) glycerol; 0.003% (wt/vol) pyronine Y; 30 m*M* Tris] (Wang et al., 1982; Huff-Lonergan et al., 1996) and 50 μL of 2-mercaptoethanol were added to protein exact samples. Gel samples were heated at 65° C for 15 minutes and then frozen at -80° C until further analysis by Western blotting.

SDS-Page Electrophoresis

Samples in sample gel buffer/tracking dye solution for troponin-T (TnT) were run on 1.5 mm thick 15% acrylamide separating gels [0.38 *M* Tris, pH 8.8; 0.1% (wt/vol) SDS; 0.05% (wt/vol) AMPER; 0.05% (vol/vol) TEMED] with 5% acrylamide stacking gels [0.125 *M* Tris, pH 6.8; 0.1% (wt/vol) SDS; 0.075% (wt/vol) AMPER; 0.125% (vol/vol) TEMED] in a running buffer [25 m*M* Tris; 0.192 *M* glycine; 2.0 m*M* EDTA; 0.1% (wt/vol) SDS] (Melody et al., 2004). Electrophoresis was conducted on a BioRad Mini-PROTEAN Tetra Cell system (BioRad Laboratories, Hercules, CA). Gels for TnT were loaded with 9 μg of sample per lane and run at a constant voltage of 120 V for 2 h 15 m.

Transfer Conditions

Proteins were transferred onto a BioRad 0.45μ polyvinylidene difluoride (PVDF) membrane (BioRad Laboratories, Hercules, CA) using a BioRad TransBlot Turbo transfer unit (BioRad Laboratories, Hercules, CA) at a constant voltage of 25 V and 2.5 A for 12 m in a transfer buffer (BioRad TransBlot Turbo transfer buffer Catalog No. 10026938, BioRad Laboratories, Hercules, CA).

Western Blotting

After transfer, all membranes were blocked in PBS-Tween [80 m*M* sodium phosphate, dibasic; 20 m*M* sodium phosphate, monobasic; 100 m*M* sodium chloride; 0.1% (vol/vol) Tween-20 and 5% (wt/vol) nonfat dry milk] for 1 h at room temperature. After blocking, membranes were placed in PBS-Tween with the primary antibody [mouse monoclonal anti-rabbit troponin-T antibody, Catalog No. T6277, Sigma Chemical, St. Louis, MO] diluted 1:35,000 in PBS-Tween and incubated overnight at 4° C. After incubation, membranes were allowed to warm to room temperature for 15 m and washed 3 times with PBS-Tween. Troponin-T blots were then incubated 1 h at room temperature with the secondary antibody [goat anti-mouse conjugated with horseradish peroxidase, Catalog No. A28177; ThermoFisher Scientific, Waltham, MA] diluted at 1:75,000 and StrepTactin-AP Conjugate [BioRad Catalog No. 161-0382, BioRad Laboratories, Hercules, CA] diluted at 1:100,00. Upon completion of secondary antibody incubation, membranes were washed 3 times with PBS-Tween at room temperature for 10 m per wash before chemiluminescence detection. Chemiluminescence was initiated using premixed reagents [ECL Prime Kit, Catalog No. RPN2236, GE Healthcare, Chicago, IL] and was detected using a F2.8 28-70 mm zoom lens camera [Alpha Innotech Corporation, San Leandro, CA]. Densitometry measurements were performed using the AlphaEaseFC software [Alpha Innotech Corporation, San Leandro, CA].

Statistical Analysis

Analysis of variance for data for meat quality, lipid oxidation, and sensory was analyzed using the PROC MIXED procedure of SAS Studio® (SAS Institute, Cary, NC). Least squares means were separated with the PDIFF option. Means were considered significant when $P \leq 0.05$. TnT Western blot data were analyzed using the PROC MIXED procedure SAS Studio® (SAS Institute, Cary, NC). Least squares means were separated with the PDIFF option. Means were considered significant when $P \leq 0.05$. The ratio of the intensity of the sample bands to the intensity of the 30-kDa band in the pooled control was used to analyze the differences in treatments. The control sample ran on all SDS-PAGE gels was a pooled control sample representative of all samples.

Results and Discussion

Meat Quality

Results are summarized in Table 3.1. No differences were observed between treatments for primal weight loss, cook loss, or Warner-Bratzler shear force in either the LL or SM ($P > 0.05$). While we did not see significant differences in primal weight storage loss, it is important to mention storage loss in FRZN samples was nearly double in both muscles compared to FRSH samples. Therefore, there may be value loss associated with freezing lamb products. Moreover, LL and SM samples in the FRSH treatment experienced less drip loss compared to samples in the FRZN treatment ($P = <0.0001$, $P = 0.0003$, respectively). These results are consistent with several other studies (Choe et al., 2016; Kim et al., 2013; Kim et al., 2011) which indicate freezing early in the aging process of meat increases drip loss after thawing. Additionally, Bueno et al., (2013) found that frozen storage did not influence lamb meat quality characteristics other than a deleterious effect on water-holding capacity, concurring with the results in the present study. Recent research on Spanish-raised lamb showed little difference in meat quality and consumer acceptability of fresh vs. frozen lamb (Muela et al., 2010, Muela et al., 2012). However, it should be mentioned both studies only stored frozen lamb to a maximum of 6 months, therefore it may be crucial for further research to be conducted to gain a better understanding of how long lamb may remain in frozen storage before quality deterioration becomes an issue with consumer acceptance.

Table 3.1. Least squares means of the effect of fresh and frozen storage of American lamb on subprimal weight loss, drip loss, cook loss, and shear force values on longissimus lumborum and semimembranosus chops

	Storage Conditions			
	Fresh	**Frozen**	**SEM**	***P*-value**
Longissimus lumborum				
n	12	12		
Subprimal weight loss, %	0.867	1.608	0.441	0.12
Drip loss, %	0.850[a]	4.800[b]	0.451	< 0.0001
Cook loss, %	17.475	17.550	1.425	0.96
WBSF, kg	2.884	3.213	0.300	0.30
Semimembranosus				
n	12	10		
Subprimal weight loss, %	0.283	0.575	0.161	0.10
Drip loss, %	2.300[a]	6.673[b]	0.766	0.0003
Cook loss, %	19.125	21.180	1.867	0.30
WBSF, kg	3.188	3.393	0.281	0.49

[a,b]Means in same group without common superscript differ ($P < 0.05$).

Protein Degradation

Results for troponin-T (TnT) are summarized in Figures 3.1 and 3.2 below. Protein degradation values are reported as relative abundance compared to the 30-kDa band of the pooled control. Treatment did not influence ($P > 0.05$) 42-kDa TnT in the LL. FRZN-LL samples had greater 37-39 kDa (P = 0.0002), 35-kDa (P <0.0001) and 34-kDa (P <.0001) TnT compared to FRSH-LL samples. Conversely, FRSH-LL samples had greater 32-kDa (P <0.0001) and 30-kDa (P <0.0001) TnT compared to FRZN-LL samples. FRZN-SM samples had greater 42-kDa (P = 0.02), 37-39 kDa (P <0.0001), 35-kDa (P <0.0001), and 34-kDa (P = 0.01) TnT compared to FRSH-LL samples. Conversely, FRSH-SM samples had greater 32-kDa (P = 0.0008) and 30-kDa (P <0.0001) TnT compared to FRZN-SM samples. Therefore, it can be concluded FRSH samples in both muscles experienced more degradation of TnT compared to FRZN samples (Figure 3.3) due to the increased 30-kDa product seen in FRSH samples

(MacBride and Parrish, 1979). These results were expected as the study design did not allow for FRZN samples to age for longer than 24 hours postmortem (Olson et al., 1976).

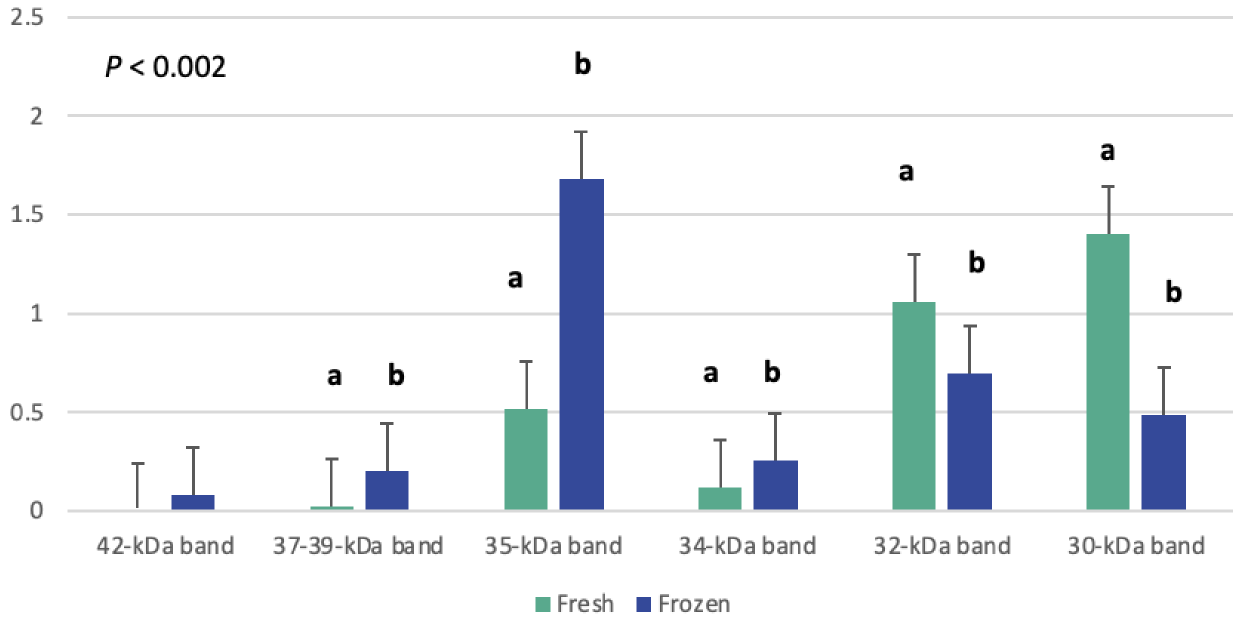


Figure 3.1. Effect of fresh and frozen storage of American lamb on troponin-T degradation in the longissimus lumborum after 14 days of storage

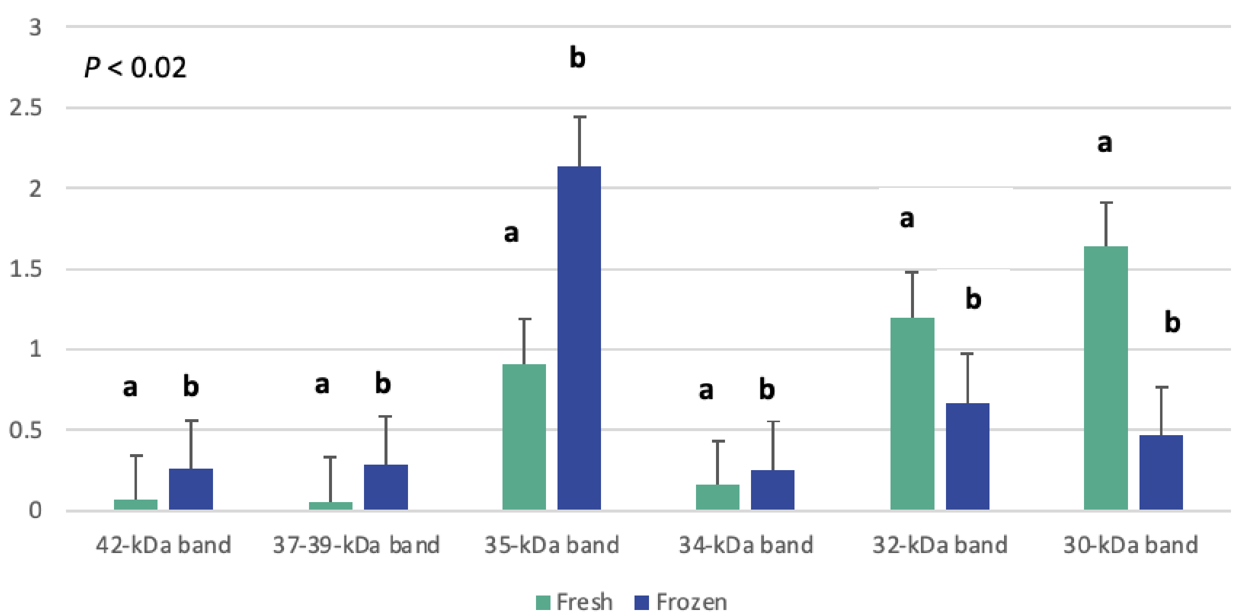


Figure 3.2. Effect of fresh and frozen storage of American lamb on troponin-T degradation in the semimembranosus after 14 days of storage

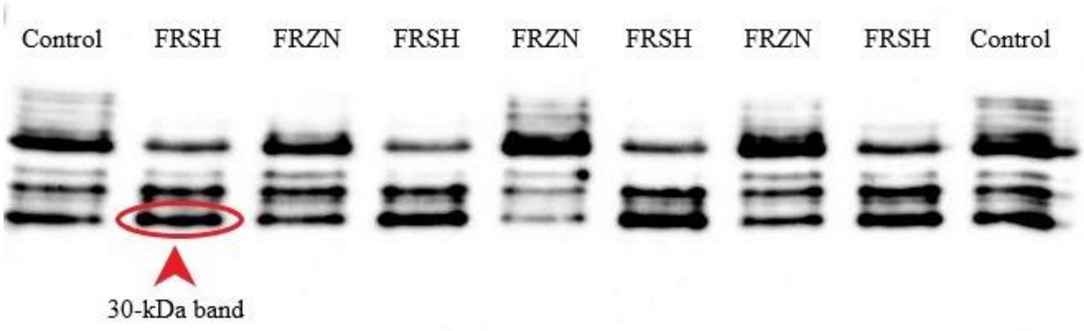


Figure 3.3. Representative Western blot of whole muscle protein extracted from lamb longissimus lumborum stored fresh or frozen for 14 days.

However, these results do offer further explanation of other observed results in the present study. Previously, increased water-holding capacity of aged meat was thought to be explained by the meat having less water to lose during the aging process due to moisture loss in the early postmortem period (Joo et al., 1999). However, this hypothesis is challenged by observations of Farouk et al. (2012) where there were not significant changes in moisture content in the early postmortem period and during aging. Therefore, another explanation for this phenomenon is needed. One such explanation is the “sponge effect” hypothesis (Farouk et al., 2012). After a series of other studies (Farouk et al., 2007; Farouk et al., 2009) it was observed water-holding capacity increased with longer ageing periods. In this hypothesis, it is explained that during the conversion of muscle to meat, channels may be formed due to the decrease in pH and muscle contraction due to rigor and these channels may allow for water to more easily drip. However, as postmortem aging occurs, the structure of these channels may be disrupted due to proteolysis of structural proteins. The breakdown of structural proteins is pivotal to the increased water-holding capacity of aged meat due to the ability of water to be physically trapped in the meat. Furthermore, there is the potential that the increased viscosity of water in meat (due to soluble protein) may further reduce the ability of water to drip out (Farouk et al., 2012). This hypothesis likely explains the results we saw in the present study as we did not allow for the FRZN treatment samples to age for any significant amount of time prior to freezing. Therefore, it can be concluded the increased water loss in the FRZN treatment likely occurred due to the increase in formed drip channels and decrease in proteolysis.

Careful consideration is needed on the timing of freezing lamb in the postmortem period. In general, most processors allow for meat to age before freezing due to the benefits in meat quality seen (Crouse and Koohmaraie, 1990, Kim et al., 2018). However, it is currently unknown if this precaution is being taken in the US lamb processing industry due to gaps in the literature and general knowledge of the US lamb processing industry. Research could be warranted to document processing practices of the US lamb industry to ensure lamb quality is being protected.

Lipid Oxidation

Results are summarized in Table 3.3 below. There was no treatment effect ($P > 0.05$) on malondialdehyde (MDA) levels in either the LL or SM. Disagreements in the literature exist on the influence of freezing on lipid oxidation in meat. Much research suggests that freezing in temperatures higher than -20° C allows for some water in meat to facilitate some primary lipid oxidation, which allows for secondary lipid oxidation to occur after thawing (Owen and Lawrie, 1975; Hansen et al., 2004; Leygonie, et al., 2012). However, it should be noted these studies were not performed in lamb meat. Moreover, it has been suggested more recently (Bueno et al., 2013; Muela et al., 2012) that frozen storage of lamb may be acceptable for most consumers due to lack of significant changes in the meat during frozen storage which impact consumer acceptance. Due to conflicts in the literature, further research is warranted to further elucidate effects on freezing in lamb.

Table 3.3. Least squares means of the effect of fresh and frozen storage of American lamb on malondialdehyde (MDA) levels (mg of MDA/kg of meat) as indicators of lipid oxidation

	Storage Conditions			
	Fresh	**Frozen**	**SEM**	***P*-Value**
Longissimus lumborum				
n	12	12		
MDA, mg/kg of meat	9.20	9.58	0.41	0.36
Semimembranosus				
n	12	12		
MDA, mg/kg of meat	9.71	9.80	0.58	0.89

Sensory

Demographics for survey participants are below in Table 3.4. Sensory results are summarized in Table 3.5 below. LL sensory samples in the FRSH treatment had significantly higher overall like, tenderness, and juiciness scores compared to samples in the FRZN treatment (P = 0.01, P = 0.02, P = 0.03, respectively). These results were expected due to increased drip loss in FRZN treatment. No differences in flavor scores were observed in LL sensory samples in the FRSH treatment compared to samples in the FRZN treatment. These results were expected due to no differences in lipid oxidation between the FRSH and FRZN treatment in both muscles. As previously stated, the effect of freezing on lipid oxidation in lamb has not been fully elucidated and therefore requires more research. However, it should be noted our levels of MDA in both treatments exceeded the threshold (4.2-7.5 mg of MDA/kg of meat) for consumers to detect off-flavors in lamb that are attributed to lipid oxidation (Berruga et al., 2005; Ponnampalam et al., 2017). Moreover, the TBARS method used in these studies are different than the methods in the presents and therefore may be difficult to fully compare. This may account for our relatively low flavor scores across both treatments in both muscles. Furthermore, not all panelists in our sensory panels self-identified as frequent lamb eaters. Therefore, due to the difference in flavor perceptions of lamb meat seen between frequent and infrequent consumers of lamb (Watkins, et al., 2013). Further research may be warranted to investigate differences in perception of frozen lamb flavor between frequent and infrequent consumers of lamb.

Additionally, no differences in overall like, flavor, tenderness, or juiciness scores were observed in SM sensory samples in the FRSH treatment compared to samples in the FRZN treatment ($P > 0.05$). These results concur with other recent research which suggests there are not major differences in fresh and frozen lamb (Muela et al., 2010, Muela et al., 2012). While we saw differences in drip loss in the SM, these sensory results are likely explained by the background toughness inherently in the SM due to muscle use in the live animal and presence of increased connective tissue. Therefore, it is likely we would not see significant differences in consumer perceptions of meat palatability characteristics due to all samples potentially being viewed as ‘tough’.

Table 3.4. Demographic data for sensory participants (n = 84)

	Count	Frequency
Gender		
Male	31	40.0
Female	53	60.0
Age		
Under 20	20	24.0
20-29	56	67.0
30-39	3	4.0
40-49	4	5.0
50-59	1	1.0
Working Status		
Student	45	54.0
Part-time	26	31.0
Full-time	13	15.0
Ethnicity		
Caucasian	69	82.0
Hispanic	5	6.0
Asian	9	11.0
Other	1	1.0
Previous lamb consumer		
Yes	63	75.0
No	21	25.0

Table 3.5. Least squares means of the effect of fresh and frozen storage of American lamb on consumer sensory attribute scores on a 0-100 continuous scale[1] of longissimus lumborum and semimembranosus chops

	Storage Conditions			
	Fresh	Frozen	SEM	*P*-Value
Longissimus lumborum				
n	12	12		
Overall Like	64[a]	56[b]	2.867	0.01
Flavor Like	64	59	3.156	0.14
Tenderness Like	62[a]	55[b]	2.760	0.01
Juiciness Like	59[a]	52[b]	2.689	0.03
Semimembranosus				
n	12	12		
Overall Like	58	57	3.876	0.85
Flavor Like	60	60	3.023	0.92
Tenderness Like	54	54	3.943	0.99
Juiciness Like	52	53	3.952	0.77

[1] 0=greatest imaginable disliking, 100=greatest imaginable liking

[a,b]Means in same group without common superscript differ ($P < 0.05$).

Conclusions

Our results indicate freezing lamb for 13 d after an initial 24-h chill did not affect lipid oxidation as measured by MDA levels. This conclusion is supported by consumer sensory panel flavor scores which indicate no differences in flavor between fresh and frozen lamb. Both FRSH-LL and FRSH-SM samples experienced less drip loss compared to FRZN samples. Other sensory attributes indicated consumers found FRSH-LL to score higher for like, tenderness, and juiciness, which could be attributed to increased protein degradation in FRSH samples due to aging. However, the same sensory results were not observed in FRSH-SM. Results suggest that greater protein degradation may influence sensory attributes in the LL but not the SM, which demonstrates that lamb legs may be frozen without negative effects on palatability while lamb loins should be kept fresh to offer the greatest opportunity for consumer satisfaction.

References

Ballin, N.Z. and R. Lametsch. 2008. Analytical methods for authentication of fresh vs. thawed meat – A review. Meat Sci. 80(2), 151-158.

Berruga, M.I., H. Vergara, L. Gallego. 2005. Influence of packaging conditions on microbial and lipid oxidation in lamb meat. Small Ruminant Res. 57 257-264.

Bueno, M., V.C. Resconi, M.M. Campo, J. Cacho, V. Ferreira, A. Escudero. 2013. Effect of freezing method and frozen storage duration on odor-active compounds and sensory perception of lamb. Food Res. Int. 54(1) 772-780.

Cho, S.H., A. Stuart, Y.H.B. Kim. 2016. Effect of different aging temperatures prior to freezing on meat quality attributes of frozen/thawed loins. Meat Sci. 116 158-164.

Farouk, M.M., M. Beggan, S. Hurst, A. Stuart, P.M. Dobbie, A.E.D. Bekhit. 2007. Meat quality attributes of chilled venison and beef. J. Food Quality 30 1023-1039.

Farouk, M.M., E. Wiklund, A. Stuart, P.M. Dobbie. 2009. Ageing prior to freezing improves water-holding capacity in beef and venison. 55th International Congress on Meat Science and Technology, Copenhagen, Denmark. 16-21 August.

Farouk, M.M., N.M. Mustafa, G. Wu, G. Krsinic. 2012. The "sponge effect" hypothesis: An alternative explanation of the improvement in the water-holding capacity of meat with ageing. Meat Sci. 90(3) 670-677.

Hansen, E., D. Juncher, P. Henckel, A. Karlsson, G. Bertelsen, L.H. Skibsted. 2004. Oxidative stability of chilled pork chops following long term frozen storage. Meat Sci. 68 497-484.

Huff-Lonergan, E., T. Mitsuhashi, F.C. Parrish, Jr., R.M. Robson. 1996. Sodium dodecyl sulfate-polyacrylamide gel electrophoresis and western blotting comparisons of purified myofibrils and whole muscle preparations for evaluating titin and nebulin in postmortem bovine muscle. J. Anim. Sci. 74 779-785.

Joo, S.T., R.G. Kauffman, B.C. Kim, G.B. Park. 1999. The relationship of sarcoplasmic and myofibrillar protein solubility to color and water-holding capacity in porcine longissimus muscle. Meat Sci. 52 291-297.

Kim, Y.B.H., M. Frandsen, K. Rosenvold. 2011. Effect of ageing prior to freezing on color stability of ovine longissimus muscle. Meat Sci. 88 332-337.

Kim, Y.B.H., G. Luc, K. Rosenvold. 2013. Pre-rigor processing, ageing, and freezing on tenderness and color stability of lamb loins. Meat Sci. 95(2) 412-418.

Lambooij, M.S., J. Veldwijk, P. van Gils, MJ.J. Mangen, E. Over, A. Suijkerbuijk, J. Plder, G.A. de Wit, M. Opsteegh. 2019. Consumers' preferences for freezing of meat to prevent toxoplasmosis – A stated preference approach. Meat Sci. 149 1-8.

Leygonie, C., T.J. Brtiz, L.C. Hoffman. 2012. Impact of freezing and thawing on the quality of meat: Review. Meat Sci. 91(2) 93-98.

Muela, E., C. Sanudo, M.M. Campo, I. Medel, J.A. Beltran. 2010. Effect of freezing method and frozen storage duration on instrumental quality of lamb throughout display. Meat Sci. 84(4), 662-669.

Muela, E., C. Sanudo, M.M. Campo, I. Medel, J.A. Beltran. 2012. Effect of freezing method and frozen storage duration on lamb sensory quality. Meat Sci. 90(1), 209-215.

Muela, E. P. Monge, C. Sanudo, M.M. Campo, J.A. Beltran. 2016. Sensory quality of lamb following long-term frozen storage. Meat Sci.114 32-37.

Olson, D.G., F.C. Parrish, Jr., M.H. Stromer. 1976. Myofibril fragmentation and shear resistance of three bovine muscles during postmortem storage. J. Anim. Sci. 41 1036-1041.

Owen, J.E. and R.A. Lawrie. 1975. The effect of an artificially induced higher pH on the susceptibility of minced porcine muscle to underdo oxidative rancidity under frozen storage. J. Food Technol. 10 169-180.

Ponnampalam, E.N., T. Plozza, M.G. Kerr, N. Linden, M. Mitchell, A.E.A. Bekhit, J.L. Jacobs, D.L. Hopkins. 2017. Interaction of diet and long ageing period on lipid oxidation and color stability of lamb meat. Meat Sci. 129 43-49.

Redden, R., E. Sanko, R. Ehrhardt, C. Hiemke. 2018. Seasonality of the US Lamb Industry. American Lamb Board. 1-17.

Smith, G.C., C.W. Spaeth, Z.L. Carpenter, G.T. King, K.E. Hoke. 1968. The effects of freezing, frozen storage conditions, and degree of doneness on lamb palatability characteristics. J Food Sci. 33 19-24.

Wang, K. 1982. Purification of titin and nebulin. Method. Enzymol. 85 264-274.

Watkins, P.J., D. Frank, T.K. Singh, O.A. Young, R.D. Warner. 2013. Sheepmeat flavor and the effect of different feeding systems – A review. J. Agric. Food Chem. 61, 3561-3579.

Zhang, S.X., M.M. Farouk, O.A. Young, K.J. Wieliczjo, C. Podmore. 2005. Functional stability of frozen normal and high pH beef. Meat Sci. 69(4), 765-772.

CHAPTER 4. PERCEPTION OF THE AMERICAN MEAT SCIENCE ASSOCIATION'S INTERCOLLEGIATE MEAT JUDING PROGRAM BENEFITS FROM PARTICIPANTS

Introduction

Student involvement in collegiate extracurricular activities has been identified as an important experience for undergraduates to develop professional skills and participate in the collegiate community (Astin, 1984). Research has been conducted for several decades about the influence of various extracurriculars, such as athletic teams, student government, and leadership in student organizations (Bray, 1948, Birkenholz and Schumacher, 1994; Foreman and Retallick, 2012; Buckley and Lee, 2021). However, some academic areas have extracurricular activities which are tailored to their fields. An extracurricular activity which is specialized to the animal and meat science departments across the United States is intercollegiate judging programs. Intercollegiate judging programs may consist of wool, livestock, equine, and meat judging.

The first intercollegiate meat judging contest was hosted by the National Livestock and Meat Board in 1926 at the International Livestock Exhibition in Chicago, where 10 teams from across the United States competed (Bray, 1948). In 1996, the American Meat Science Association (AMSA) took over coordination and execution of the intercollegiate meat judging program. While there is no defined mission or goals associated with the AMSA intercollegiate meat judging program, there has been a consensus for decades that the intercollegiate meat judging program aids in developing participant's professional skills, such as decision making, as well as introduces participants to the meat industry (Bray, 1948; Davis et al., 1991; Field et al., 1998). However, there has also been criticisms of intercollegiate judging programs which often include the program not accurately reflecting the industry (Field et al., 1998). While there have been several studies conducted to understand the influences of intercollegiate judging programs (Davis et al., 1991; Field et al., 1991; Mefford, 2011; Miller et al., 2011) on participants, these studies are either outdated or focus on participants from one institution.

Therefore, the objectives of this project were: 1) evaluate the AMSA intercollegiate meat judging program and the effect it has on participants across institutions; 2) identify areas of strengths and weakness of the intercollegiate meat judging program; and 3) recommend potential changes to the intercollegiate meat judging program based on respondent feedback.

Materials and Methods

Intercollegiate meat judging participants (n = 552) voluntarily responded to a 10–15-minute Qualtrics survey (Table 4.1) which evaluated the AMSA meat judging program on areas of experiences of meat judging program, skill building, introduction to the US meat industry, as well as areas of improvement for the meat judging program. Before release, the survey was piloted with a small group of junior meat judging team members at Iowa State University to check for bias. Respondents were recruited to participate in the survey through social media, alumni lists, and through other AMSA media channels. The survey was open for 14 days to accept responses. Respondents were divided into three groups: A-Division participation (n = 98), Senior-Division participation (n = 369), and participation in both divisions (n = 85). Data were analyzed using the PROC FREQ procedure of SAS Studio® (SAS Institute, Cary, NC).

Table 4.1. Survey instrument distributed to respondents

Classroom Success and Student Involvement
What was your final cumulative undergraduate collegiate GPA?
What other activities were you involved in during your collegiate career?
Experiences and Influence of the Meat Judging Program
Please rank the following experiences in the meat judging program (1-6) in order of importance to you.
Do you believe the meat judging program influenced your career path in any way?
Understanding of Meat Science and Industry
Please rank the following activities (1-6) in order of how they influenced your understanding of meat science and the meat industry.
Did participation in the meat judging program aid in your understanding of how the meat industry operates?
In your personal life, how often do you rely on knowledge obtained from the meat judging program to make informed decisions as a consumer?
Professional Skills Development
Please rank the professional skills (1-6) in order of most beneficial to least beneficial to you.
The meat judging program improved my interpersonal communication skills.
The meat judging program improved my organizational skills.
The meat judging program improved my time management skills.
The meat judging program improved my decision-making skills.
The meat judging program improved my writing skills.
The meat judging program furthered my professional network.
Areas of Improvement
In what areas could the intercollegiate meat judging program be improved?

Results and Discussion

Demographics

Demographics of respondents are shown below for the three groups in tables (Table 4.2 and 4.3). Additionally, respondents who are employed in the meat industry were asked to identify their careers further in the meat industry, this data is shown in Table 4.4.

Table 4.2. Demographic data for respondents who participated in A-Division (n = 98) and Senior-Division (n = 369) intercollegiate meat judging contests

A-Division		**Senior-Division**	
Year	**Count**	Year	**Count**
1970's	7	1970's	11
1980's	10	1980's	27
1990's	13	1990's	47
2000's	28	2000's	92
2010's	40	2010's	192
Region		Region	
East	9	East	46
Midwest	68	Midwest	152
South	19	South	134
West	2	West	37
Education Level		Education Level	
Associate's	13	Associate's	0
Bachelor's	53	Bachelor's	145
Master's	24	Master's	149
Doctorate	2	Doctorate	63
Professional	1	Professional	11
Prefer not to answer	2	Prefer not to answer	0
No degree	3	No degree	1
Career		Career	
Self-employed	10	Self-employed	23
Undergraduate student	3	Undergraduate student	0
Graduate student	4	Graduate student	44
Academia	7	Academia	57
Meat industry	15	Meat industry	103
Livestock industry	11	Livestock industry	42
Government	12	Government	16
Allied industry	8	Allied industry	23
Other	28	Other	61

Table 4.3. Demographic data for respondents (n = 85) who participated in intercollegiate meat judging contests

A-Division Year	**Count**	Senior-Division Year	**Count**
1970's	4	1970's	3
1980's	14	1980's	13
1990's	8	1990's	9
2000's	29	2000's	29
2010's	30	2010's	31
A-Division Region		Senior-Division Region	
East	6	East	6
Midwest	53	Midwest	41
South	26	South	37
West	0	West	1
Career		Education Level	
Self-employed	14	Associate's	1
Undergraduate student	2	Bachelor's	44
Graduate student	1	Master's	28
Academia	9	Doctorate	7
Meat industry	17	Professional	3
Livestock industry	12	Prefer not to answer	0
Government	7	No degree	2
Allied industry	3		

Table 4.4. Meat industry careers of respondents across all divisions

	A-Division (n=15)	**Senior-Division (n=103)**	**Both[1] (n=17)**
Research and Development	2	31	3
Food Safety and Quality Assurance	3	21	5
Sales	6	18	3
Procurement	1	6	1
Technical Services	0	10	1
Operations	3	17	4

[1]Participated in both A-Division and Senior-Division

Classroom Success and Student Involvement

Classroom success was measured by reported final collegiate grade points average (GPA) on a 4.0 scale. Results are shown across all three groups below (Table 4.5). Based on reported

GPAs from respondents, it can be interpreted that participants in the intercollegiate meat judging program achieved high success in the classroom (over 75% of participants achieved over a 3.0 across all three groups). Furthermore, results show respondents were also heavily involved in other activities besides the intercollegiate meat judging program (Figures 4.1-4.3). These results concur with Astin's (1984) theory of student involvement. In this theory, Astin postulates that college students who invest significant time and energy into extracurricular programming derive more positive benefits from their educational program. In other words, students who are heavily involved in activities on campus are more likely to gain needed skills to be successful after graduating. Furthermore, research has show students who are more heavily involved in extracurriculars perform better in the classroom (Wyrick, 1998).

Table 4.5. Self-reported GPA[1] of participants in all divisions of the intercollegiate meat judging program

	A-Division (n = 98)	**Senior-Division (n = 369)**	**Both[2] (n = 85)**
3.5-4.0	36	182	35
3.0-3.49	39	130	40
2.5-2.99	16	44	8
2.0-2.49	3	6	0
Do not recall	4	7	2
Prefer not to answer	0	0	0

[1]Grade point average on a 4.0 scale
[2]Participated in both A-Division and Senior-Division

Experiences and Influence of the Intercollegiate Meat Judging Program

Respondents were asked to rank six experiences (professional skills development, technical skills development, personal relationships, professional relationships, opportunity to travel, exposure to meat industry) from the meat judging program, based on importance to themselves. Experiences were ranked on a scale of 1 to 6, with 1 being most beneficial and 6 being least beneficial. Results are shown across all three groups below (Figures 4.4-4.6). Across all three groups, professional skills development was ranked as the most important experience of the meat judging program. While other research has not addressed the importance of professional skills development to participants, we do know our results support other conclusions made that participation in intercollegiate judging programs assists participants in the development of important professional skills, such as interpersonal communication skills and decision-making skills (Davis et al., 1991; Field et al., 1991; Mefford, 2011; Miller et al., 2011). Furthermore, responses show across all three groups the intercollegiate meat judging program influenced the career path of many participants (Figure 4.7).

Understanding of Meat Science and Meat Industry

Respondents were asked to rank six activities (meat science courses, meat judging, department clubs, internships/employment, AMSA activities, other activities) based on their influence on their understanding of the meat industry. Experiences were ranked on a scale of 1 to 6, with 1 being most beneficial and 6 being least beneficial. Results are shown across all three groups below (Figures 4.8-4.10). Furthermore, respondents were asked if involvement in the intercollegiate meat judging program further their understanding of how the meat industry operates (Figure 4.11). Both questions revealed that participation in the intercollegiate program played a large role in respondent's understanding of how the meat industry operates. This finding is in line with other research's findings which indicate participation in intercollegiate judging programs aids in the development of deeper understanding of the meat and livestock industries (Bray, 1948; Davis et al., 1991). Lastly, participants were also asked, as consumers, how often they make informed decisions about the meat and food industry based on their participation in the meat judging program. Results are shown below across all three groups (Table 4.6). Interestingly, these results show the importance of the intercollegiate meat judging program beyond the skills that may be used by participants in the meat and livestock industry profession. In other words, the intercollegiate meat judging program does an excellent job of providing participants with the ability to make informed decisions as consumers regarding the meat industry regardless of their career path.

Table 4.6. Respondents use of knowledge obtained from the intercollegiate meat judging program to make informed decisions about the meat industry reported across all divisions

	Daily	**Few times/week**	**Few times/month**	**Few times/year**	**Never**
A-Division (n = 66)	22	19	22	3	0
Senior-Division (n = 290)	98	127	56	8	1
Both[1] (n = 69)	28	22	16	2	1

[1]Participated in both A-Division and Senior-Division

Professional Skills Development

Respondents were asked to rank six professional skills (interpersonal communication, organization, time management, decision making, written communication, and development of professional network) based on importance to them. Skills were ranked on a scale of 1 to 6, with 1 being most beneficial and 6 being least beneficial. Results are shown across all three groups below (Figure 4.12-4.14). Additionally, respondents were asked to indicate their agreement (strongly disagree to strongly agree) on statements regarding whether the meat judging program helped them develop the following professional skills: interpersonal communication, organization, time management, decision making, written communication, and development of professional network. Results are shown across all three groups below (Figure 4.15-4.17). Our results reflect conclusions in past studies (Bray, 1948; Davis et al., 1991; Field et al., 1998; Mefford, 2011) which found a major benefit to intercollegiate judging programs is the opportunity to develop important professional skills. Furthermore, our results concur with other research across multiple extracurricular activities which indicate a major benefit of student involvement is the ability to develop and hone multiple professional skills (Birkenholz and Schumacher, 1994; Foreman and Retallick, 2012; Buckley and Lee, 2021).

Areas of Improvement

Respondents were also given the opportunity to provide insights on areas where they believe the meat judging program could be improved to provide more benefits to participants. Responses were recorded from 102 respondents from the original set of 552 respondents. From the responses, two major themes were noticed by the research team.

The first theme (n = 26) was an emphasis on community building, teamwork, and development of professional networks. The second theme (n = 21) was an emphasis on providing more industry applicability to meat judging contests. Word clouds for each of these themes are included below (Figure 4.18 and Figure 4.19). Buckley and Lee (2021) found that students who were involved in various extracurricular activities on university campuses in Ireland reported that development of teamwork skills were a major asset to their university experiences. This conclusion was in line with other research on this topic (Burke et al., 2005; Clark et al., 2015) and therefore points to an important consideration for AMSA.

Interestingly, our results signal that many respondents feel the intercollegiate meat judging program does not provide enough opportunity for participants to further their professional network while other research (Bray, 1948; Davis et al., 1991) conclude that this is a major benefit of the intercollegiate meat judging program. Little research (Field et al., 1998) has mentioned or included discussion of industry applicability to the intercollegiate meat judging program. The current study indicates many past participants believe intercollegiate meat judging program needs to introduce students to the meat industry beyond fresh meat. Several references were made to processing and processed meat by respondents, as well as references to providing context to classes with scenarios. Based on our results, especially those encompassing the integral role of the intercollegiate meat judging program in the introduction of the US meat industry to undergraduate students, it may be important for AMSA to consider evaluating the intercollegiate meat judging program for industry applicability.

Lastly, while not observed empirically in this project, it is crucial to highlight the lack of defined mission and goals of the AMSA intercollegiate meat judging program readily available. In Astin's theory of student involvement (1984), Astin highlights the importance of having the ability to evaluate the effectiveness of an extracurricular program, as well as the importance of having defined outcomes for a student experience to evaluate. If AMSA defined missions, goals, and expected student outcomes for the intercollegiate meat judging program it would be simpler and more effective to review the program for effectiveness and ensure the program is maximizing the experience for all student participants.

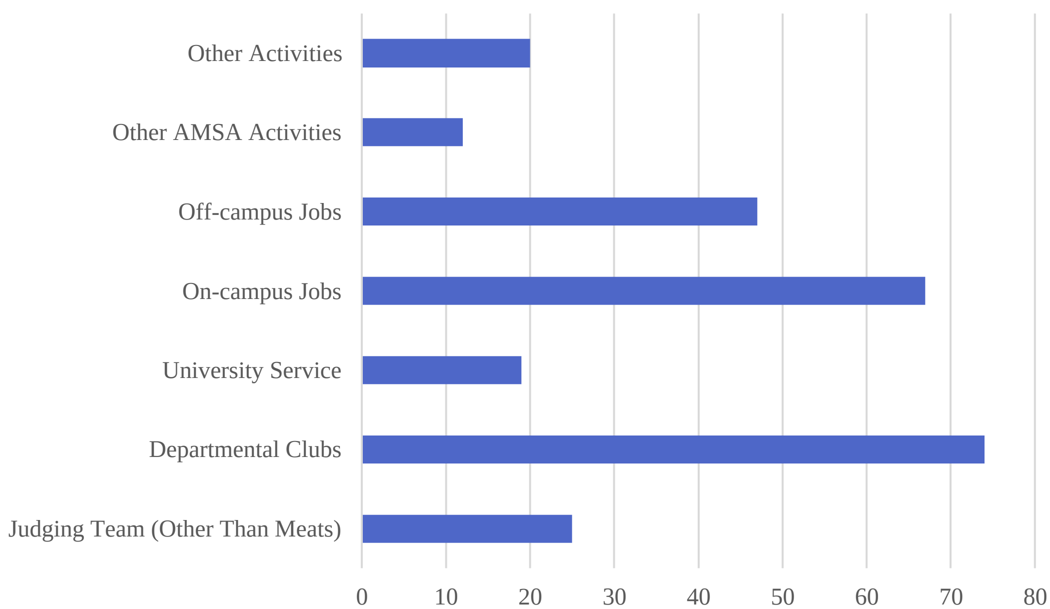


Figure 4.1. Other activities involvement by A-division participants (n = 98) in the intercollegiate meat judging program during their undergraduate career

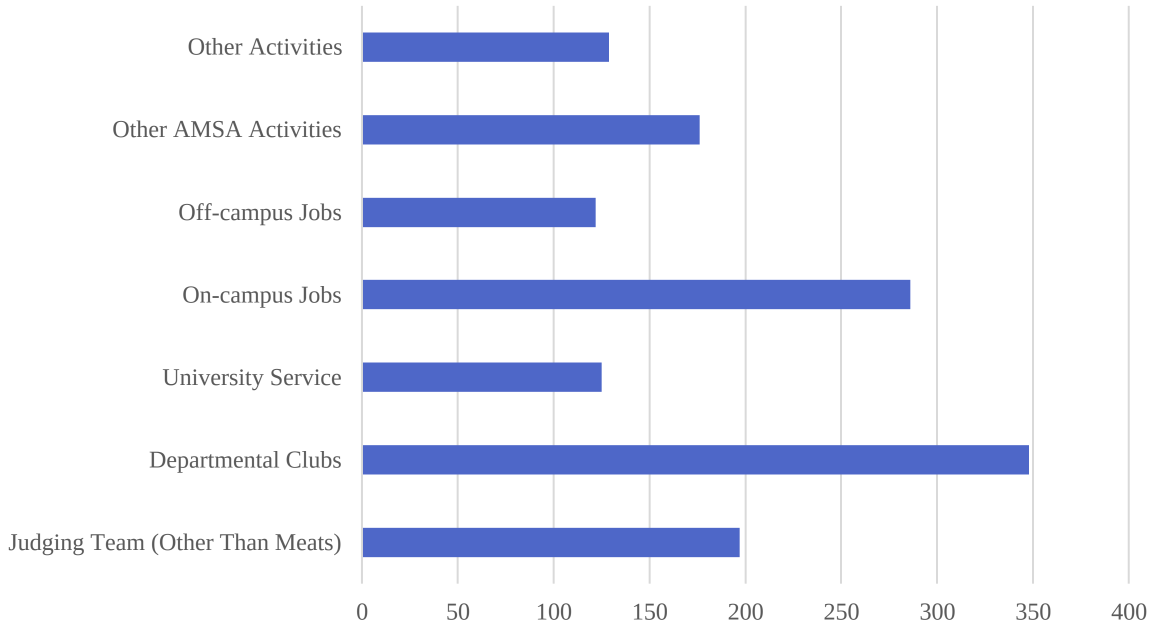


Figure 4.2. Other activities involvement by Senior-division participants (n = 369) in the intercollegiate meat judging program during their undergraduate career

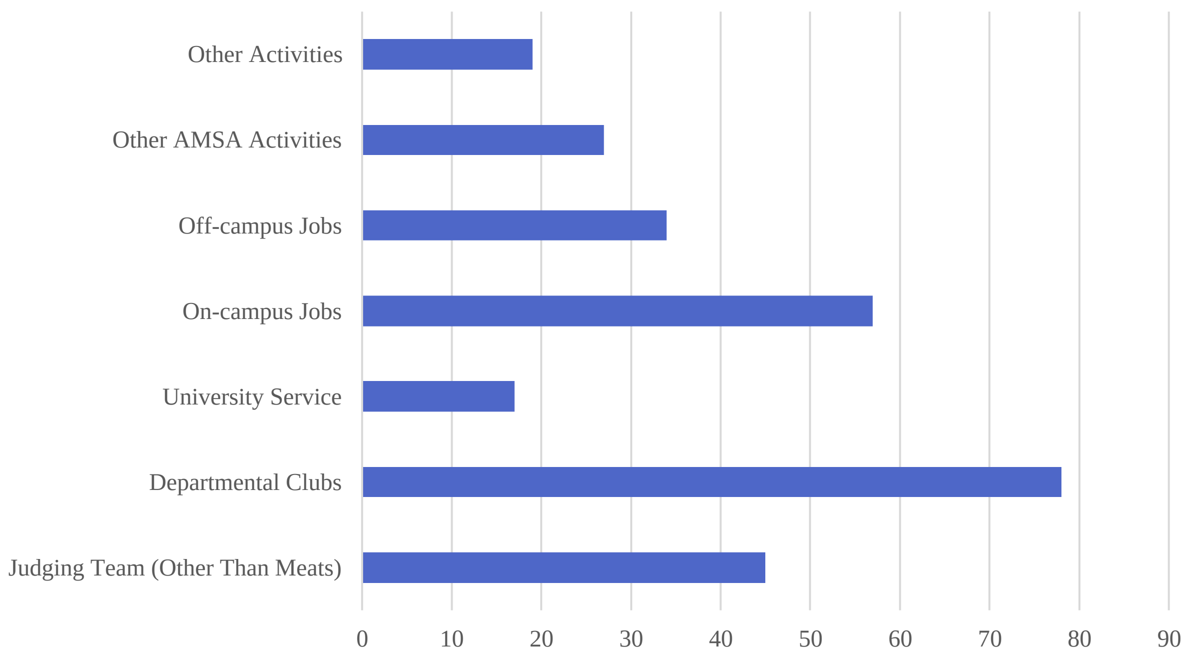


Figure 4.3. Other activities involvement by participants who competed in both A and Senior-division (n = 85) in the intercollegiate meat judging program during their undergraduate career

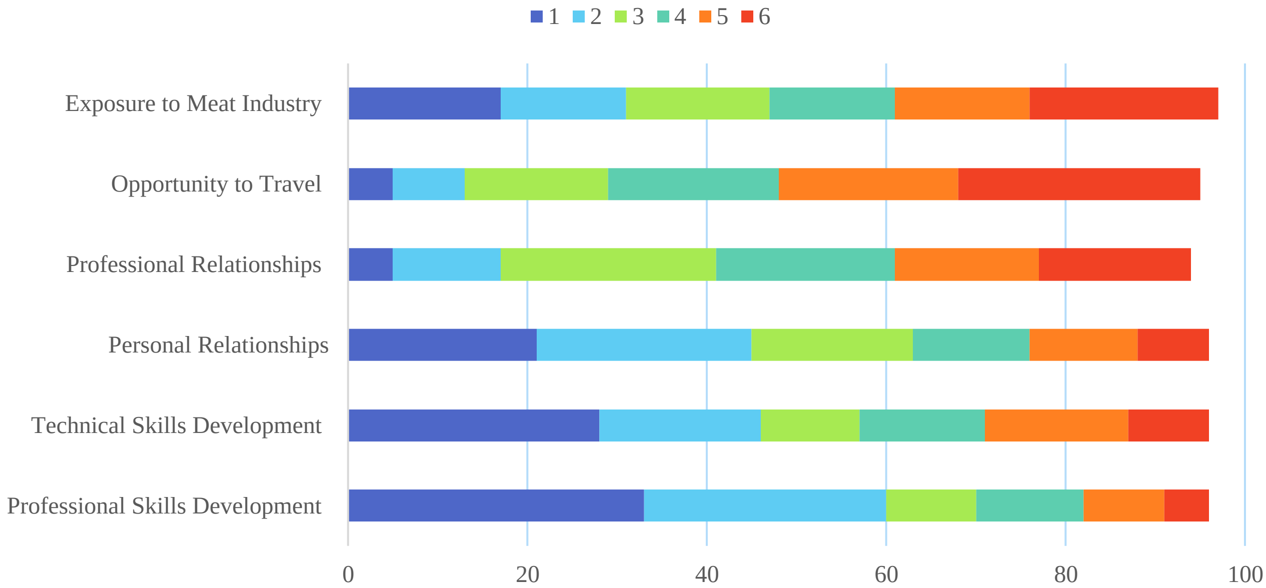


Figure 4.4. Ranking of experiences offered by the intercollegiate meat judging program and their benefit to A-division participants (n = 98). Ranking is on a 1-6 scale with 1 = most influential and 6 = least influential

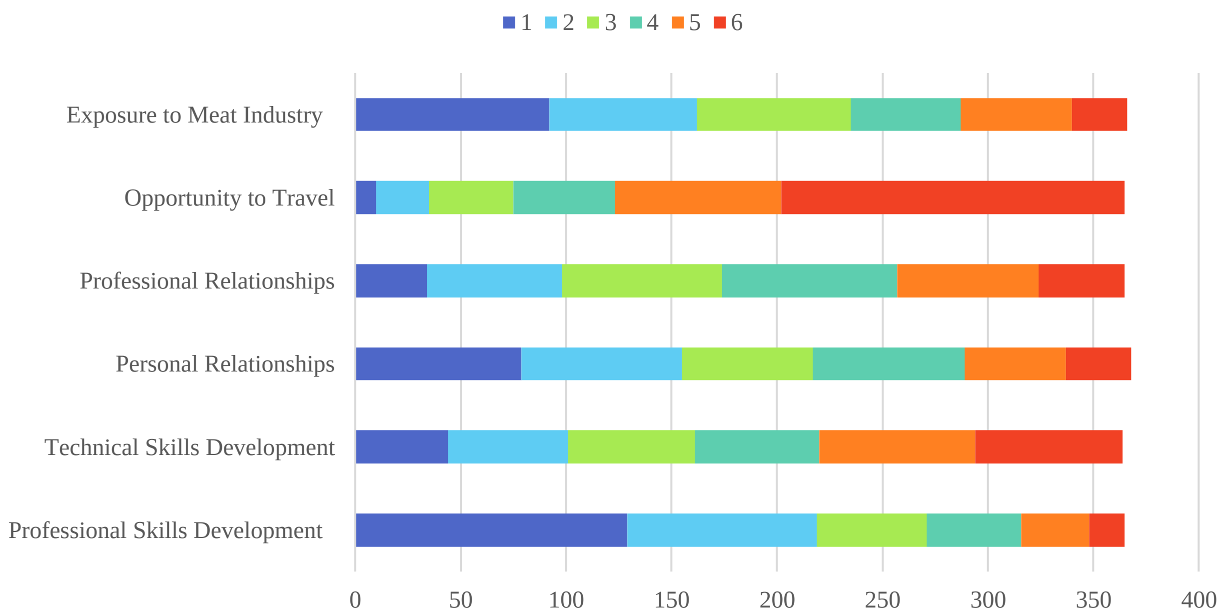


Figure 4.5. Ranking of experiences offered by the intercollegiate meat judging program and their benefit to Senior-division participants (n = 369). Ranking is on a 1-6 scale with 1 = most influential and 6 = least influential

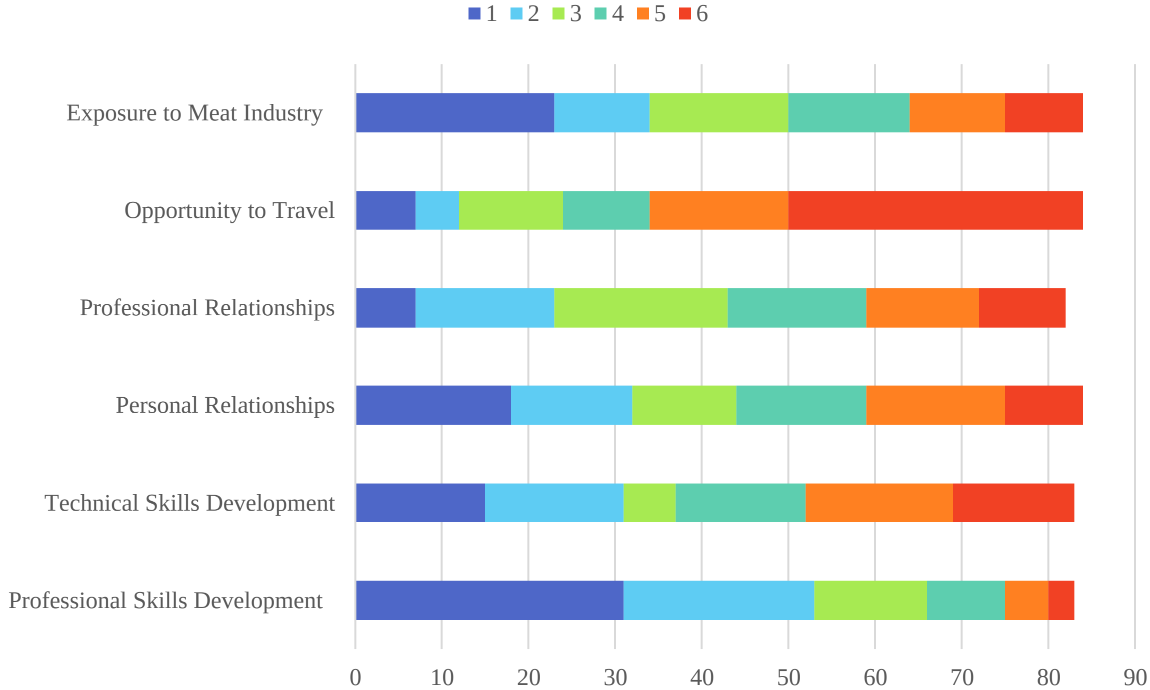


Figure 4.6. Ranking of experiences offered by the intercollegiate meat judging program and their benefit to participants who competed in both A and Senior-division (n = 85). Ranking is on a 1-6 scale with 1 = most influential and 6 = least influential

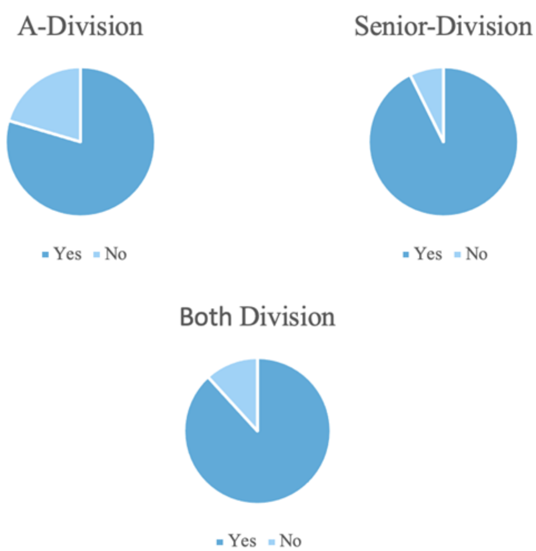


Figure 4.7. Response to "Did participation in the intercollegiate meat judging program influence your career path?" Both divisions are respondents who participated in A-division and Senior-division

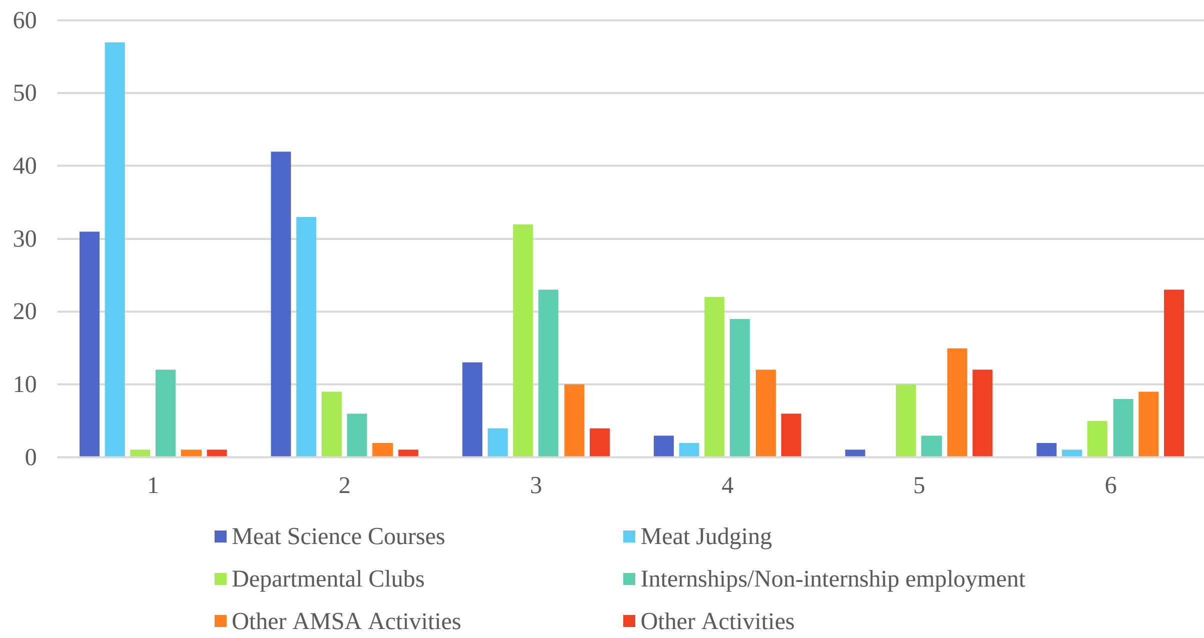


Figure 4.8. Ranking of activities which influenced A-division participant's (n = 98) understanding of meat science and industry. Ranking is on a 1-6 scale with 1 = most influential and 6 = least influential and is on the x-axis. Number of respondents is represented on the y-axis.

Figure 4.9. Ranking of activities which influenced Senior-division participant's (n = 369) understanding of meat science and industry. Ranking is on a 1-6 scale with 1 = most influential and 6 = least influential and is on the x-axis. Number of respondents is represented on the y-axis.

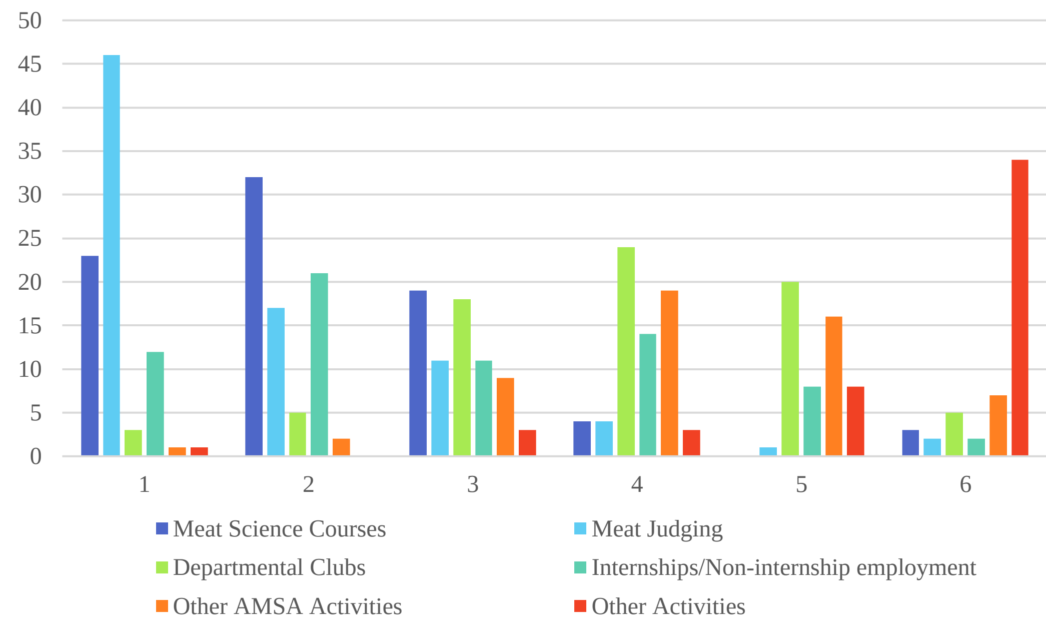


Figure 4.10. Ranking of activities which influenced participants who competed in both A and Senior-division (n = 85) understanding of meat science and industry. Ranking is on a 1-6 scale with 1 = most influential and 6 = least influential and is on the x-axis. Number of respondents is represented on the y-axis.

Figure 4.11. Response to “Did participation in the intercollegiate meat judging program aid in your understanding of the meat industry?” Both divisions are respondents who participated in A-division and Senior-division.

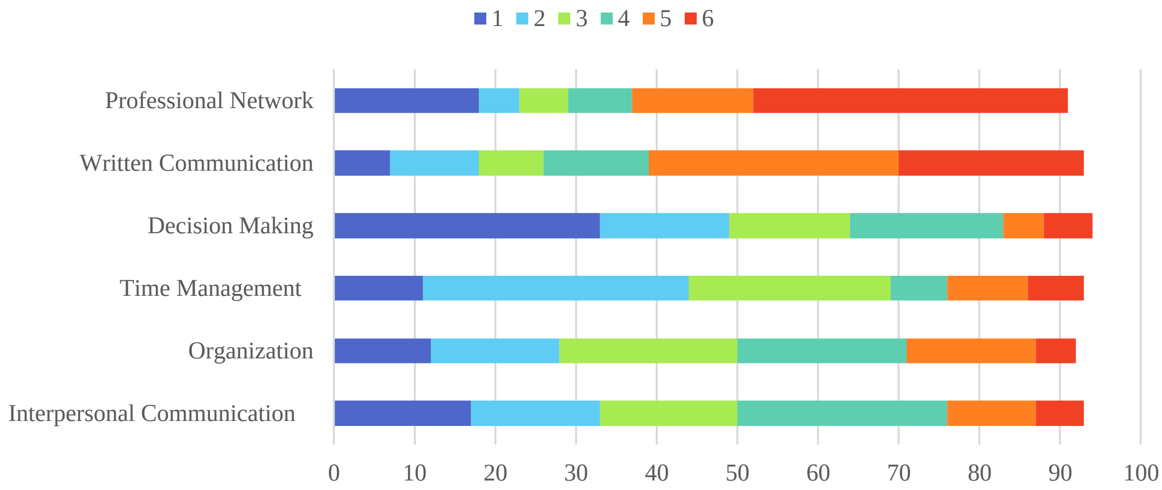


Figure 4.12. Ranking of professional skills development by A-division participant's (n = 98) and their benefit. Ranking is on a 1-6 scale with 1 = most beneficial and 6 = least beneficial. X-axis represents number of respondents.

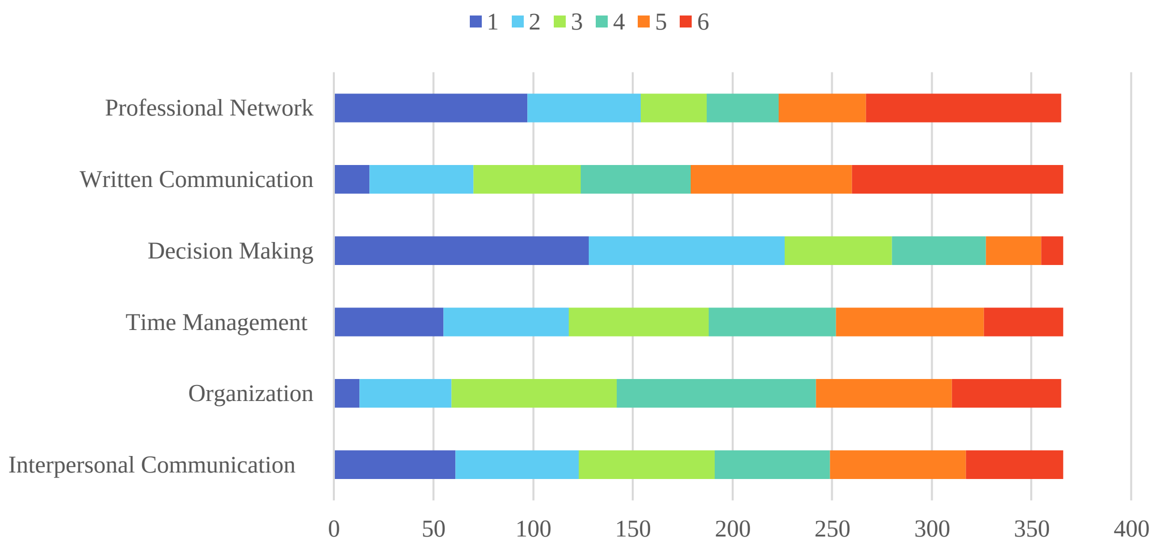


Figure 4.13. Ranking of professional skills development by Senior-division participant's (n = 369) and their benefit. Ranking is on a 1-6 scale with 1 = most beneficial and 6 = least beneficial. X-axis represents number of respondents.

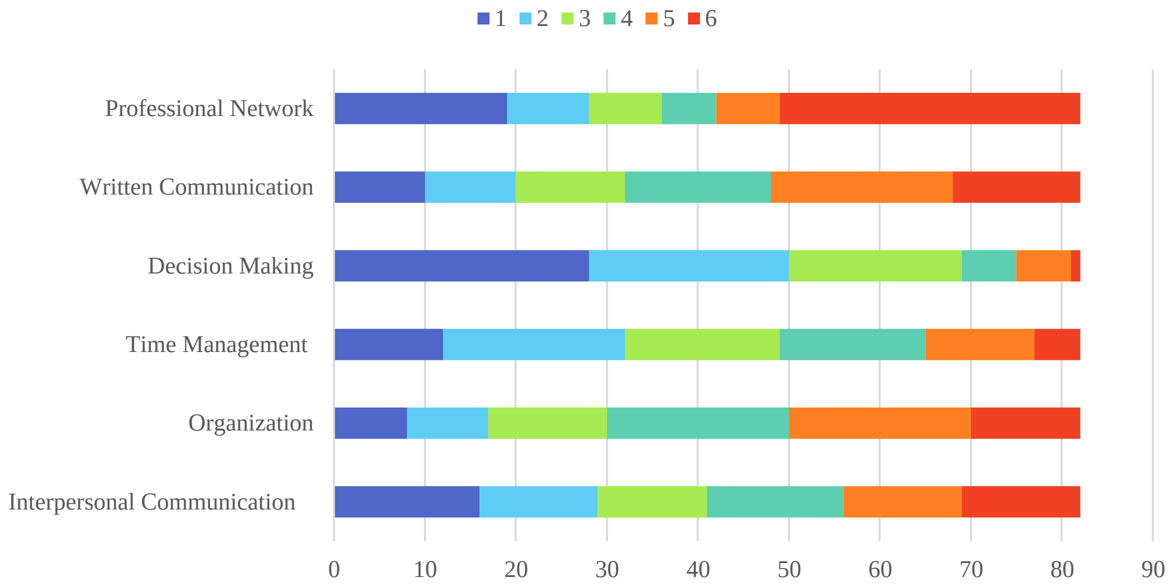


Figure 4.14. Ranking of professional skills development by participants who competed in both A and Senior-division (n = 85) and their benefit. Ranking is on a 1-6 scale with 1 = most beneficial and 6 = least beneficial. X-axis represents number of respondents.

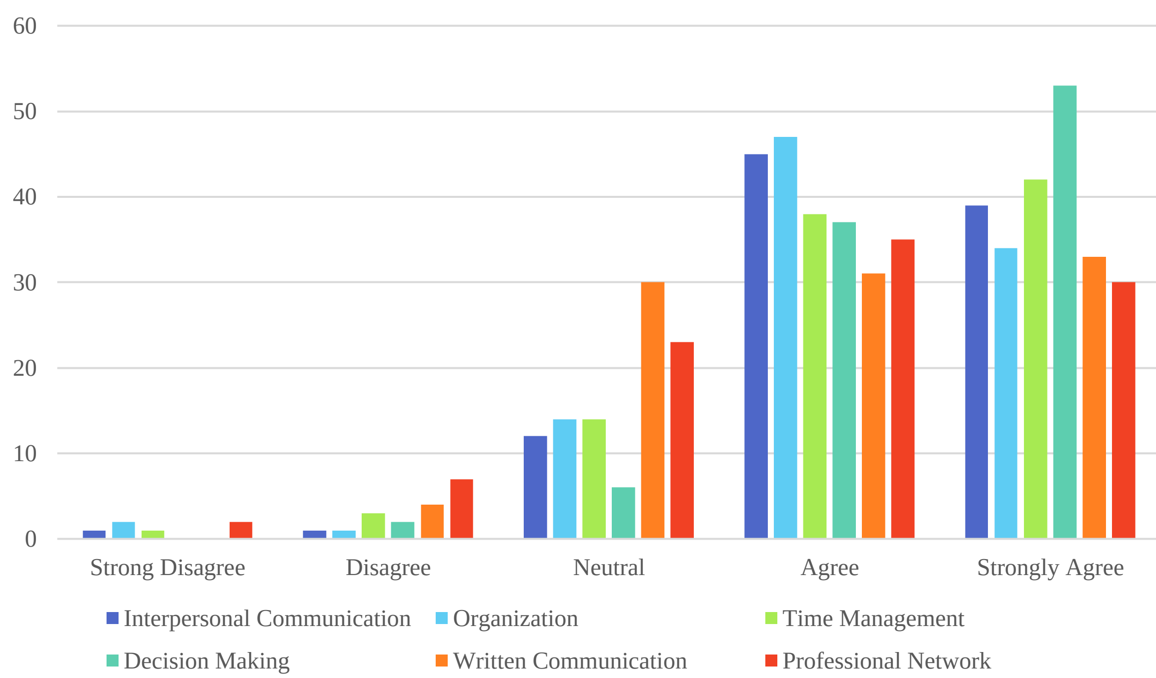


Figure 4.15. Professional skills development by A-division participant's (n = 98). Y-axis represents number of respondents.

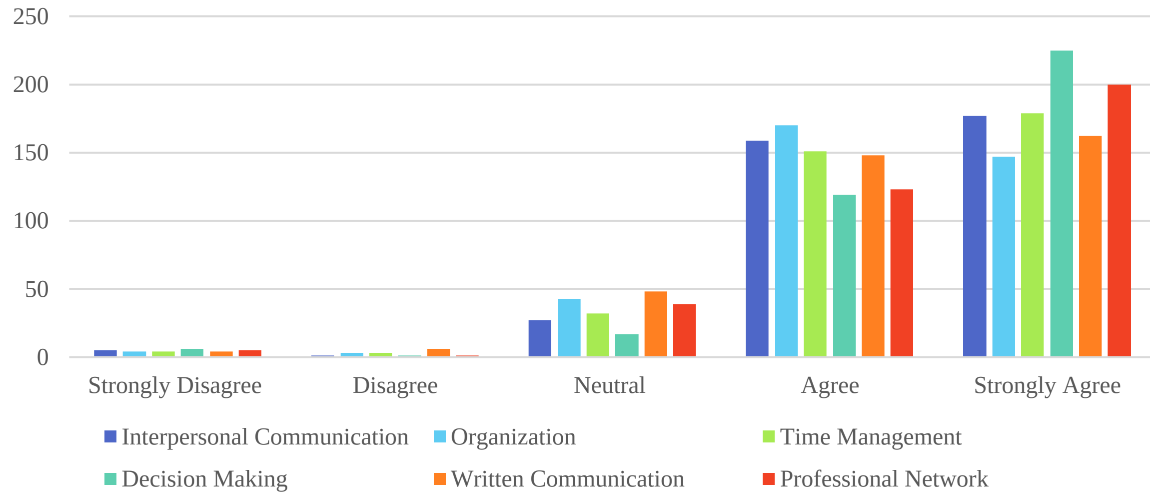


Figure 4.16. Professional skills development by Senior-division participant's (n = 369). Y-axis represents number of respondents.

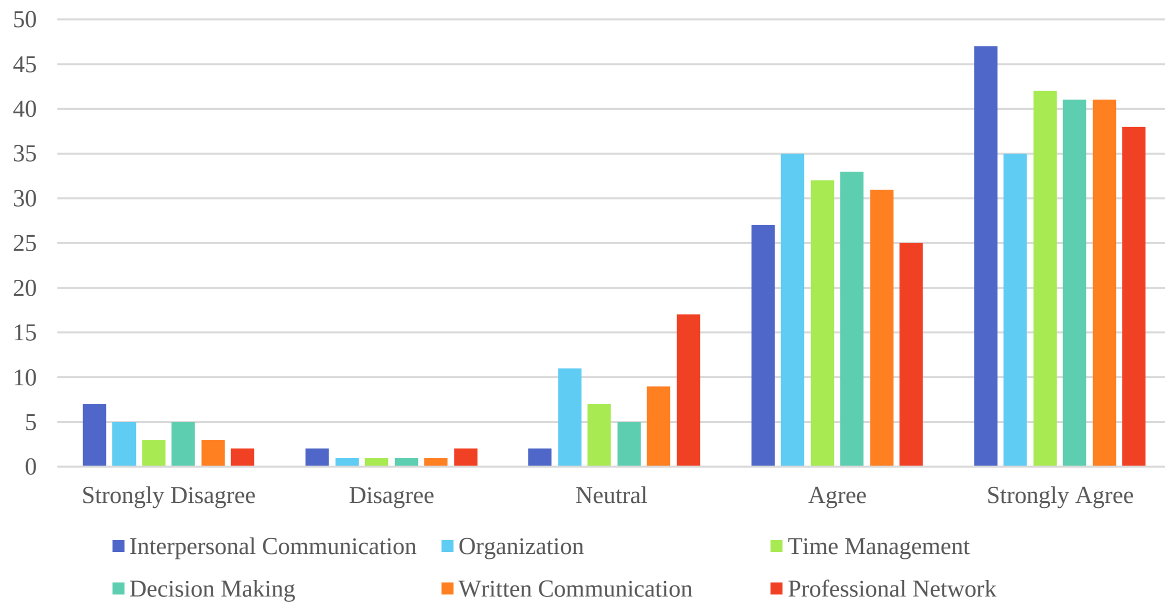


Figure 4.17. Professional skills development participants who competed in both A-division and Senior-division (n = 85). Y-axis represents number of respondents.

Figure 4.18. Areas of improvement for the intercollegiate meat judging team regarding community building

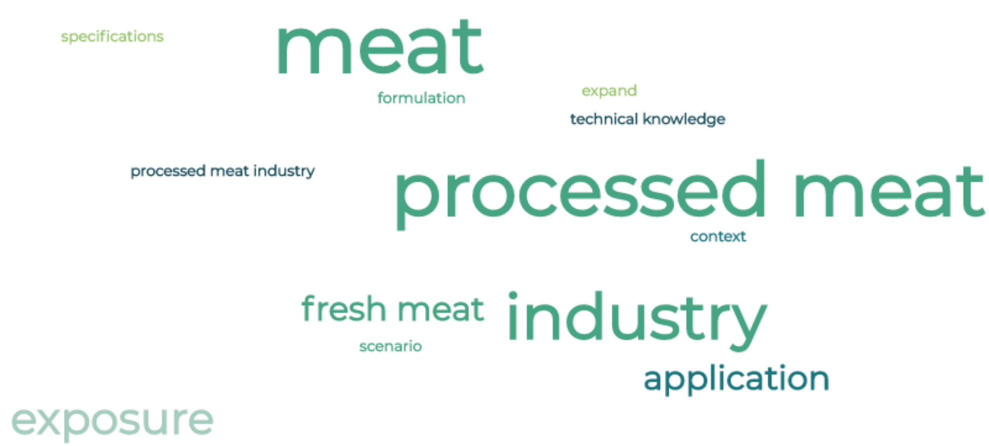


Figure 4.19. Areas of improvement for the intercollegiate meat judging team regarding industry application.

Conclusions

The results above show the intercollegiate meat judging program is a very positive and exceptionally beneficial experience for participants. Results show the program not only aids in development of important skills, but it also serves as an important gateway for many students into the meat and food industry. Based on areas of improvement discussed above, it would be beneficial to continue to explore new ways to connect participants with industry personnel as this was an area identified several times in our results as a weakness of the current meat judging program. Another area of improvement identified included providing more industry applicability to the current meat judging contest structure. Two areas consistently brought up in text responses were processed meats/other proteins and including a problem-solving component based on common industry issues. Lastly, AMSA has not defined the goals and mission of the intercollegiate meat judging program. Goals and a mission would provide more opportunity to showcase what the intercollegiate program accomplishes to interested students, department and university administration, and potential sponsors.

References

Astin, A.W. 1984. Student involvement: A developmental theory for higher education. J. Coll. St. Personnel. 25, 297-308.

Birkenholz, R.J. and L.G. Schumacher. 1994. Leaderships skills of college of agriculture graduates. J. Agr. Educ. 35(4), 1-8.

Burke, V., I. Jones, M. Doherty. 2005. Analyzing student perceptions of transferrable skills via undergraduate degree programs. Act. Learn. High Educ. 6(2), 132-144.

Bray, R.W. 1948. Meat judging contests and their place in education. 1st Recip. Meat Conf. Proc., Chicago, IL.

Buckley, P. and P. Lee. 2021. The impact of extracurricular activity on the student experience. Act. Learn. High Educ. 22(1), 37-48.

Clark, G., R. Marsden, J.D. Whyatt, L. Thompson, M. Walker. 2015. 'It's everything else you do…': Alumni views on extracurricular activities and employability. Act. Learn. High Educ. 16(2), 133-147.

Davis, G.W., M.F. Miller, D.M. Allen, K.L. Dunn. 1991. An assessment of intercollegiate meat judging from 1926 to 1989. NACTA J. 35(4), 28-31.

Field, T.G., R.D. Green, J.A. Gosey, H.D. Ritchie. 1998. A summary of intercollegiate judging activity, funding, and philosophy. NACTA J. 42(3), 27-31.

Foreman, E.A. and M.S. Retallick. 2012. Undergraduate involvement in extracurricular activities and leadership development in College of Agriculture and Life Sciences students. J. Agr. Educ. 53(3), 111-123.

Mefford, C.S. 2011. Interpersonal and career skills gained from competing on an Oklahoma State University judging team. M.S. thesis, Oklahoma State Univ., Stillwater, OK. (https://shareok.org/bitstream/handle/11244/15005/Mefford_okstate_0664M_13141.pdf?sequence=1)

Miller, C.C., C.C. Carr, J.H. Brendemuhl, J.C. Ricketts, B.E. Meyers, T.G. Roberts. 2011. Quantifying the critical thinking skills of students who receive instruction in meat-animal or meat product evaluation. NACTA J. 55(1), 50-54.

Wyrick, J. 1998. Why involvement matters: A review of research on student involvement in the collegiate setting. Coll. Stud. Aff. J. 17(2) 4-17.

APPENDIX A. PANELIST DEMOGRAPHIC BALLOT

ID #: ___________

<u>PANELIST DEMOGRAPHIC INFORMATION</u>

1. **Please indicate your age:**

    a. Under 20
    b. 20-29 years old
    c. 30-39 years old
    d. 40-49 years old
    e. 50-59 years old
    f. Over 60

2. **Please indicate your current working status:**

    a. Full-time
    b. Part-time
    c. Student
    d. Not employed
    e. Retired

3. **Please indicate your gender:**

    a. Female
    b. Male
    c. Other
    d. Prefer not to say

4. **Please indicate your ethnicity:**

    a. Caucasian
    b. Hispanic
    c. Black
    d. Asian or Pacific Islander
    e. American Indian
    f. Other

5. Have you ever consumed lamb?

   a. Yes
   b. No

6. Please circle the number of times a year you consume lamb. *Clarification on frequency terms are provided below.*

At Home:	Never	Almost Never	Sometimes	Frequently
Restaurant:	Never	Almost Never	Sometimes	Frequently

Frequency Terms:

Never = 0 times per year

Almost Never = 1-2 times per year

Sometimes = 3-5 times per year

Frequently = More than 5 times per year

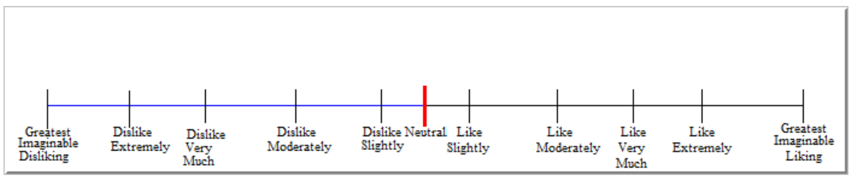
APPENDIX B. SENSORY BALLOT

Lamb Sensory Evaluation

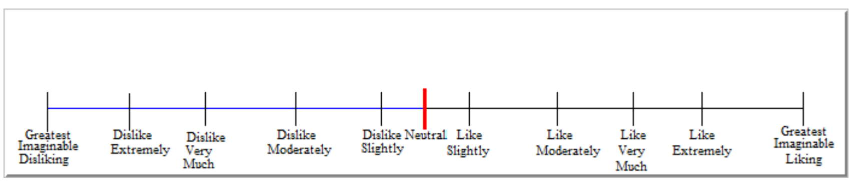
April 23, 2021

ID #: ______________ **Sample #:**______________

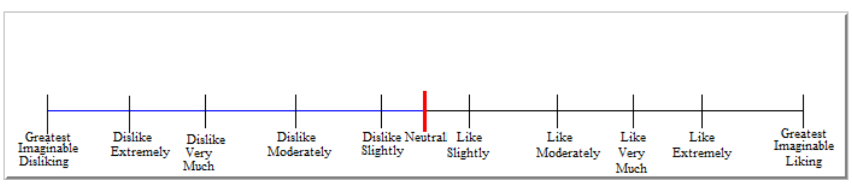
Please Rate your Overall Liking



Please Rate your Liking of the Flavor



Please Rate your Liking of the Tenderness



Please Rate your Liking of the Juiciness