Summer 2012

Alternative Fabrication Methods for the Beef Carcass

Justine J. Hosch

University of Nebraska-Lincoln, hoschjustine@gmail.com

Follow this and additional works at: http://digitalcommons.unl.edu/animalscidiss

Part of the Animal Sciences Commons

http://digitalcommons.unl.edu/animalscidiss/52
Alternative Fabrication Methods for the Beef Carcass

By

Justine Hosch

A THESIS

Presented to the Faculty of
The Graduate College at the University of Nebraska
In Partial Fulfillment of Requirements
For the Degree of Master of Science

Major: Animal Science

Under the supervision of Professor Chris R. Calkins

Lincoln, NE
August 2012
Alternative Fabrication Methods for the Beef Carcass

Justine Hosch, M.S.

University of Nebraska, 2012

Advisor: Chris R. Calkins

To fabricate heavier beef carcasses alternative fabrication methods for the chuck and round were evaluated. Carcasses (364 to 386 kg) were selected for forequarter (n=32) and hindquarter (n=30) evaluation. Forequarter breaks at the third/fourth and fifth/sixth rib, with the rib beginning at the sixth/seventh rib, were processed into whole muscles. Bone, lean trim, fat, and muscles were weighed and *Longissimus dorsi* (LD) steaks were subject to Warner-Bratzler Shear Force (WBS). Both subprimals had over 60% lean yield and no differences among WBS results ($P=0.49$, 0.39, respectively). To evaluate effects of modifying the chuck/rib break short rib subprimals (n=20) were aged for 21d post mortem at 2 °C. Subprimals (n=10) were weighed whole (kg) and each rib (ribs 2-12) separated. Each ribs bone, lean, and fat were separated and weighed (g). Ten short rib subprimals were sliced into 6 mm slices, cooked on an electric skillet, and served to a trained sensory panel. Ribs 5-7 were similar ($P<0.0001$) and intermediate in percent lean (50%). Ribs 2-4, 6, 11, and 12 had less than 20% bone per rib ($P<0.0001$). In sensory panel ratings ribs 2-4 and 6-9 rated most tender among samples ($P < 0.0001$). Ribs 6-8 were rated highest for juiciness, and ribs 5 and 11 were least juicy ($P<0.0001$). To evaluate hindquarter fabrication, the cranial portion of the *Biceps femoris* was removed. Extended sirloin caps (n=20) from each carcass were weighed (kg), vacuum packaged, and aged for 25 d at 2°C. Steaks (2.54 cm) from caps were cut perpendicular (n=10) or parallel (n=10) to muscle fiber direction. Steaks were consumed in a sensory panel and/or
subject to WBS evaluation. Steaks from the cranial portion of the cap, regardless of cutting method, had less connective tissue and were more juicy and tender compared to more caudal steaks ($P < 0.0001$). Steaks cut parallel were less tender ($P < 0.0001$) compared to perpendicular. With increasing carcass weights, alternative fabrication methods should be considered to add variety to beef cuts.

Key words: beef, chuck, round
ACKNOWLEDGEMENTS

After completing my Master’s project, many thanks are due to my professors, colleagues, and loved ones. I first need to start off by thanking my previous professors from Iowa State University, especially Dr. Steven Lonergan and Dr. Sherry Olsen, for spurring an interest in meat science, leading to the pursuit of my Master’s degree. It is a discipline I am truly passionate about and can’t wait to share with others what I have accomplished and learned.

Second, I need to share my thanks to Dr. Chris Calkins, Dr. Steve Jones, and Dr. Dennis Burson for serving as members of my committee. I appreciated your wisdom and counsel throughout my project and graduate school career. I personally thank Dr. Jones for allowing me to act as a teaching assistant for his ANS 486 course. Dr. Jones understood my passion for teaching individuals and provided me with an opportunity to do so. I would also like to thank Dr. Gary Sullivan for offering support and insight to graduate student life. Finally I would like to extend thanks to Dr. Chris Calkins for providing me the opportunity to further my education. I appreciated your role as my advisor and reference for various scholarships, awards, and travel opportunities.

Special thanks to my fellow meat science graduate students, both past and present. Words cannot express the gratitude I hold for you and your efforts put forth. Your dedication and support throughout the duration of my project did not go unnoticed. Thank you for being patient when plans for my project changed, when I didn’t have the answers right away, or when I needed assistance with statistical analysis. I attained knowledge on aspects of research, leadership, and friendship. Thank you. I would also like to thank my graduate student friends outside the meats discipline: Amy and Kristin. I will always cherish our Wednesday evenings spent together in feast and fellowship.
I would like to extend a special thanks to Tommi Jones for her assistance in coordinating taste panels and kitchen hours. You are a compassionate individual and are truly a valuable resource to the meats group. I am ever so grateful for the role Sherri Pitchie played as the Meat Science department secretary. Thank you for your assistance in making copies, labels, and providing guidance to life’s challenges. I would also like to thank Calvin Shrock and his undergraduate workers for coordinating fabrication times in the meat lab. Fabrication was sporadic for this project and I thank you for your patience and understanding.

I would also like to thank Greater Omaha Packing Co. for allowing a special tour of their facilities and fabrication practices. A special thanks to Paula Bates and Brian McFarlan of Tyson Foods, Inc. for their efforts in coordinating collection dates and times for my project. I enjoyed meeting you and exchanging progressive ideas for the industry.

I need to extend my gratitude to the Beef Checkoff, for funding part of my project through the National Cattlemens Beef Association. I am thankful for their financial contribution as well as the opportunity to work closely with the Beef Innovations Group, especially with Mrs. Bridget Wasser and Dr. Tony Mata. Throughout the duration of the collection process for my project I had opportunities to interact with these two professionals. From our discussions I learned how to be innovative in thought and practical in nature. There was never a dull moment on our excursions and I appreciate your support throughout this project.

I would also like to extend a special thanks to my family for their support, especially my sister Holly. You provided motivation and laughter at times when I needed them the most, thank you so much. Thank you to all of my friends from Iowa State
University. The hours spent on the phone during my trips to and from Nebraska will always be treasured. At last, I would like to thank Chasen for your unconditional love and support. You pushed me to succeed throughout the duration of my program and your words of encouragement, although concise, provided enthusiasm towards meat science and the meat industry. These last two years have been a challenge and I am so excited to start our new life together. I could not have done any of this without you. Thank you.
# TABLE OF CONTENTS

ABSTRACT

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

INTRODUCTION

REVIEW OF LITERATURE

I.  The US Beef Industry
    II.  History of Beef Fabrication
    III.  Tenderness Mapping
    IV.  Alternative Fabrication
    V.   Summary

MATERIALS & METHODS

Pelvic Audit

Short Rib Evaluation

Development of Chuck Subprimals

Extended Sirloin Cap Evaluation

LITERATURE CITED

MANUSCRIPTS

An Evaluation of Pelvic Bone Shape in Beef Carcasses

Abstract

Introduction

Materials & Methods

Results & Discussion

Tables & Figures

Literature Cited
<table>
<thead>
<tr>
<th>Appendix</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Variation in round fabrication methods</td>
</tr>
<tr>
<td>2</td>
<td>Beef carcass fabrication mandated by the Office of Price Administration</td>
</tr>
<tr>
<td>3</td>
<td>Photographs of pelvic bones from a fabricated beef steer carcass weighing 888 lbs (404 kg)</td>
</tr>
<tr>
<td>4</td>
<td>Examining splitting accuracy and its effect on aitch bone size and shape</td>
</tr>
<tr>
<td>5</td>
<td>Locations of short rib linear measurements</td>
</tr>
<tr>
<td>6</td>
<td>Individual short ribs (2-12) utilized during the yield assessment</td>
</tr>
<tr>
<td>7</td>
<td>Short rib slice (2-12) used to prepare 6mm taste panel serving size</td>
</tr>
<tr>
<td>8</td>
<td>Anatomical location of 2 and 3-rib subprimals</td>
</tr>
<tr>
<td>9</td>
<td>Diagram supporting anatomical locations of 2 and 3-rib subprimal measurements</td>
</tr>
<tr>
<td>10</td>
<td>Single muscle fabrication technique utilized during 2 and 3-rib subprimal fabrication</td>
</tr>
<tr>
<td>11</td>
<td>Removal of the extended sirloin cap</td>
</tr>
<tr>
<td>12</td>
<td>Location and designation of steaks fabricated perpendicular to muscle fiber direction</td>
</tr>
<tr>
<td>13</td>
<td>Location and designation of steaks fabricated parallel to muscle fiber direction</td>
</tr>
<tr>
<td>14</td>
<td>Muscle fiber map of extended sirloin cap</td>
</tr>
<tr>
<td>15</td>
<td>Extended sirloin cap regions utilized to analyze WBS and sensory results from 2.54 cm steaks cut perpendicular and parallel to muscle fiber direction</td>
</tr>
<tr>
<td>16</td>
<td>Trained sensory panel consent form</td>
</tr>
<tr>
<td>17</td>
<td>Trained sensory panel evaluation form</td>
</tr>
<tr>
<td>18</td>
<td>Sensory panel ranking form – tenderness</td>
</tr>
<tr>
<td>19</td>
<td>Sensory panel ranking form – connective tissue</td>
</tr>
<tr>
<td>20</td>
<td>Sensory panel ranking form - juiciness</td>
</tr>
<tr>
<td>21</td>
<td>Sensory attributes, connective tissue, and cooking loss of steaks fabricated parallel to muscle fiber direction</td>
</tr>
<tr>
<td>22</td>
<td>Sensory attributes, connective tissue, and cooking loss of steaks fabricated perpendicular to muscle fiber direction</td>
</tr>
<tr>
<td>23</td>
<td>Warner-Bratzler Shear Force results from extended sirloin cap steaks fabricated parallel to muscle fiber direction</td>
</tr>
<tr>
<td>24</td>
<td>Warner-Bratzler Shear Force results from extended sirloin cap steaks fabricated perpendicular to muscle fiber direction</td>
</tr>
</tbody>
</table>

**RECOMMENDATIONS FOR FUTURE RESEARCH** | 164
INTRODUCTION

Historically, beef carcass fabrication methods in the United States were based heavily on tradition and consumer ethnicity. Up until the 1940’s, no standards for beef fabrication existed. In December of 1942, President Truman through the Office of Price Administration, placed a price ceiling on all commodities sold in the United States, including the sale of beef and beef primals. With this law in place, standard definitions of beef cuts were necessary and thus methods of carcass fabrication. Even though the policy was lifted in 1945 beef carcass in the United States has remained the same, despite improved cattle production efficiency, innovative production methods, and altered consumer demands.

Muscles within the beef carcass vary by fiber type composition as well as collagen content, allowing for single muscle fabrication methods to capture and provide a consistent product to consumers. Beef palatability is determined by a variety of inherent characteristics: tenderness, juiciness, and flavor; however, tenderness is the most important economic and quality factor (NCBA 2010). Many studies have been conducted to classify muscles according to fiber-type composition, Warner-Bratzler shear force (WBS) and thus meat quality (Cassens and Cooper, 1971; Ashmore, 1974; Seideman and Theer, 1986, Kirchofer et al., 2002).

Tenderness mapping via WBS results allowed muscle profiling work and allowed the US to begin marketing value cut steaks from underutilized muscles that are highly palatable (NCBA, 2001). Most of the variation among muscle quality exists in the beef chuck and round. These muscles were previously left in roasts, but currently through
alternative single-muscle fabrication, value can be added to the carcass and variety can be offered to the consumer.

This study focused on the development of new steakable subprimals from both the hindquarter (*Biceps femoris*) and forequarter (*Longissimus dorsi*) muscles and muscle groups. By developing new innovative subprimals from these locations, discrete alterations will occur in other subprimals in the beef carcass. This study worked to analyze the impact of alternative fabrication methods with a goal to ultimately produce a quality and consistent product.
The US Beef Industry

Since 1970, the average live weight for beef cattle in the United States has increased roughly 300 pounds, equating to an added 7.5 pounds per animal per year (USDA-AMS, 1970, 2011). This significant increase in productivity of US beef cattle is likely a result of increased management strategies, utilization of diversified technologies, crossbreeding and genetic evaluation of cattle, and a growing demand for US beef (Mintert et al., 2009).

Parallel to increased live weights is increased hot carcass weight (HCW) and increased muscle size in beef cattle. According to the 2002 National Beef Quality Audit, fed steer and heifer *Longissimus dorsi* muscle (LM) size ranged from 50 to 150 cm$^2$ in the United States (McKenna et al., 2002). Variation in LM size in beef cattle can be attributed to a variety of factors: animal weight, sex, breed, genetic variation, utilization of implant protocol, and other management strategies. This large variation in LM size results in changes in consumer demand. In a study by Leick et al. (2012) consumers tended to select thinner ribeye steaks (thin and average cut) and thicker sirloin steaks (average and thick cut). As the LM area in steaks continues to increase, the industry can alter the thickness in which these steaks are cut to still meet consumer preferences.

The LM muscle is highly valued in the beef carcass. Ribeye and loin primals are sold at premiums of $60-100 per cwt over that of chuck and round primals. Optimal size of LM steaks has been identified in both the foodservice and retail sectors (Dunn et al., 2000; Sweeter et al., 2005). It was determined as HCW increased and equivalent LM size, consumers have no preference to heavy or light weight carcasses. Consumers were
willing to pay a $1.50/kg premium for large ribeye steaks (105-119 cm²), and discount large ribeye steaks cut in half over $1.00/kg (Sweeter et al., 2005). With limited consumer concerns, the industry continued to shift towards larger, heavy weight beef carcasses.

Yield grades are a method to predict the level of carcass cutability. In 1992, the mean yield grade for beef breeds, *Bos* Indicus, and dairy carcasses were 3.03, 3.06, and 2.56, respectively (Griffin et al., 1992). A positive correlation existed with HCW and kg of retail cuts, and thus a negative correlation associated with percent retail cuts (Epley et al., 1970). In an evaluation of subprimal yields from beef carcasses of varying carcass weight, sex, and class, fat trimmed from carcasses ranged from 7.9 to 15.6% (Griffin et al., 1992).

As a result of limited consumer concern and higher percent of retail yields in heavier carcass weights, the industry has continued to improve live animal weights prior to harvest. Because of increasing carcass weights, challenges have been presented to the industry in regards to beef fabrication, specifically the availability of cuts for consumers.

**Beef Carcass Fabrication in the United States**

In the United States geographic and economic factors played a role in the history and development of beef carcass fabrication styles utilized today. The United States, unique in development, began with a multitude of ancestral and cultural backgrounds. As a result traditional cutting styles specific of country/location of origin were brought to the US. In the early 1800’s, cutting methods varied greatly due to city location along the East coast (Appendix 1). This variation in fabrication was a result of buying habits and
cut preferences from consumers, as well as butcher heritage. Three main fabrication styles were documented (Romans, et al., 1974): Chicago/Western, New York/Eastern, and the National style (established by National Livestock and Meat Board).

Most alterations in carcass fabrication occurred post-halving of the carcass. The separation of the hind and forequarter was considered a reasonable and consistent cut in the beef carcass between the 12th and 13th rib; closely cut to the shape of the 12th rib. Variation in splitting the fore and hindquarter did exist however among large cities in the East. Hindquarters in Philadelphia had no ribs, indicating division of hind and forequarter posterior to the 13th rib. Conversely, a Boston hindquarter typically had three ribs present (Reynolds, 1963). According to Tomhave (1925) more than one rib left on the hindquarter offered a higher price to the seller, a result of more pounds and valued cuts. In Chicago one rib was left on the hindquarter, resulting in a break between the 12 and 13th rib-similar to today. This remaining rib was perceived to hold shape of the loin during the fabrication of strip steaks (Tomhave, 1925), as well provided means to hang the loin on the meat tree – a series of hooks on a trolley designed to hold subprimal cuts. There is also conviction that the remaining rib on the hindquarter ensured the customer they were getting an acceptably sized hindquarter.

After the carcass had been split into the fore and hindquarter, butchers had freedom to fabricate the remainder of the carcass. Most variation in carcass fabrication occurred at the sirloin/round break. According to Romans et al. (1974), three popular styles of round fabrication existed: Eastern, Chicago, and Diamond. This variation was likely due to an alteration of the angle, or combination of angles, at which the round-sirloin break occurred.
The Eastern round, also known as the New York style, produced smaller cuts and
had a higher percentage of bones removed. The break was a result of a 45° angle through
the ball of the aitch bone. Because of this splitting location, the Eastern round contained
no ball tip. This separation tactic occurred at a pre-conceived location that hypothesized
improved tenderness in the sirloin (Bull, 1961).

The Chicago style round is comparable to the round fabricated today. A straight
cut through the juncture of the last sacral and first caudal vertebrae and the hip joint
separated the round and sirloin (NAMP, 2007). This cutting line exposed the ball of the
femur but did not sever the protuberance. This fabrication style resulted in a ball tip that
was split in half, and cut against the grain. The Chicago/Western fabrication style
resulted in a smaller sirloin steak when compared to that of sirloin steaks fabricated via
the National cutting method (Romans, 1974)

By far the most unique round was the Diamond styled round. This fabrication
style required two cutting angles and exposed the ball of the femur without severing the
protuberance. The first cut occurred at a point on the fourth sacral vertebrae and extended
to the ball of the femur. The second cut started at the ball of the femur and continued to a
point on the ventral edge exposing the tensor fasciae latae (NAMP, 2007). The obliquus
abdominis internus was excluded and the full knuckle remained attached to the round.
Not only did this fabrication style add pounds to the round primal, but it also kept the ball
tip intact for customers.

Prior to 1942 cuts from these fabrication styles and more were available across
the US. With the decision to engage in World War II, lifestyles and industries changed.
In December of 1942 President Roosevelt’s Office of Price Administration issued The
Emergency Price Control Act (National Provisioner, 1942). Through this enactment, a maximum price for beef and veal carcasses, wholesale cuts and processed products was established to prevent early marketing of cattle, and encourage farmers to keep their feedlots full and produce cattle with varying degrees of finish. Ceiling prices were set determinant of primal and grade of cattle (AA, A, B, C cutter/canner, and bulls). Kansas City, MO was deemed as the central location for pricing, zones that required additional freight incurred an increase of $0.25/lb for beef to finance the extra tare and icing (National Provisioner, 1942).

Further, provisions were mandated for cutting the nine primary wholesale cuts of beef: regular chuck, rib, brisket, short plate, fore shank, round, sirloin, short loin, and flank. Carcass fabrication was distinct, with separation of the hindquarter and forequarter between the animal’s 12th and 13th ribs, and definitions for the above primals were provided in the act (Appendix 2).

Through the Emergency Price Control Act only certain combinations of cuts were permitted (National Provisioner, 1942). Alternative fabrication was only allowed when suppliers sold cuts directly to purveyors of meals.

The cross cut chuck was obtained with a straight line cut between the fifth and sixth ribs, adjacent to the fifth rib. This division produced the chuck primal: the cross cut chuck, regular chuck, brisket and fore shank. The round was produced with a straight line cut that started at the juncture of the last (fifth) sacral vertebra and the first tail (caudal) vertebra, passing through the point just missing the end of the protruberance of the femur bone. With this cut, two tail vertebra should remain on the round, along with the tip or rear corner of the fifth sacral vertebra.
In 1945, ceiling prices for beef were lifted and in 1947 the Office of Price Administration was abolished (National Archives, 1995). Livestock production was again at the providence of the producer, and cattle were finished to variable degrees of marbling and live weights. Beef fabrication, however, did not resume to methods prior to the 1942 act. Major packing plants continued to separate the chuck and rib at the fifth/sixth rib junction and the sirloin/round at the fifth sacral vertebrae. Alternative fabrication methods were not researched until the early 1990’s behind initiatives of the National Cattlemen’s Beef Association (Von Seggern et al., 2005).

**Tenderness in Beef**

Beef palatability is determined by a variety of inherent characteristics: tenderness, juiciness, and flavor; with tenderness being the most important economic and quality factor (NCBA 2001, 2010). Tenderness is influenced by various factors including postmortem proteolysis, intramuscular fat/marbling, connective tissue, and the contractile state of the muscle (Belew et al., 2003).

Since the early 1940’s, efforts have been made to determine tenderness differences among muscles in the beef carcass. It was discovered that beef muscles vary in the amounts of collagenous and elastic tissue as well as in the amounts of fat and the size of muscle bundles (Ramsbottom, 1944). A portion of muscle profiling work relies on the importance of muscle fiber-type composition, and the variation that exists between muscles. Muscles with higher concentrations of α-white fibers have more connective tissue, less intramuscular fat, and are less tender when compared to muscles with a higher proportion of β-red fibers (Calkins et al., 1981).
These muscles that are higher in proportions of α-white fibers typically exist in the round. McKeith et al. (1985) reported that the *Biceps femoris* (BF) had greater collagen content, but similar sarcomere length to that of the LM. This parallel to a higher proportion of α-white fibers designates the BF in the round to be less tender.

Retail cuts from the rib and loin have been highly sought after, with demand lacking for cuts from the chuck and round. This lack of demand is due to perceived differences in tenderness and apparent fiber-type composition distinctions (Belew et al., 2003). Great variation in texture of muscles is determined by the size of the bundles of fibers (fascicle) and the amount of connective tissue (perimysium) surrounding the bundles (Ramsbottom, 1944). Similarly, connective tissue content as well as ease of fragmentation account for a majority of the differences in tenderness of muscles (Shackelford et al., 1995). According to the 2010/2011 National Beef Tenderness Survey, cuts from the round continue to be the least tender suggesting a need for improved aging and consumer education on preparation practices (NCBA, 2011).

Due to the significant role tenderness plays in the marketing of beef, vast improvements in the genetic selection and management of cattle have been achieved by producers. From 1990 to 1999, a 20% increase in tenderness was exhibited in the National Beef Tenderness Survey; and subsequently at 18% increase from 2000 to 2005 (NCBA, 2010). However, there is still progress to be made. Lusk et al. (2001) indicated that consumers are willing to pay a premium for tender steaks.

When determining tenderness of beef objectively, Kerth et al. (2002) discovered core location had a noticeable effect (P < 0.01) on WBS results in the *Longissimus dorsi* (*LD*). A medial-lateral WBS gradient existed in the LD (P < 0.05) with steaks on the
lateral side being less tender when compared to other regions (Kerth, 2002). Similarly Belew et al. (2003) observed tenderness variation among and within muscles related to this study: very tender (WBS < 3.2 kg): Serratus ventralis; tender (3.2 < WBS < 3.9 kg): LD; intermediate (3.9 < WBS < 4.6 kg): Gluteus biceps.

Because both the fore and hindquarter of the beef carcass show areas for alternative fabrication, it is important to understand the quality of muscles that exist in both of these regions.

**Forequarter Muscles**

The *Serratus Ventralis* (SV) is a large, fan-shaped muscle within the forequarter lying from the dorsal region just over the ribs and ventral toward the sternum or brisket (NCBA, 2000). According to Johnson et al. (1988) it is the largest muscle in the beef forequarter, accounting for 19.1% of total forequarter weight. Although the SV is not used in locomotion, it functions to protract and retract the shoulder, and flex the neck when acting unilaterally (Jones, et al., 2000). The SV rated medium in organoleptic tests and shear readings (Ramsbottom, 1944). This was considered a result of a moderately large fascicule and moderately thick connective tissue present in the SV.

In later years, the SV was classified as having intermediate fiber-type composition (Kirchofer et al., 2002); a mix of α-white and β-red fiber types. The SV has been classified as one of the most tender muscles in the beef forequarter (Johnson et al., 1988, Kukowski et al., 2004; Von Seggern et al., 2005). In a study by Johnson et al. (1988) the SV was reported to be one of the more tender muscles from the chuck when evaluated with WBS. In a comprehensive beef muscle ranking the muscle was considered as one of
the juiciest muscles (Sullivan, 2011); similar to findings by Kukowski et al (2004).

USDA Choice SV steaks were rated more tender than those from Select, and the SV was rated as being similar ($P < 0.05$) to the LT for overall like, tenderness, juiciness, flavor and price/\$0.45 kg (Kukowski et al., 2004).

Another large component of forequarter weight is muscles that comprise the chuck roll, specifically the *Longissimus* dorsi. The LD and *Multifidus dorsi* were somewhat less tender at the anterior ends of the muscles (Ramsbottom, 1944). Steaks from the LD located in the chuck primal were among the least tender, but are still utilized as steaks (Sullivan, 2011). However, Johnson et al. (1988) found LD steaks from the chuck primal as the most tender muscle from the beef forequarter, similar to WBS results from Paterson and Parrish (1986). These results conclude that this portion of the LD should be fabricated into steaks as opposed to roasts.

**Hindquarter Muscles**

Not only is the beef round the largest primal of the hindquarter, it also contains a majority of the muscles posterior to the thoracic cavity. The BF was found to be progressively more tender from the insertion end to the origin end of the muscle (Ramsbottom, 1944). Conversely, in work by Reuter et al. (2002) and Senaratne et al. (2010) the BF had its lowest WBS values at the origin (sirloin end), intermediate WBS values at the insertion, and its highest WBS values in a middle region 7 to 10 cm posterior to the separation point between the sirloin and round ($P < 0.05$). In an analysis of fiber-type composition, the BF was classified as being $\alpha$-white (Kirchofer et al., 2002). This classification suggests the BF has a greater concentration of connective tissue and a
lesser degree of marbling. Steaks from the *gluteus biceps* had increased WBS values as movement towards the center of the muscle progressed (Belew et al., 2003). When compared to other muscles of the round (*Semimembranosus, Semitendinosus, and Adductor femoris*) the BF had the greatest amount of WBS variation (SD = 1.09 kg) (Reuter et al., 2002). The BF also had lower WBS values on the side closest to the *Semitendinosus* (ST) rather than toward the *Vastus lateralis* (*P < 0.05*), no consistent differences in WBS from the superficial side to the deep side of the BF (Reuter et al., 2002). Although the BF had shorter sarcomere length when compared to that of the LD, there is a weak relationship between sarcomere length and tenderness (*r*=0.25; *P* < 0.01; McKeith et al., 1985).

Shear mapping methods have allowed for muscle profiling and investigation of tenderness gradients across a muscle (Zuckerman et al., 2002). Realizing the tenderness challenge in the BF, Shanks et al. (2002) tested pre-rigor skeletal separations in the round with intentions to improve tenderness. Differences between treatments and controls for WBS values were not found in the BF of the round; likely a result of muscle location and excessive collagen content in the BF.

Beef Alternative Merchandising (BAM; funded by The Beef Checkoff) suggests increased profits will result with new cut collections and recipe and cooking tips for consumers (NCBA, 2012). By fabricating beef primals according tenderness gradients and overall acceptability, these new cut collections can be achieved. Alternative cuts suggested through BAM offer cuts similar to value and quality to that of middle meats, often from the round and chuck.
Alternative Fabrication

From the National Consumer Retail Beef Study (Savell et al., 1987, 1989), as well as other studies, it has been revealed that tenderness or meat texture is the single most important factor affecting consumer acceptance of beef products. Values for Warner Bratzler Shear Force (WBS) have indicated that a high percentage of retail steak cuts from the round and chuck have a majority of scores less than “slightly tender” (Morgan et al., 1991). Due to the effect of tenderness on consumer acceptability and the lack of tenderness in the beef chuck and round, alternative fabrication efforts have been focused on cutting styles in both the fore and hindquarter.

Other countries across the globe utilize single muscle fabrication techniques. This method allows muscles that have different tenderness and palatability characteristics to be marketed whole as steaks or roasts, providing a uniform eating experience. Fabrication styles similar to these have recently become prevalent in the US with items such as the merlot cut, flat iron, petite tender, etc. These cuts, innovative in style, have had significant results on the industry. Annually the flat iron adds an additional 83 million pounds of steakable product to the marketplace (Sullivan, 2003). Being innovative in carcass fabrication in both the fore and hindquarter of beef carcasses can have sizeable returns for the industry.

Muscles have been classified according to fiber-type composition, and thus meat quality (Cassens and Cooper, 1971; Ashmore, 1974; Seideman and Theer, 1986, Kirchofer et al., 2002). Due to fiber-type variation, muscles will differ in muscle color, color stability, tenderness, and ultimate muscle pH and thus overall palatability. Muscles from the beef chuck and round vary greatly in fiber type composition. In the round, nine
of twelve muscles were classified as white; whereas in the chuck, out of twenty-six muscles observed, ten were red, nine were intermediate, and seven were white (Kirchofer et al., 2002). This variation in chuck and round muscle fiber-type composition, further suggests alternative and whole muscle fabrication from these primals should be considered.

Tenderness mapping via WBS results allowed muscle profiling work and an investigation of tenderness gradients across a muscle (Zuckerman et al., 2002). Muscle profiling work by Von Seggern et al. (2005) evaluated the differences in physiochemical and sensory differences between 39 muscles in the beef carcass. Following this influential research, the U.S. beef industry began marketing value cut steaks from underutilized muscles that are highly palatable (NCBA, 2001). Eminent examples would be flat iron (infraspinatus) and petite tender (teres major) steaks. These muscles were previously left in chuck roasts, but currently through alternative single-muscled fabrication add value to the carcass and variety to the consumer.

**Alternative Forequarter Fabrication**

The beef forequarter accounts for 52% of total carcass side weight. Marketability of cuts from the beef forequarter, primarily within the chuck primal, have been deprived due to high variability in the cut-out yield and muscle palatability characteristics (Johnson et al., 1988). Several studies (Ramsbottom et al., 1945; Johnson, et al., 1988; NCBA, 2000) indicate that larger muscles from the chuck may be suitable as steaks rather than incorporated in roasts. Muscle profiling work has been done on many muscles in the beef carcass but only two studies have focused on muscles in the
forequarter (Ramsbottom and Strandine, 1948; Choi et al., 1987). In work done by
Johnson et al. (1988) the SV and LD were considered some of the most tender muscles in
the beef forequarter. The Infraspinatus and Spinalis dorsi accounted for 22% of total
forequarter weight. Being tender in nature and a sufficient size of forequarter weight,
ultimately these muscles could be fabricated into single muscle steaks.

A result of tradition, and ease of fabrication the beef chuck and rib are separated
at the fifth/sixth rib junction. Today, with the ability to remove the thoracic limb prior to
chuck/rib separation, there is no logical explanation as to why this primal break remains.
Reuter et al. (2002) examined rib steaks from ribs 2-12. Retail weights tended to increase
from the second rib steak to the 10th rib steak and decline slightly from the 10th to 12th rib.
These results are similar to those found by Sweeter et al. (2005). Because size of the LD
increases, anterior to posterior, a parallel increase in value would occur.

Reuter et al., (2002) suggested moving the chuck-rib break to the sixth/seventh rib
junction because of the consistency in tenderness from ribs 7 through 12. This alteration
would result in four fewer 2.5 cm steaks sold in the rib, but would guarantee a
consistently tender ribeye roll. In a consumer preference study, ribeye steaks from ribs 6
and 7 spent longer time in the retail case and resulted in a greater amount of pulls
(Sweeter et al., 2005). These results were attributed to the increased number of muscles
that are present in ribeye steaks from these locations. Steaks from ribs 4-6 had higher
weighted-average WBS values when compared to all other ribs; however, animal-to-
animal variation was 36% greater than rib-to-rib variation in WBS (Reuter et al., 2002).

Moving the chuck-rib break forward to the fourth/fifth rib junction could also be
considered. There were no significant (P<0.05) differences in WBS values among rib
locations four through six and the sixth rib location is currently successfully marketed as ribeye steaks. Furthermore, animal-to-animal variation suggests steaks as far anterior as the second rib could be utilized as ribeye steaks without compromising tenderness. (Reuter et al., 2002) The implementation of a fourth/fifth rib chuck-rib break would also retain consumer purchase preference compared to current ribeye steaks and would allow for four additional 2.5cm ribeye steaks, or an additional 1.8 kg to the ribeye roll.

Pfeiffer (2005) created an innovative ribeye roll by removing all lateral chuck muscles (\textit{Transversus abdominis, Diaphragma pars costalis et sternalis, Rhomboideus thoracis, Trapezius pars thoracicas, Latissimus dorsi, Serratus ventralis thoracis}) and then separating the chuck from the rib between ribs four and five. This innovative ribeye roll was more (P < 0.001) valuable; had greater total subprimal saleable yield, and forequarter values (P < 0.001) for the innovative style. Because the LD originates at the fourth rib location this break should be strongly considered. Values for WBS were highest for rib 4, intermediate for ribs 5 and 6, and lowest for steaks from the seventh rib and posterior; WBS values did not vary for these ribs either (Reuter et al., 2002).

It was recognized by Pfeiffer et al. (2005) that this innovative cut may not realize the same unit prices in a market setting as the conventional IMPS #112A Beef Rib, Ribeye Roll, Lip-On. Regardless, saleable yield was greater (P < 0.001) for the innovative chuck roll when compared to the conventional and the saleable yield of the innovative subprimal included less (P < 0.01) lean trimmings.

Studies have shown that steaks from the seventh and eighth rib locations have higher amounts of kernel fat, which may have an effect on consumer preference (Reuter et al., 2002; Sweeter et al., 2005). Steaks that are left in the retail case longer due to lack
of customer approval discolor and are removed from the retail display, ultimately causing economic loss.

As mentioned previously the SV, a significant portion of the forequarter, encompasses potential for alternative fabrication. As a result of limited function as a motility muscle, tender regions in the SV may exist. Being a large component of the forequarter weight, the SV has potential to be fabricated into single muscle steaks. Additionally, the muscle fibers run parallel to the long axis of the SV with heavy sheets of surface connective tissue (NCBA, 2000) providing a means for single muscle fabrication. However, in a consumer willingness-to-pay trial by Kukowski et al. (2004) the SV was rated lowest for like of shape, like of size, and overall like of appearance. Because of its unique shape and function, this extensive muscle results in long and narrow steaks that are atypical to consumers when compared to oval shaped steaks from the middle meats.

Aside from being fabricated into Denver steaks, the SV is a large component of chuck and rib short ribs. Retail cuts from the beef wholesale rib contain the largest percentage of seam fat when compared to cuts from the chuck, loin, and round (USDA, 1990). In a study by Wulf et al. (1994) short ribs (ribs 6-12) were fabricated according to IMPS 107, and were then sliced using a band saw into 7 slice-each slice then contained one of the ribs 6-12. More variation existed in USDA yield grade as opposed to hot carcass weight and USDA quality grade. Seam fat accounted for a majority of fat followed by external fat and internal fat. Both external fat and internal fat increased similarly with increasing yield grade resulting in a decrease in the percentage of muscle
and bone prevalent (Wulf et al., 1994). The *Latissimus dorsi* was present in the largest amount toward the anterior end of the rib primal and tapered off proceeding posterior and ended at the 11th rib location (Wulf et al., 1994). The SV was present only in the 6, 7, and 8 rib bone slices.

In a study by Searls et al. (2005), SV steaks were fabricated from the dorsal-cranial end of each muscle to the ventral-caudal end. There were differences (P < 0.001) in tenderness values throughout the SV; however, the SV did not have a consistent pattern of tenderness with the five middle steaks, of the ventral side being more tender (P < 0.05) than the dorsal side (Searls et al., 2005). This variation in tenderness could be a result of the physical construction of the muscle as a whole and its function, mean steak WBS value was 4.37 kg with a SD of 1.27 kg (Searls et al., 2005). As mentioned previously, muscle fibers become stronger and more concentrated when they connect with connective tissue (Schackelford et al., 1995); therefore, with a large amount of connective tissue dispersed throughout the SV, it is clear why there would be no true mapping pattern of tenderness (Von Seggern et al., 2005).

**Alternative Hindquarter Fabrication**

Under normal U.S. beef carcass fabrication methods, the point of round-sirloin separation results in a portion of the BF remaining on the sirloin; however there remains an equally tender portion of the BF in the round. In mapping tenderness of the round, Senaratne et al. (2010) found the most proximal BF steak (closest to the sirloin/round separation) was the most tender region of the muscle. The WBS values indicated the
most proximal 2 steaks of the long head BF would result in more tender steaks than most of the rest of the muscle, and could be marketed as premium to other round steaks.

The BF had the greatest amount of WBS variation (SD = 1.09 kg) when compared to the SM, ST, and AD in the round, indicating the importance of location (Reuter et al., 2002). Similar to Senaratne et al. (2010) the BF had its lowest WBS values at the origin (sirloin end). Intermediate WBS values were reported at the insertion, and its highest WBS values in a middle region 7 to 10 cm posterior to the separation point between the sirloin and round (P < 0.05). The BF also had lower WBS values toward the ST side than toward the Vastus lateralis side, but no consistent WBS differences from the superficial side to the deep side (P < 0.05) (Reuter et al., 2002).

The overall muscle fiber orientation of the BF was bipennate (Senaratne et al., 2010). At the sirloin/round separation region of the long head of BF had more horizontal fiber orientation than the rest of the muscle, and the long head BF had increasing angularity of muscle fibers from distal to proximal end on the horizontal axis. So in fabricating the extended sirloin cap, thought should be given to steak cutting method: parallel or perpendicular to muscle fiber direction. In a study by McKenna (2003), the beef round outside round (IMPS #171B) was fabricated perpendicular to muscle fibers rather than the traditional slightly parallel style. Through this fabrication style, a shift toward smaller steaks was achieved, along with decreased percentage retail yields decreased and processing time increased. The proximal portion would be oriented such that steaks are cut across the grain, perpendicular to muscle fiber direction (Senaratne et al., 2010).
The beef sirloin butt is considered a profitable cut that offers cost control as a result of multiple applications that minimize product inventory as well as portion flexibility and moderately priced beef (NCBA, 2001). More importantly, the top sirloin butt is versatile which allows for creative cuts and expanded menus. In NCBA’s *Beef Value Cuts: New Cuts for the New Consumer* alternative fabrication of the sirloin suggests to remove the top cap or coulotte, by following the natural seam. Reuter et al. (2002) further recommends separation at a point immediately anterior to its caudal origin at the lateral tuberosity of the *tuber ischiadicum*. Once the cap is separated from the sirloin, steaks on the distal end can be cut across the grain with the remainder portion being cut into cubes or strips, adding value and variety. Of course, cap removal prior to round-sirloin separation will have a negative impact on the BF remaining in the round. When the bottom round was fabricated in this fashion, the innovative top sirloin cap (coulotte) was higher (P < 0.001) yielding than the conventional cut. Consequently, the bottom round was lower (P < 0.001) yielding in comparison to the conventional bottom round flat (Pfeiffer, 2005).

A slight rotation of the point of separation between the sirloin and round on its midpoint axis would allocate more of the tender portion of the BF to the sirloin, thereby utilizing the tender region of the BF more effectively and yielding more sirloin steaks (Reuter et al., 2002). This proposed fabrication method would eliminate the ball tip, leaving the whole quadriceps muscle group intact, but would require that the tri-tip (IMPS 185C; USDA 1975) be removed prior to separating the round from the sirloin in order to prevent cutting the tri-tip into two pieces.
When considering alternative hindquarter fabrication methods a distinguishable anatomical landmark is necessary for effectiveness and consistency during fabrication. The aitch bone, being the only representable and visible bone in the round, could be considered a suitable landmark. However, little research in regards to the consistency of size and shape of the aitch bone, in correlation to market animal sex and weight is available. Johnson et al. (1988) in a replacement female study stated that the relationships among external body measurements, internal pelvic area are unclear. Bellows et al. (1971a) and Ward (1971) found that some external body measurements were correlated with pelvic area; however, Brown et al. (1982) found no significant relationship among external body measurements and pelvic dimensions. Limited information is available on slope of rump and pelvic structure (angles of the pelvis) and their relationship to internal pelvic area. Significant correlations of prebreeding pelvic area with prebreeding weight and precalving pelvic area with precalving weight were .56 and .5, respectively. Hook width measurements had the highest correlation to internal pelvic area, and hook-to-pin length had the second highest correlation. Pelvic angles, hypothesized to indicate pelvic structure, and the estimated and calculated slope of rump variables, in general, had low correlations with internal pelvic measurements (Johnson, et. al., 1988).
Summary

Today, producers and industry personnel are faced with a challenge to produce enough protein to feed an ever-growing population. In 2050, the projected world population is set to reach nine billion people. Of course with this increase in human population, a paralleled increase in the world’s GDP will be observed. With that being said, the beef industry will gain new consumers that want a high quality and valued protein source.

Efficiency in cattle production will continue to increase in the US as long as a demand for high quality beef exists. Producers will achieve heavier HCW at fewer days; larger animal size is not something of the past. So the ability to develop alternative fabrication methods for heavy weight beef carcasses is essential. Past fabrication techniques for beef cattle are based heavily on tradition and feasibility of cuts in the marketplace. Today the industry is faced with a challenge from consumers that demand cuts that are convenient to prepare and consistent in quality. Through the utilization of single muscle fabrication in both the chuck and round, the industry can provide a higher concentration of steakable items to consumers that are uniform in tenderness.

Furthermore, producers can ultimately benefit from alternative fabrication methods in the beef carcass; an eminent example is that of the flat iron steak. The US beef industry currently produces 20% of the world’s beef with 9% of the world’s cattle (USDA-AMS, 2012). To maintain this efficiency and exceptional ability, the industry needs to be innovative in the approach we market beef and beef products.
However, with these increasing efficiencies in cattle, economics of production need to be considered. As fabrication styles shift towards smaller single-muscle retail cuts, percent retail yields decreased and processing times and labor intensity increased (McNeill et al., 1998; Weatherly et al., 2001; McKenna et al., 2003). Similarly, a shift from bone-in to boneless cuts will result in decreased retail yields and increased processing times (Lorenzen et al., 1997). Therefore yields and economics behind alternative fabrication methods need to be assessed.

Therefore, through this thesis alternative fabrication methods were evaluated in both the round and chuck focusing on the development of new cuts as well as an evaluation of previous high dollar items from the beef carcass. The results from this research will be influential in the development and further implementation of alternative fabrication methods here in the US.
MATERIALS & METHODS

Aitch Bone Audit

Aitch Bone Collection

Pelvic bones from the right side of twenty-five beef carcasses were collected on Friday, July 15, 2011. Bones were collected from the Tyson, Inc. facility in Lexington, NE to characterize the variation in bone shape due to gender and weight at harvest. When selecting carcasses sex, hide color, side weight and carcass weight were recorded. Carcasses were classified within the following weight ranges: 272-318, 319-363, 364-408, 409-454, and > 455 kg. At least two heifer and two steer carcasses were selected from each range.

Carcasses were pulled into the re-grade bay by Tyson personnel and the pelvises from these carcasses were identified with carcass crayon (Dixon International, Model No. 1530R. The Dixon Store, Shreveport, LA). Pelvic bones were marked with respective letters on the sacral vertebrae and ball of the aitch bone. All twenty five carcasses entered commercial production, and were split into round and sirloin primals. After fabrication of boneless round and sirloin cuts, the two pieces of the pelvis were obtained - the hip portion from the sirloin and the aitch portion from the round. These counterparts were then transported to Loeffel Meat Laboratory at the University of Nebraska-Lincoln for measurement and analysis.

Aitch Bone Evaluation

Prior to evaluation, both the hip and aitch bone pieces had additional connective tissue and lean removed. All hip and aitch bone pieces were then weighed (kg) and
measured to determine the three-dimensional shape of the pelvis. Weight (kg) was captured (WeighTronix, Model No. WI-110. Avery WeighTronix Fairmont, MN) for both the hip and aitch bone portions; thus total pelvic weight for one side was determined by the summing these weights.

Measurements were defined prior to data collection with intentions to capture the true dimensional shape of the pelvis. In measurement definitions, the aitch bone is the cut surface of the pelvic *Symphysis pubis*, a result from splitting of the carcass. All hip and aitch bone dimensions were measured using a cloth measuring tape (cm). Anatomical terms to describe measurement locations were assumed similar to those in a beef carcass hanging from the Achilles tendon.

Aitch bone length was measured on the aitch bone portion of the pelvis. Aitch bone length was determined as the distance from the ball of the aitch bone at its most cranial point, to the most posterior (*ischium*) portion of the aitch bone. Cartilage of the ball and ischium portions of the aitch bone was included in measurements. Maintaining the planar location of the aitch bone length measurement, a second cloth measuring tape was placed perpendicular to this plane. Starting at this location, the distance was measured to the furthest lateral point of the aitch bone. The linear location of the aitch bone depth line on the aitch bone length plane was recorded. From the aitch bone depth and length measurements, aitch bone angle was calculated in Microsoft Excel (Microsoft Office, Version 2007) using the Pythagorean theorem. Circumference of the *Symphysis Pubis* was measured on the aitch bone portion of the pelvis as the distance around the aitch bone at its most narrow position.
The following measurements were obtained while the hip and aitch bone portions were held together. To obtain a measurement for hook width, the surface of the aitch bone was placed on a table. The distance from the table to the lateral surface of the ilium was measured. This value was then multiplied by two to calculate the total hook-hook distance in a pelvis. Pin width was also measured with the aitch bone surface on a table, as the distance from the flat lateral surface of the ischium. Pelvic depth was measured as the distance from the ball of the aitch bone to the planar center of the 4th sacral vertebrae. Pelvic depth was measured as the distance from the ischium to the planar center of the fourth 4th sacral vertebrae. Finally Pelvic Length was measured on the lateral surface of the pelvic bone as the distance from the center edge of ischium to the center edge of the Ilium.

Photographs were taken of both the hip and aitch bone pieces from various angles to further illustrate the variation in pelvic shape (Appendix 3). Photographs were also taken to explain accuracy of carcass splitting (Appendix 4).

Statistical Analysis

Weights and dimensional measurements of pelvic bones were analyzed independently using ANOVA in PROC GLM procedure of SAS (SAS 2009, Version 9.2, Cary, NC) as 2 × 5 factorial design (2 levels of sexes – heifers and steers; five levels of carcass weight groups -272-318, 319-363, 364-408, 409-454, and > 455 kg). Mean separation was performed using LSMEANS with LINES options in SAS at \( P \leq 0.05 \).
Short Rib Evaluation

Short Rib Collection

Twenty short rib subprimals were collected from the Tyson, Inc. facility in Lexington, NE on September 22, 2011. Both the left and right sides of Choice, YG 3 carcasses weighing between 364 and 386 kg were tagged for collection. The tagged carcasses were sorted off into the regrade bay courtesy of Tyson, Inc. personnel for further identification. Carcasses were numbered, using a carcass crayon (Dixon International, Model No. 1530R. The Dixon Store, Shreveport, LA); carcass side was also identified so that “10L” would denote: the left side of animal 10. Numbers were inscribed on the medial (bone) side of the short ribs in location respective to beef chuck, short ribs (IMPS #130, NAMP 2007) and beef short ribs (IMPS #123, NAMP 2007). Essentially, ribs 2-12 were identified for collection.

The carcasses then entered commercial production, and the chuck and rib were separated at the 5-6 rib junction. Chuck short ribs (IMPS #130, NAMP) were removed from the chuck primal by Tyson personnel. Chuck short ribs (ribs 2-5) were collected and vacuum packaged separately. Short ribs from the rib primal (ribs 6-12) were fabricated, by Tyson personnel, and then collected and vacuum packaged. Given the novelty of this study, the short ribs collected from the rib primal included the familiar rib (IMPS #123, NAMP), and/or plate (IMPS #123, NAMP) beef short ribs, and extended the primal length to include ribs 9-12-which are typically fabricated to beef rib, rib fingers (IMPS #124A, NAMP).

Both sets of short ribs were transported under refrigeration to the Loeffel Meat Laboratory at the University of Nebraska-Lincoln. It was determined that chuck and beef
short ribs from the right side of the carcass would be utilized to evaluate product yield. Subsequently, chuck and beef rib short ribs from the left side were evaluated by a trained taste panel for tenderness, flavor and juiciness. Rib subprimals for yield evaluation were fabricated 12 d post mortem. Rib subprimals for taste panel evaluation were aged for 21d post mortem at 2°C prior to being fabricated.

**Short Rib Yield Fabrication**

Prior to fabrication, the chuck (ribs 2-5) and beef short rib (ribs 6-12) subprimals were weighed whole (kg) on the meat lab’s scale (WeighTronix, Model No. WI-110. Avery WeighTronix Fairmont, MN). Distances of width, length, and depth were measured (cm) using a cloth measuring tape (Appendix 5). All dimensions were measured with the measuring tape lying flush against the meat surface. Short rib width (distance from dorsal to ventral edge of subprimal) was measured at rib locations 2 & 5, and 6 & 12 following the natural curve of the subprimal. Short rib length was measured on the dorsal and ventral edges of the subprimal from anterior to posterior end, again following the natural curve of the subprimal. Measurements for length and width were recorded for both the medial and lateral sides of both subprimals. Width measurements occurred at each rib location on the dorsal and ventral surface of the subprimals. All measurements were anchored on the medial edge, in the center of each rib bone. Three width measurements were obtained: width of bone, width of bone and lean, and total width. From these measurements lean width could be calculated.

Following measurement analysis, each rib was individually cut from its subsequent subprimal. Ribs were separated with a dorsal to ventral cut, dividing the lean
in half between ribs (Appendix 6). Each rib was then boned, and the associated lean was
separated from subcuteaneous and intermuscular fat. Bone, lean, and fat from each rib
were weighed (g) using a small gram scale (Mettler Toledo, Mondel No. BD1201,
Columbus, OH).

Short Rib Taste Panel Fabrication

Prior to fabrication, the chuck (ribs 2-5) and beef short ribs (ribs 6-12) were
weighed whole (kg) using the meat lab’s scale (WeighTronix, Model No. WI-110. Avery
WeighTronix, Fairmont, MN). Both chuck and beef short ribs (ribs 2-12) were sliced
from anterior to posterior end into 6 mm slices using a band saw (Biro Model No. 3334,
The Biro, MFG. Co. Marblehead, OH). Ribs were identified on each slice, 2-12
(Appendix 7). Each rib was then separated from their subsequent counterpart by dividing
the lean between ribs in half. This cutting style allowed for the lean associated with an
individual rib to be sampled during panel sessions. The rib slices from each rib were
packaged separately using nylon-polyethylene vacuum pouches (3 mil STD barrier,
Prime Sources, St. Louis, MO) and vacuum sealed with a Multivac Packaging machine
(MULTIVAC C500, Multivac Inc. Kansas City, MO). Rib slices were immediately
frozen at -20°C.

Short Rib Taste Panel Preparation

Sample size for taste panel evaluation was 6 mm thick-slices containing one rib
bone and it’s associated lean including: Serratus Ventralis, Intercostales interni, and
Intercostales externi. Within 24 hrs prior to taste panel preparation, rib slices were
placed in a 4°C cooler to thaw. Individual short rib slices were cooked on a Rival 11”
Square Electric Skillet (Rival Products, Model No. S11, 120V ~ 60 HZ, 1200 W. Boca Raton, FL). Slices were cooked at 204˚C for 45 s per side. Short rib pieces were then transferred to a second frying pan at 149˚C for 4 minutes time per side. Cooked short rib slices were then kept in a preheated countertop warmer at the 3.5 temperature level (Model TMPT, WELL BLOOMFIELD, LLC, Verdi, NV) no longer than 15 minutes prior to serving.

For sensory analysis, ribs 2-12 were served to a trained taste panel to distinguish organoleptic differences between rib locations. Ratings for organoleptic properties were based on an 8-point scale for tenderness (1 = extremely tough – 8 = extremely tender), juiciness (1 = extremely dry – 8 = extremely juicy), and off-flavor intensity (1 = extremely mild – 8 = extremely intense).

The trained sensory panel (6 members) consisted of staff from the University of Nebraska-Lincoln. Panelists were trained according to AMSA 1995 guidelines. In training sessions panelists were asked to rate individual rib samples numerically based on the amount of tenderness, juiciness, and off-flavor intensity per sample. These attributes were then discussed between panelists and the training coordinator. Panelists were asked not to address the visual differences among samples. The amount of connective tissue in samples was not assessed. Panelists were provided individual 6 mm rib slices from ribs 2-12 from USDA Choice carcasses. Six training sessions were conducted from October 24, 2011 through October 28, 2011. Panelists were paid $10.00 for each training session.

Taste panel sessions took place from October 31, 2011 to November 15, 2011, and included 20 panels total. Panelists were allocated to individual booths lighted with
red fluorescent lights to minimize visual differences between slices. Panelists utilized Compusense Five (Compusense Inc., Release 2.2, Guelph, ON Canada) on individual laptop computers to enter their ratings and additional comments for each sample served. During taste panels, the same 8 point hedonic scale was utilized for sample rating. An exhaust fan was used to create negative air pressure and remove odors from the taste panel room. Panelists were provided a cup of tepid, double distilled de-ionized water and unsalted crackers to cleanse their palates between sample servings. Panelists were also supplied with toothpicks and napkins due to the nature of the sample. Six samples were served during morning sessions and five samples were provided during afternoon sessions. With this serving order, all ribs from one animal were served in a single day. Taste panelists were compensated $10.00 per panel.

Statistical Analysis

Sensory data (tenderness, juiciness, and off-flavor intensity) on short ribs were analyzed independently using ANOVA in PROC GLIMMIX in SAS (SAS 2009, Version 9.2, Cary, NC) as completely randomized designs. Rib number was the main effect, and the animal and panelist were considered random effects. Separation of means was carried out using LSMEANS with DIFF and LINES options in SAS at $P \leq 0.05$. 
Development of Chuck Subprimals

Subprimal Collection

Twelve beef carcasses were tested for alternative forequarter fabrication at the Tyson, Inc. facility in Amarillo, TX on October 17, 2011. Carcasses weighing between 364 and 386 kg and grading USDA Low Choice, YG 3 were selected. During fabrication, both the right and left sides of the carcasses were utilized. Alternative forequarter fabrication occurred on all twelve right sides; the left sides on six carcasses were fabricated traditionally (IMPS 113, NAMP) and were considered controls.

Two alternative forequarter fabrication methods were evaluated based on the location of the chuck-rib break; focusing specifically on the resulting effects on other subprimals. Both methods of fabrication resulted in the development of a new 2 or 3-rib subprimal. Each cutting method started the rib primal at the seventh rib, as opposed to the sixth rib in traditional fabrication (Appendix 8). This of course resulted in a rib primal that was one rib shorter for both fabrication methods.

Method A resulted in a 3 rib subprimal-separation of the chuck and rib between ribs three and four; two ribs cranial to the typical chuck/rib break. Method B resulted in a 2 rib subprimal after the chuck and rib were separated between ribs four and five; one rib cranial to the typical chuck/rib break. Six right sides were fabricated as Method A and six right sides as Method B. All forequarter fabrication methods occurred while the carcass was suspended from an “S” hook through the 12th rib.

Alternative fabrication commenced with the removal of the Latissimus dorsi (lifter meat) from the 12th rib cranial to the sixth rib location. After the lifter meat was
removed, the cartilaginous caudal region of the scapula was located. A meat hook was used to separate the cartilaginous tip from the carcass by pulling the tip cranially with great force. From this scapular location, an incision was made cranial following the seam caudal to the elbow. Pulling the scapula towards the cranial end, the knife was kept close to the medial side of the scapula, leaving the *Subscapularis* on the suspended carcass. Once the medial side of the scapula was free from the carcass, a cut could be made that would free the thoracic limb from the forequarter.

The chuck/rib break location (3/4 or 4/5) was then identified dependent on respective treatment. Once the innovative break was located, a knife was used to separate the chuck and rib through a ventral-to-dorsal cut in the intercostal lean. A band saw (Biro Model No. 3334, The Biro, MFG. Co. Marblehead, OH) was used to cut the thoracic vertebrae on the dorsal side of the forequarter. The alternative break was completed by sawing caudally to cranially along the dorsal ridge of the brisket primal. The reduced chuck primal was set aside for further fabrication.

On the remaining portion of the suspended forequarter the inside and outside skirt steaks (*IMPS #121D & #121C respectively, NAMP 2007*) were removed. Using a band saw, a straight cut ventral to, but not more than 7.5 cm from the *Longissimus dorsi* at the loin end, to a point on the chuck end ventral to, but not more than 10.0 cm from the *Longissimus dorsi* was made to separate the ribeye subprimal from the ribs (*IMPS #107, NAMP 2007*). The chine bone was removed from the ribeye subprimal using a band saw. Using a knife and meat hook, feather bones on the dorsal side of the subprimal were removed. A division was then created using a knife, depending on treatment, between
ribs to create a respective 2 or 3-rib subprimal. In both treatments the knife cut was flush to the most posterior rib of the alternative subprimal.

Weights (kg) of the following subprimals were recorded: chuck short ribs, beef short ribs, chuck eye log, chuck roll, underblade, pectoral meat, boneless ribeye roll, back ribs, and the new rib subprimals. Both the underblade and pectoral subprimals were untrimmed when weighed.

The 2-rib and 3-rib subprimals were then vacuum packaged, and were transported to the University of Nebraska-Lincoln Loeffel Meat Laboratory under refrigeration. Both 2-rib and 3-rib subprimals were aged at 2°C for 21 days.

*Subprimal Fabrication*

All 2-rib and 3-rib subprimals were removed from packaging and devoid of excess purge, weighed (kg) on the meat lab’s scale (WeighTronix, Model No. WI-110 Avery WeighTronix Fairmont, MN). The length and width of the subprimals were measured (Appendix 9) for both fabrication styles using a cloth measuring tape. Primal width was measured as the distance from cranial face to caudal face, on the lateral side of the subprimal; essentially the length of the *Longissimus dorsi* muscle. Cranial and caudal lengths were measured on the 3-rib subprimals associated with the 3-4 chuck-rib break. Cranial subprimal length was measured as the distance from dorsal edge to ventral edge on the cranial lateral side. Respectively, caudal subprimal length was measured as the distance from dorsal to ventral edge on the caudal lateral side. The midpoint length of the 2-rib subprimal was also measured.
After measurements were obtained, all 2-rib and 3-rib subprimals were fabricated similarly to obtain individual muscles (Appendix 10). Exterior fat was first removed from the subprimal. Using a knife to follow the natural curvature of the ribs, the back ribs were then removed. Each muscle was then excised from the subprimal and labeled with tags that kept muscle orientation apparent: cranial and caudal ends. Weights for the following components were collected (g): Longissimus dorsi, Longissimus costarum, Complexus, Spinalis/Multifidus dorsi, Serratus ventralis, Intercostales interni, ligamentum nuchae, backribs, fat, connective tissue, and lean trim. The Longissimus dorsi, Longissimus costarum, Complexus were packaged according to primal number in nylon-polyethylene vacuum pouches (3 mil STD barrier, Prime Sources, St. Louis, MO) and vacuum sealed with a Multivac Packaging machine (MULTIVAC C500, Multivac Inc. Kansas City, MO). Muscle components were vacuum packaged and immediately frozen at -20°C.

Subprimal WBS Evaluation

To objectively test tenderness variation in the 2-rib and 3-rib subprimal, steaks from the Longissimus dorsi were prepared for Warner Bratzler Shear Force assessment. All Longissimus dorsi muscles from Method A and Method B fabrications were placed in a 4°C cooler to thaw for 24 hrs. Once thawed, three steaks (2.54 cm) were cut from Method A Longissimus dorsi and two steaks (2.54 cm) were cut from Method B Longissimus dorsi. Method A steaks were obtained from anterior, middle and posterior locations within the muscle, whereas Method B only had an anterior and posterior steak. In practice, the anterior steak obtained from Method B fabrication was of similar
anatomical location to that of the middle steak obtained from Method A. Anterior steaks were fabricated first and consisted of the most cranial 2.54 cm of the *Longissimus dorsi*. The posterior steaks were then cut as the most caudal 2.54 cm. Middle steaks from Method A were taken from the middle 2.54 cm of the remaining *Longissimus dorsi* piece. Steaks were identified according to location and pre-cook weights and temperatures were recorded.

Steaks were cooked on a Hamilton Beach Indoor-Outdoor Grill (Hamilton Beach/Proctor Silex, Inc., Model 31605A, Series Type G16 Grill, 120 v ~ 60 Hz, 1200 W) to an internal temperature of 71°C; after being flipped once at 35°C. Internal temperature was monitored using an OMEGA thermometer (Model 450A, OMEGA Engineering Inc., Stamford, CT) with a type T thermocouple (Model L-0044T Fine Wire Thermocouples, OMEGA Engineering Inc., Stamford, CT) inserted in the geometric center of the steak. Cooked steak weight was recorded to determine cooking loss. Cooked steaks were then placed on a plastic tray and overwrapped with oxygen permeable film. Steaks were stored at 4°C for 24 hrs prior to being cored and sheared.

Cooked steaks were retrieved from the cooler and had cores prepared (Delta 20.3 cm Drill Press, Mfg. Ser. No. W9609, Model 11-950, Delta International Machinery Corp., Pittsburgh, PA). Due to size, four 1.3 cm cores were retrieved from anterior Method A steaks, whereas all other steaks from both Method A and B had six cores. These cores were sheared using a tabletop Warner Bratzler Shear Force machine (Salter Breckenell, Model 235 6X: Motor for Shearer: Bodine Electric Company, Small Motor S/N 0291KUIL 0009 Chicago, IL). Results were recorded for each core sheared.
Statistical Analysis

The 2-rib and 3-rib WBS results were analyzed independently using ANOVA in PROC GLM in SAS (SAS 2009, Version 9.2. Cary, NC) as completely randomized designs. Location and animal were considered as main and random effects, respectively. Separation of means was carried out using LSMEANS with LINES options in SAS at $P \leq 0.05$. 
Extended Sirloin Cap Evaluation

Extended Sirloin Cap Collection

Thirty Low Choice, YG 3 beef carcasses were selected on October 18, 2011, to assess alternative hindquarter fabrication methods at the Tyson, Inc. facility in Amarillo, TX. Carcass weights were recorded prior to fabrication and ranged from 364 to 386 kg. All right sides had the cranial portion of the Biceps femoris removed prior to separation of the sirloin and round (Appendix 11). All hindquarter fabrication occurred while the carcass was suspended from the Achilles tendon.

An imaginary line was made from the dorsal tip of the aitch bone to the lateral side of the carcass. From this landmark, a cut was made adjacent to the spinal column, following the curvature of the pelvic bone. This cut came cranial toward the origin of the Biceps femoris. Again from the lateral landmark a cut was made at a 45˚ angle to the long axis of the carcass to the ventral edge of the Biceps femoris. The Biceps femoris was then pulled down until the insertion point of the muscle was visible, and could be removed. The extended sirloin cap, or Biceps femoris untrimmed weight was recorded (kg) for each carcass. All exterior fat and connective tissue (silverskin) was removed from the cap and again the weight (kg) was recorded. Length, width, and height (cm) were measured on each Sirloin cap using a plastic ruler. Length of the cap was determined on the lateral surface of the muscle as the distance from the insertion point of the Biceps femoris to the posterior cut surface. Width was measured across the cut surface as the distance from the ventral to dorsal edge. Depth of the sirloin cap was measured as the distance from the medial to lateral edge of the cut surface. Height and
width measurements were also taken in the midpoint of the muscle using the same plastic ruler.

To analyze the effect of extended sirloin cap removal, the remainder of the *Biceps femoris* (bottom round) was removed from ten carcasses. The untrimmed and subsequently trimmed weight of the bottom round was recorded. The length from the cut surface to the ischiatic head was measured to determine anatomical location of the cut.

The thirty extended sirloin caps were vacuum packaged and transported to the University of Nebraska-Lincoln Loeffel Meat Laboratory under refrigeration. Six bottom rounds were vacuum packaged and transported to the university as well. Both extended sirloin cap and bottom rounds were aged for 25 d at 2°C.

*Extended Sirloin Cap Fabrication*

To evaluate steak cutting methods in the extended sirloin cap, two steak fabrication styles were utilized: perpendicular (n=10) and parallel (n=10) to fiber direction. Steaks from both fabrication styles were 2.54 cm thick. In both steak cutting methods, a divisional cut was made from dorsal to ventral edge approximately 3 inches cranial from the cut surface. This divisional cut was marked by a connective tissue seam on the dorsal side, as well as the end to a slight bulge in the *Biceps femoris*.

Steaks fabricated parallel to the grain originated from two locations: cranial to the divisional cut (E steaks) and posterior from the divisional cut (D steaks). Both D and E steaks were individually fabricated by dorsal to ventral cuts (Appendix 12). After fabrication, steaks were labeled according to location and respective number. The most caudal steak from location E was labeled as E1, the steak cranial from it was labeled as
E2 and so on. The most cranial steak from location D was labeled as D1, the steak posterior from D1 was labeled as D2 and so on. Aside from numerical classification, anatomical orientation was identified on each steak’s label. The number of steaks from each location was recorded. After steak fabrication, steaks were packaged in nylon-polyethylene vacuum pouches (3 mil STD barrier, Prime Sources, St. Louis, MO) and vacuum sealed with a Multivac Packaging machine (MULTIVAC C500, Multivac Inc. Kansas City, MO) and frozen at -20°C.

Steaks fabricated perpendicular to the grain came from three locations (Appendix 13). These locations (A, B, C) were created by two knife cuts from the ventral to dorsal edge, with one being the divisional cut. During steak location development, fiber direction was imperative. Steaks from location A came from the cranial third of the cap. Steaks from location B came from the middle portion of the cap, and cranial from the divisional cut. Steaks from the C location were from the posterior third of the cap, and posterior to the divisional cut. Within each of these three locations steaks were then cut perpendicular to fiber direction, or an cranial to caudal cut. Steaks were identified numerically within their location 1-5, starting with 1 at the ventral edge. Aside from numerical classification, anatomical orientation was identified on each steak’s label. The number of steaks from each location was recorded. After steak fabrication, steaks were packaged in nylon-polyethylene vacuum pouches (3 mil STD barrier, Prime Sources, St. Louis, MO) and vacuum sealed with a Multivac Packaging machine (MULTIVAC C500, Multivac Inc. Kansas City, MO) and frozen at -20°C.
Extended Sirloin Cap WBS Evaluation

To objectively test tenderness variation between cutting styles, extended sirloin cap steaks were prepared for Warner Bratzler Shear Force assessment. Steaks from ten extended sirloin caps (five cut perpendicular to fiber direction, and five cut parallel to fiber direction) were placed in a 4°C cooler to thaw for 24 hrs. The steaks respective anatomical orientation was maintained throughout the cooking and shearing process (Appendix 14).

Pre-cook weights (g) and temperatures (°C) were recorded for each steak. Steaks were cooked on a Hamilton Beach Indoor-Outdoor Grill (Hamilton Beach/Proctor Silex, Inc., Catalog No. HB9, Model 31605A, Series Type G16 Grill, 120 v ~ 60 Hz, 1200 W) to an internal temperature of 71°C; after being flipped once at 35°C. Internal temperature was monitored using an OMEGA thermometer (Model 450A, OMEGA Engineering Inc., Stamford, CT) with a type T thermocouple (Model L-0044T Fine Wire Thermocouples, OMEGA Engineering Inc., Stamford, CT) inserted in the geometric center of the steak. Cooked steak weight was recorded to determine cooking loss. Cooked steaks were then placed on a plastic tray and overwrapped with oxygen permeable film. Steaks were stored at 4°C for 24 hrs prior to being sheared.

Cooked steaks were retrieved from the cooler and cores were prepared (Delta 20.3 cm Drill Press, Mfg. Ser. No. W9609, Model 11-950, Delta International Machinery Crop., Pittsburgh, PA). To preserve anatomical location parallel-cut steaks were separated into 3 cm pieces via a lateral-medial cut. Cores were first obtained from the most ventral piece, moving from medial to lateral edge. Core preparation proceeded in this same fashion moving dorsally across the steak. To preserve anatomical location in
perpendicular-cut steaks, they were cut into 3 cm pieces with a medial-lateral cut. Cores were first obtained from the most cranial piece, moving from medial to lateral edge. Core preparation proceeded in this same fashion moving caudally. Cores were sheared using a tabletop Warner Bratzler Shear Force machine (Salter Breckenell, Model 235 6X: Motor for Shearer: Bodine Electric Company, Small Motor S/N 0291KUIL 0009 Chicago, IL) in the same order they were prepared. Results were recorded for each core sheared.

**Extended Sirloin Cap Taste Panel**

The same trained taste panelists were utilized for the extended sirloin cap as the short rib analysis. Within 24 hrs prior to taste panel preparation, steaks were placed in a 4°C cooler to thaw. Pre-cook weights (g) and temperatures (°C) were recorded for each steak.

Steaks were cooked on a Hamilton Beach Indoor-Outdoor Grill (Hamilton Beach/Proctor Silex, Inc., Catalog No. HB9, Model 31605A, Series Type G16 Grill, 120 v ~ 60 Hz, 1200 W) to an internal temperature of 71°C; after being flipped once at 35°C. Internal temperature was monitored using an OMEGA thermometer (Model 450A, OMEGA Engineering Inc., Stamford, CT) with a type T thermocouple (Model L-0044T Fine Wire Thermocouples, OMEGA Engineering Inc., Stamford, CT) inserted in the geometric center of the steak. Cooked steak weight was recorded to determine cooking loss. After the cooked steak weight was recorded, steaks were cut into 1.27 x 1.27 x 1.27 cm individual cubes. Cooked samples were then kept in a preheated countertop warmer at
the 4 temperature level (Model TMPT, WELL BLOOMFIELD, LLC, Verdi, NV) for no longer than 15 minutes prior to serving.

The trained sensory panel (5 members) consisted of staff from the University of Nebraska-Lincoln. Panelists were trained according to AMSA 1995 guidelines. In training sessions panelists were asked to rate extended sirloin cap samples numerically based on the amount of juiciness, tenderness, connective tissue, and off-flavor intensity per sample. For sensory analysis, samples were served from all steak locations. Ratings for organoleptic properties were based on an 8-point scale for juiciness (1 = extremely dry – 8 = extremely juicy), tenderness (1 = extremely tough – 8 = extremely tender), connective tissue (1 = abundant amount - 8 = no connective tissue), and off flavor intensity (1 = extremely mild – 8 = extremely intense).

These attributes were then discussed between panelists and the training coordinator. Six training sessions were conducted from October 24, 2011 through October 28, 2011. Panelists were paid $10.00 for each training session.

Taste panel sessions took place from January 30, 2012 through February 13, 2012. Panelists were allocated to individual booths lighted with red fluorescent lights to minimize visual differences between samples. Panelists utilized Compusense Five (Compusense Inc., Release 2.2, Guelph, ON Canada) on individual laptop computers to enter their ratings and additional comments for each sample served. During taste panels, the same 8 point hedonic scale was utilized for sample rating. An exhaust fan was used to create negative air pressure and remove odors from the taste panel room. Panelists were provided a cup of double distilled de-ionized water and unsalted crackers to cleanse
their palates between sample servings. Panelists were also supplied with toothpicks and napkins.

At most, seven samples were served during a session. Some sessions had five or six samples due to a lack of sample from a respective steak. The serving order was designed so that samples were served from the same anatomical location, regardless of cutting style. With this serving manner, attributes could be analyzed according to steak location and cutting style. Taste panelists were compensated $10.00 per panel.

Pre-cook weights (g) and temperatures (˚C) were recorded for each steak. Steaks were cooked on a Hamilton Beach Indoor-Outdoor Grill (Hamilton Beach/Proctor Silex, Inc., Catalog No. HB9, Model 31605A, Series Type G16 Grill, 120 v ~ 60 Hz, 1200 W) to an internal temperature of 71˚C; after being flipped once at 35˚C. Internal temperature was monitored using an OMEGA thermometer (Model 450A, OMEGA Engineering Inc., Stamford, CT) with a type T thermocouple (Model L-0044T Fine Wire Thermocouples, OMEGA Engineering Inc., Stamford, CT) inserted in the geometric center of the steak. Cooked steak weight was recorded to determine cooking loss.

Statistical Analysis

Shear force data were analyzed independently using the PROC GLIMMIX procedure of SAS (Version 9.2, Cary, NC, 2002 – 2008). Steak location and animal were considered the main and random effects, respectively. Separation of means was carried out using LSMEANS with DIFF and LINES options in SAS at $P \leq 0.05$.

Sensory data (tenderness, juiciness, connective tissue and off-flavor intensity) of extended sirloin caps were analyzed independently using ANOVA in PROC GLIMMIX.
in SAS as completely randomized designs. Data were analyzed two ways: by steak location and by region within the extended sirloin cap. When analyzing sensory data based on specific location, animal and panelist were considered the random effects with steak location as the main effect. When data were analyzed according to steak region within the cap, animal and panelist were considered the random effects with fabrication style (parallel or perpendicular) as the main effect. The interaction between fabrication style and steak region was also assessed. Separation of means was carried out using LSMEANS with DIFF and LINES options in SAS at $P \leq 0.05$.

Cooking loss was analyzed using the PROC GLIMMIX procedure of SAS. Steak location and/or steak region were the main effects; animal was the random effect. When significance ($P < 0.05$) was indicated by ANOVA, mean separations were performed using the LSMEANS and PDIFF functions of SAS.
LITERATURE CITED


MANUSCRIPT I

An evaluation of pelvic bone shape in beef carcasses

J.J. Hosch, K.A. Varnold, L.S. Senaratne-Lenagala, and J.E. Hergenreder, and C.R. Calkins

Animal Science Department¹, University of Nebraska-Lincoln, Lincoln 68583-0908

A contribution to the University of Nebraska Agricultural Research Division, Lincoln, NE 68583.
¹Correspondence: A213 Animal Science: Telephone: 402.472.6314; Fax: 402.472.6362. Email address: ccalkins1@unl.edu R Calkins, PhD)
ABSTRACT

Pelvic bones from the right side of twenty five beef carcasses were collected and analyzed to characterize the variation in bone size and shape. Two heifer and two steer carcasses were selected from each of the following weight ranges: 272-318, 319-363, 364-408, 409-454, and > 455 kg. Two pieces of the pelvis were obtained - the hip portion from the sirloin and the aitch portion from the round. The following measurements were recorded: hip bone weight, aitch bone weight, total pelvic weight, aitch bone length, aitch bone depth, aitch bone angle, pubic symphysis circumference, hook width, pin width, cranial pelvic depth, caudal pelvic depth, and pelvic length. A 2 x 5 (sex x weight range) factorial design was utilized. Hip bone weight, aitch bone weight, and total pelvic weight increased with increasing carcass weight (total pelvic weight = 2.37, 2.59, 2.73, 3.01, and 2.86 kg, respectively; P = 0.03). Longer aitch bone length (P = 0.04) and pelvic length (P = 0.03) were observed in steers when compared to heifers (aitch bone length = 15.8 and 14.9 cm; pelvic length = 39.2 and 36.2 cm, respectively). Photographs were taken of both the hip and aitch bone pieces from various angles to further illustrate the variation in pelvic shape. From representative photography of 6 mm medial to lateral slices it appears the size of the ball of the aitch bone and shape (angle) of the aitch bone was influenced by the accuracy of how the carcass was split. As the cut progressed laterally from the true pelvic midline, the shape of the ball became distorted, changing from circular to oblong in nature. Similarly, the angle of the aitch bone increased, becoming more planar and less acute. These data suggest that aitch bone shape is influenced by accuracy of carcass split and that gender differences are reflected in the pelvic bone characteristics.
Key Words: aitch bone, beef, pelvis.
Introduction

When considering alternative hindquarter fabrication methods a distinguishable anatomical landmark is necessary for effectiveness and consistency during fabrication. Currently, the beef round is separated by a straight cut beginning at the juncture of the last sacral vertebrae and the first caudal vertebrae, exposing the ball of the femur without severing the protuberance (NAMP, 2007). This typically occurs about ¾” cranial to the ball of the aitch bone.

Depending on plant location or market demands the angle of the round/sirloin break can be slightly altered to add more pounds to the sirloin primal (notably the ball tip). At a +40 percent price differential, adding weight to the sirloin primal is enticing.

When a carcass is split evenly into left and right sides, pelvic fibrocartilage, or the Symphysis pubis (SP), is visible providing means as an anatomical landmark. The cut surface of the SP is often referred to as the aitch bone.

In a study by Laster et al. (1974) pelvic dimensions in replacement beef heifers were influenced by breed of sire ($P<0.01$) and breed of dam ($P<0.05$); however, most of the differences in pelvic size among breeds were due to differences in animal body weight. Significant correlations in replacement beef heifers of prebreeding pelvic area with prebreeding weight and precalving pelvic area with precalving weight were 0.56 and 0.50, respectively (Johnson et al, 1988), reflecting that larger animals have a larger pelvic area.

However, relationships among external body measurements and internal pelvic area are unclear for market animals (Brown et al., 1982). In the progression of alternative hindquarter fabrication development, the aitch bone was identified as a visible bone in the round and thus a potential anatomical landmark for fabrication. Due to lack of research in market animals on the
variation in aitch bone shape and size of the ball of the aitch bone, an evaluation of pelvic size and shape was necessary.

**Materials & Methods**

Pelvic bones from the right side of twenty-five beef carcasses were collected to characterize the variation in bone shape due to gender and weight of animal at harvest. When selecting carcasses, sex, hide color, side weight and carcass weight were recorded. Carcasses (n=4) were selected within the following weight ranges: 272-318, 319-363, 364-408, 409-454, and > 455 kg, with at least two heifer and two steer carcasses selected from each range.

Carcasses were railed off to the re-grade bay and the pelvises from the respective carcasses were identified. All twenty five carcasses entered commercial production, and were split into round and sirloin primals. After fabrication of boneless round and sirloin cuts, the two pieces of the pelvis were obtained - the hip portion from the sirloin and the aitch portion from the round. These counterparts were then transported to Loeffel Meat Laboratory at the University of Nebraska-Lincoln for measurement and analysis.

Prior to evaluation, both the hip and aitch bone pieces had additional connective tissue and lean removed. All hip and aitch bone pieces were weighed (kg) and measured to determine the three-dimensional shape of the pelvis. Measurements were defined (Table 1) prior to data collection with intentions to capture the true dimensional shape of the pelvis (Figure 1). In measurement definitions, aitch bone refers to the cut surface of the pelvic SP, a result from splitting of the carcass. The ball of the aitch bone is a circular extremity on the cranial end. All hip and aitch bone dimensions were measured using a cloth measuring tape (cm). Anatomical terms to describe measurement locations were assumed similar to those in a beef carcass hanging from the Achilles tendon.
Photographs were taken of both the hip and aitch bone pieces from various angles to further illustrate the variation in pelvic shape. The aitch bone piece of the pelvis was cut into 6 mm cross-sectional slices parallel and perpendicular to the medial face of the SP. Pictures of the aitch bone slices can be found in Figure 2 and Figure 3 respectively.

Weights of both the hip and aitch bone portion, as well as all of the dimensional measurements were analyzed independently using the PROC GLM procedure of SAS (SAS 2002-2008, Version 9.2. Cary, NC). CONTRAST statements were used to test for significance (P < 0.05) between sex, weight, and weight*sex interactions.

**Results & Discussion**

Weight of the hip bone, or ilium portion of the pelvis increased (P < 0.05) linearly with increasing carcass weight (Table 2). Similar results were reported for the aitch bone weights (P < 0.05), and thus resulted in increased total pelvic weight with increasing carcass weight (total pelvic weight = 2.37, 2.59, 2.73, 3.01, and 2.86 kg, respectively; P < 0.05) ; visible in Figures 4-6.

Between heifers and steers there were no differences for Aitch bone depth (cm), aitch bone angle (˚), symphysis pubis circumference (cm), hook width (cm), pin width (cm), pelvic depth 1 (cm), and pelvic depth 2 (cm), linear measurements. Longer aitch bone length (P < 0.05) was observed in steers when compared to heifers (15.8 and 14.9 cm, respectively). In addition, an increase in pelvic length (P < 0.05) was observed in steers when compared to heifers (39.2 and 36.2 cm).

Linear measurements: Aitch bone length (cm), aitch bone depth (cm, aitch bone angle (˚), symphysis pubis circumference (cm), hook width (cm), pin width (cm), pelvic depth 1 (cm), pelvic depth 2 (cm), pelvic length (cm), did not vary due to changes in total carcass weight.

Once all linear measurements had been recorded and analyzed, select aitch bone pieces were subject to further analysis. Pelvises that exhibited extreme shape and size variation were
sliced into 6 mm slices using a band saw (Biro Model No. 3334, The Biro, MFG. Co. Marblehead, OH). Pelvises were sliced either perpendicular or parallel to the face of the aitch bone. Perpendicular slices exhibited changes in the width of the aitch bone portion, and changes in width due to accuracy of carcass splitting. Similarly, slices parallel to the aitch bone face allowed an analysis of changes in the shape of the aitch bone (curved vs. planar), and shape of the aitch bone ball (circular vs. oblong) due to accuracy during carcass splitting.

Photographs were taken of both the hip and aitch bone pieces from various angles to further illustrate the variation in pelvic shape. From representative photography of 6 mm medial to lateral, or parallel, slices it appears the size of the ball of the aitch bone and shape (angle) of the aitch bone was influenced by the accuracy of how the carcass was split. As the cut progressed laterally from the true pelvic midline, the shape of the ball became distorted changing from circular to oblong in nature. Similarly the angle of the aitch bone increased, becoming more planar and less acute.

As carcass weight increased, aitch bone, hip bone, and total pelvic bone weight increased. Differences in length of the aitch and pelvic bone exist between heifer and steer carcasses. These data suggest that aitch bone shape is influenced by accuracy of carcass split and that gender differences are reflected in the pelvic bone characteristics. Due to great variation in the shape of the aitch bone, it is not feasible to use the ball of the aitch bone as a suitable anatomical landmark for alternative carcass fabrication.
Table 1: Definitions for anatomical locations of linear measurements evaluated.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Bone Utilized</th>
<th>Measurement Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip Bone Weight</td>
<td>Hip Bone</td>
<td>Weight of trimmed hip bone.</td>
</tr>
<tr>
<td>Aitch Bone Weight</td>
<td>Aitch Bone</td>
<td>Weight of trimmed aitch bone.</td>
</tr>
<tr>
<td>Total Pelvic Bone Weight</td>
<td>Both</td>
<td>Weight of trimmed hip and aitch bone pieces.</td>
</tr>
<tr>
<td>Aitch Bone Length</td>
<td>Aitch Bone</td>
<td>Measured on the Symphysis pubis surface from the top of the ball to the lower point on the ischium side.</td>
</tr>
<tr>
<td>Aitch Bone Depth</td>
<td>Aitch Bone</td>
<td>Measured as the distance from the furthest point on the aitch bone to a location perpendicular to the Aitch Bone Length measurement (cartilage was included in the measurement).</td>
</tr>
<tr>
<td>Aitch Bone Angle</td>
<td>Aitch Bone</td>
<td>Calculated as the hypothetical angle utilizing the Aitch Bone Length and Depth measurements. Calculated using the Pythagorean theorem.</td>
</tr>
<tr>
<td>Symphysis Pubis C.</td>
<td>Aitch Bone</td>
<td>Measured as the distance around the aitch bone at its most narrow point.</td>
</tr>
<tr>
<td>Hook Width</td>
<td>Both</td>
<td>After affixing the hip and aitch bone pieces together, the exposed aitch bone surface was placed on a flat surface. Then the distance from the flat surface to the lateral point of the ilium was measured. This number was then multiplied by two.</td>
</tr>
<tr>
<td>Pin Width</td>
<td>Both</td>
<td>After affixing the hip and aitch bone pieces together, the exposed aitch bone surface was placed on a flat surface. Then the distance from the flat surface to the lateral point of the ischium was measured. This number was then multiplied by two.</td>
</tr>
<tr>
<td>Pelvic Depth 1</td>
<td>Both</td>
<td>The distance from the top of the ball of the aitch bone to the center of the 4th sacral vertebrae.</td>
</tr>
<tr>
<td>Pelvic Depth 2</td>
<td>Both</td>
<td>The distance from the ischium-end of the aitch bone to the center of the 4th sacral vertebrae.</td>
</tr>
<tr>
<td>Pelvic Length</td>
<td>Both</td>
<td>The distance from the center of the distal edge of the ischium to the center of the caudal edge of the ilium.</td>
</tr>
</tbody>
</table>
Table 2: Least square means of linear pelvic bone measurements according to carcass weight and sex.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Carcass Weight, kg</th>
<th>Carcass Sex</th>
<th>P-Values</th>
<th>Weight x Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>272-318</td>
<td>319-363</td>
<td>364-408</td>
<td>409-454</td>
</tr>
<tr>
<td>Hip Bone Weight (kg)</td>
<td>1.70</td>
<td>1.83</td>
<td>1.95</td>
<td>2.14</td>
</tr>
<tr>
<td>Aitch Bone Weight (kg)</td>
<td>0.66</td>
<td>0.76</td>
<td>0.78</td>
<td>0.87</td>
</tr>
<tr>
<td>Total Weight (kg)</td>
<td>2.37</td>
<td>2.59</td>
<td>2.73</td>
<td>3.01</td>
</tr>
<tr>
<td>Aitch Bone Length (cm)</td>
<td>15.53</td>
<td>14.71</td>
<td>15.52</td>
<td>14.68</td>
</tr>
<tr>
<td>Aitch Bone Depth (cm)</td>
<td>5.35</td>
<td>5.29</td>
<td>5.13</td>
<td>4.74</td>
</tr>
<tr>
<td>Aitch Bone Angle (˚)</td>
<td>108.95</td>
<td>106.83</td>
<td>110.90</td>
<td>111.56</td>
</tr>
<tr>
<td>S. pubis circumference (cm)</td>
<td>5.60</td>
<td>6.23</td>
<td>6.38</td>
<td>5.70</td>
</tr>
<tr>
<td>Hook Width (cm)</td>
<td>19.08</td>
<td>20.38</td>
<td>19.95</td>
<td>20.34</td>
</tr>
<tr>
<td>Pin Width (cm)</td>
<td>7.60</td>
<td>8.22</td>
<td>7.98</td>
<td>8.41</td>
</tr>
<tr>
<td>Pelvic Depth 1 (cm)</td>
<td>22.40</td>
<td>22.98</td>
<td>23.2</td>
<td>23.39</td>
</tr>
<tr>
<td>Pelvic Depth 2 (cm)</td>
<td>24.73</td>
<td>26.07</td>
<td>25.38</td>
<td>24.95</td>
</tr>
<tr>
<td>Pelvic Length (cm)</td>
<td>37.55</td>
<td>36.23</td>
<td>36.93</td>
<td>36.43</td>
</tr>
</tbody>
</table>
Figure 1: Location of anatomical measurements collected.

Linear measurements: A, aitch bone length; B, aitch bone depth; C, aitch bone angle; D, symphysis pubis circumference. Measurements (cm) obtained using a cloth measuring tape.

Linear measurements: E, pelvic depth 1; F, pelvic depth 2; G, pelvic length. Measurements (cm) obtained using a cloth measuring tape.
Figure 2: Differences in shape of aitch bone ball and angle of aitch bone from aitch bone pieces sliced parallel to the face of the aitch bone.
Figure 3: Differences in width of aitch bone pieces sliced perpendicular to the face of the aitch bone.
Figure 4: Change in hip bone weight with increasing carcass weight ($P = 0.04$).
Figure 5: Change in aitch bone weight with increasing carcass weight ($P = 0.05$).
Figure 6: Change in total pelvic bone weight with increasing carcass weight ($P = 0.03$).
Literature Cited


MANUSCRIPT 2

Variation in composition and sensory properties of beef short ribs$^{1,2}$

J.J. Hosch, C.R. Calkins, K.A. Varnold, L.S. Senaratne-Lenagala, M.E. Semler, M.D. Chao

Department of Animal Science, University of Nebraska-Lincoln, Lincoln 68583-0908

$^1$A contribution to the University of Nebraska Agricultural Research Division, Lincoln, NE 68583.

$^2$Correspondence: A213 Animal Science: Telephone: 402.472.6314; Fax: 402.472.6362.
Email address: ccalkins1@unl.edu (Chris R Calkins, PhD)
ABSTRACT

To determine the effects of modifying the chuck/rib break on beef short rib offerings, a sensory evaluation and yield determinations were conducted. Short rib subprimals (n=20) were collected from both the left and right sides of Choice, YG 3 carcasses. Chuck short ribs (ribs 2-5) and rib short ribs (ribs 6-12) were collected and vacuum packaged. Short ribs from the left side were weighed whole (kg) and each rib (ribs 2-12) was individually cut and boned. Bone, lean, and fat from each rib were weighed (g). Short ribs from the right side were aged for 21d post mortem at 2°C. Short ribs were sliced cranial to caudal into 6 mm slices. Ribs were separated by cutting between ribs equidistant to each adjacent rib and product was vacuum packaged and frozen at -20°C. Within 24 hrs of taste panel preparation slices were placed in a 4°C cooler to thaw. Individual short rib slices were cooked on electric skillets at 204°C for 45 s per side, and were transferred to a second skillet at 149°C for 4 min per side. Panelists rated short ribs slices on 8-point scales for tenderness, juiciness, and off-flavor intensity. Ribs 9-12 had the largest percentage of separable fat per rib (over 35%) and thus lower percentage lean (P<0.01). Ribs 5-7 were similar and intermediate in percent lean at roughly 50% (P<0.01). Ribs 5-8 contained a greater percentage of bone, with ribs 2-4, 6, 11, and 12 having less than 20% bone per rib (P<0.0001). Ribs 2-4, and 6-9 were similar in tenderness and were rated the most tender among samples (P < 0.0001). Rib 5 was similar to ribs 9 and 10 for tenderness, and ribs 11 and 12 were rated least tender among samples (P < 0.0001). Ribs 6-8 were rated highest for juiciness, and ribs 5 and 11 were rated least juicy (P<0.0001). There were no differences in off-flavor intensity among samples (P = 0.53). Given the similarities in tenderness and yields, a modification to the chuck/rib primal break would have minimal effects on short rib offering available.
Key words: chuck, beef, rib, short ribs
Introduction

Short ribs hold a large portion of international market demand for beef; particularly in Asian countries. In 2011 exports to Asian countries totaled 336,654 metric tons; 44% of total beef exports in 2011 (USMEF, 2012). Short rib offerings include: Chuck (IMPS #130; NAMP, 2007), Rib (IMPS #123; NAMP, 2007), and Plate (IMPS #123; NAMP, 2007) beef short ribs. There are two primary locations where short rib offerings are derived: ribs 2-5 (chuck short ribs) and ribs 6-8 (beef short ribs). Ribs 9-12, although still a portion of the rib primal are commonly processed to beef rib, rib fingers (IMPS #124A; NAMP, 2007).

The *Serratus ventralis* (SV) is a large, fan-shaped muscle lying from the dorsal region just over the ribs ventral toward the sternum or brisket (NCBA, 2000). According to Johnson et al. (1988) it is the largest muscle in the beef forequarter accounting for 19.1% of total forequarter weight. Aside from being fabricated into Denver steaks, the SV is a large component of chuck and rib short ribs, particularly ribs 2-8. In a consumer based study the SV was rated as being similar ($P < 0.05$) to the *Longissimus thoracis* for overall acceptance, tenderness, juiciness, flavor and price (Kukowski et al., 2004).

Due to its limited function as a motility muscle, the SV has been classified as one of the most tender muscles in the beef forequarter (Johnson et al., 1988, Kukowski et al., 2004; Von Seggern et al., 2005). When assessing Warner-Bratzler Shear Force (WBS) of SV steaks differences ($P < 0.001$) in tenderness values existed, but no consistent tenderness pattern was realized (Searls et al., 2005). This variation in tenderness could be a result of the physical construction of the muscle as a whole and explain why moist cookery is utilized when preparing short ribs.
Ribs 9-12 are commonly marketed as rib finger meat. This study compared the potential value of these ribs as an alternate to beef short ribs. In a sensory evaluation by Searls et al. (2005) the ventral side of the SV was more tender (P < 0.05) than that of the dorsal side. It was also noted that the ventral portion of ribs 9-12 has a greater presence of lean (Von Seggern et al., 2005).

With the available technology to remove the thoracic limb prior to chuck/rib separation, alterations to these traditional primals are accessible. By altering the location of the chuck/rib primal break, novel short rib offerings could be created, and perhaps the addition of ribs 9-12 to current short rib offerings.

**Materials & Methods**

Twenty short rib subprimals were identified on both the left and right side of Choice, YG 3 carcasses weighing between 364 and 386 kg. The selected carcasses were numbered and carcass side was identified. Numbers were inscribed on the medial (bone) side of the short ribs in location respective to Beef Chuck, Short Ribs (IMPS #130; NAMP, 2007) and Beef Short Ribs (IMPS #123; NAMP, 2007). Ultimately ribs 2-12 were identified for collection.

The carcasses then entered commercial production, and the chuck and rib were separated at the fifth/sixth rib junction. Chuck short ribs (ribs 2-5) were removed from the chuck and rib short ribs (ribs 6-12) from the rib primal. It was determined that chuck and beef short ribs from the right side of the carcass would be utilized in evaluating product yield. Subsequently, chuck and beef short ribs from the left side would be consumed in a sensory panel, and were aged for 21d post mortem at 2˚C prior to being fabricated.
**Short Rib Yield Fabrication**

Prior to fabrication, the chuck and rib short rib subprimals were weighed whole (kg). Distances of width, length, and depth were measured (cm) using a cloth measuring tape lying flush against the meat surface.

Following measurement analysis, each rib was individually cut from its subsequent subprimal. Ribs were separated with a dorsal to ventral cut, dividing the lean in half between ribs. Each rib was boned, and the associated lean was separated from subcutaneous and intermuscular fat. Bone, lean, and fat from each rib were weighed (g).

**Short Rib Taste Panel Fabrication**

Prior to fabrication, the chuck (ribs 2-5) and beef short ribs (ribs 6-12) were weighed whole (kg) and sliced anterior to posterior into 6 mm slices using a band saw. After being identified, each rib was separated from its subsequent counterpart by dividing the lean between ribs in half. The rib slices from each rib were vacuum packaged separately and frozen at -20°C.

**Short Rib Taste Panel Preparation**

Sample size for taste panel evaluation was a 6mm thick slice containing one rib bone and its associated lean including: *Serratus ventralis, Intercostales interni*, and *Intercostales externi*. Within 24 hrs prior to taste panel preparation, rib slices were placed in a 4°C cooler to thaw. When selecting samples for sensory panel evaluation, slices with a greater portion of available lean were preferred. Thus rib slices 2-4 were selected from the dorsal edge of the chuck subprimal, and rib slices 5-12 were selected from the ventral edge.
Individual short rib slices cooked on a Rival 11” Square Electric Skillet (Rival Products, Model No. S11, 120V ~ 60 HZ, 1200 W. Boca Raton, FL) at 204˚C for 45 s per side. Short rib pieces were then transferred to a second frying pan at 149˚C for 4 minutes time per side. Cooked short rib slices were kept in a preheated countertop warmer at the 3.5 temperature level no longer than 15 minutes prior to serving.

For sensory analysis, ribs 2-12 were served to a trained taste panel of five to distinguish organoleptic differences between rib locations. Ratings for organoleptic properties were based on an 8-point hedonic scale for tenderness (1 = extremely tough – 8 = extremely tender), juiciness (1 = extremely dry – 8 = extremely juicy), and off flavor intensity (1 = extremely mild – 8 = extremely intense).

Panelists were allocated to individual booths lighted with red fluorescent lights to minimize visual differences between slices. Panelists utilized Compusense Five (Compusense Inc., Release 2.2, Guelph, ON Canada) on individual laptop computers to enter their ratings and additional comments for each sample served. An exhaust fan was used to create negative air pressure and remove odors from the taste panel room. Six samples were served during morning sessions and five samples were provided during afternoon sessions. With this serving order, all ribs from one animal were served in a single day.

Statistical Analysis

Short rib yield data were analyzed independently using ANOVA in PROC GLM in SAS (SAS 2009, Version 9.2. Cary, NC) as completely randomized designs. Rib number and animal were considered as main and random effects, respectively. Separation of means was carried out using LSMEANS with LINES options in SAS at $P \leq 0.05$. 
Sensory data (Tenderness, juiciness, and off-flavor intensity) on short ribs were analyzed independently using ANOVA in PROC GLIMMIX in SAS (SAS 2009, Version 9.2, Cary, NC) as completely randomized designs. Rib number as the main effect, and the animal and panelist as random effects were considered. Separation of means was carried out using LSMEANS with DIFF and LINES options in SAS at $P \leq 0.05$.

**Results & Discussion**

Panelist rated short ribs slices on 8-point scales for tenderness, juiciness, and off-flavor intensity. In taste panel ratings, ribs 2-4, and 6-9 were similar in tenderness and were rated the most tender ($P < 0.0001$) among samples (Table 1). Rib 5 was less tender than ribs 2-8 and similar to ribs 9 and 10 for tenderness. Ribs 11 and 12 were rated least tender among samples ($P < 0.0001$). This divergence in perceived tenderness between ribs four and five is likely a result of slice location; dorsal versus ventral, respectively.

In a study by Johnson et al. (1988) the SV was reported to be one of the more tender muscles from the chuck when evaluated using WBS. Tenderness mapping of the SV resulted in sporadic WBS results ranging from 3.2 to 4.4 kg, with a tendency for posterior steaks to be more tender (Grimes et al., 2008). The SV was also assessed with WBS by Searls et al. (2005) resulting in a mean shear force value of 4.37 kg with a SD of 1.27 kg. According tenderness classifications: very tender ($WBS < 3.2$ kg), tender ($3.2 < WBS < 3.9$ kg), intermediate ($3.9 < WBS < 4.6$ kg), and tough ($WBS > 4.6$ kg), as defined by Belew et al. (2003), the SV would rate as intermediate in tenderness.

Ribs 6-8 were rated highest for juiciness, and ribs 5 and 11 were rated least juicy ($P<0.0001$). There were no differences in off-flavor intensity among samples ($P = 0.53$).
Intercostal muscles between ribs 9-12 are commonly marketed as rib finger meat. This study evaluated usefulness of these ribs as short ribs. Ribs 9-12 had the largest percentage of separable fat per rib (over 35%) and thus lower percentage lean (P<0.0001). In a study by Wulf et al. (1994), the 9th rib location had the least amount of external fat and greatest amount of seam fat with inverse amounts moving both anterior and posterior. Ribs 5-7 were similar and intermediate in percent lean at roughly 50% (P<0.0001). Ribs 5-8 contained a greater percentage of bone, with ribs 2-4, 6, 11, and 12 having less than 20% bone per rib (P<0.0001) (Figure 1).

Given that the ventral portion of ribs 9-12 have a greater presence of lean than the dorsal half, only the ventral half of ribs 9-12 were assessed in both the yield and sensory evaluations. Each individual rib was traced to explore the compositional differences among ribs (Figures 2, 3, and 4). There is considerable variation in lean to fat ratio from the dorsal to ventral areas of the ribs. Toward the anterior end of the carcass (ribs 2-4) the dorsal region is very low in lean while the ventral edge is high in lean content. For the rest of the ribs, the more dorsal area yielded more visible lean. The visible lean at the ventral edge is high and relatively consistent for ribs 2-6 and then begins to diminish toward the more posterior ribs. This pattern approximates the distribution of lean dissected from the individual rib section (Figure 1).

Given the similarities composition and few differences in tenderness it appears chuck short ribs could be sold at a value similar to that of rib short ribs. More importantly, the addition of chuck short ribs to the rib short rib primal would add value to that primal while maintaining similar acceptability in consumer ratings and yield properties.
Table 1: Sensory attribute results for short rib slices 2 – 12.

<table>
<thead>
<tr>
<th>Rib (^2)</th>
<th>Tenderness</th>
<th>Juiciness</th>
<th>Off-flavor Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>5.07(^{abc})</td>
<td>4.76(^{bcd})</td>
<td>2.47</td>
</tr>
<tr>
<td>3</td>
<td>5.11(^{abc})</td>
<td>4.89(^{bcd})</td>
<td>2.27</td>
</tr>
<tr>
<td>4</td>
<td>5.21(^{ab})</td>
<td>4.72(^{cd})</td>
<td>2.21</td>
</tr>
<tr>
<td>5</td>
<td>4.72(^{d})</td>
<td>4.05(^{f})</td>
<td>2.36</td>
</tr>
<tr>
<td>6</td>
<td>5.40(^{a})</td>
<td>5.29(^{a})</td>
<td>2.63</td>
</tr>
<tr>
<td>7</td>
<td>5.28(^{ab})</td>
<td>5.08(^{ab})</td>
<td>2.46</td>
</tr>
<tr>
<td>8</td>
<td>5.32(^{ab})</td>
<td>5.01(^{abc})</td>
<td>2.44</td>
</tr>
<tr>
<td>9</td>
<td>5.02(^{bcd})</td>
<td>4.81(^{bcd})</td>
<td>2.12</td>
</tr>
<tr>
<td>10</td>
<td>4.81(^{de})</td>
<td>4.61(^{de})</td>
<td>2.52</td>
</tr>
<tr>
<td>11</td>
<td>4.31(^{c})</td>
<td>4.30(^{ef})</td>
<td>2.47</td>
</tr>
<tr>
<td>12</td>
<td>4.29(^{f})</td>
<td>4.72(^{cd})</td>
<td>2.38</td>
</tr>
<tr>
<td>Pooled</td>
<td>0.818</td>
<td>0.781</td>
<td>0.683</td>
</tr>
<tr>
<td>SEM</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{a, b, c, d, e, f, l}\) Means in the same row having different superscripts are significant at \(P < 0.05\).

\(^1\) Sensory attributes rated by trained taste panel sessions on 8-point scales: tenderness (1 = extremely tough – 8 = extremely tender), juiciness (1 = extremely dry – 8 = extremely juicy), and off flavor intensity (1 = extremely mild – 8 = extremely intense).

\(^2\) Ribs respective to animal rib location. Ribs 9V, 10V, 11V, and 12V were collected from the ventral half of ribs 9-12.
Figure 1: Least square means for individual short rib tissue composition by percentage.

Means in the same row having different superscripts are significant at $P < 0.05$.

1 Individual ribs separated with a dorsal to ventral cut. Bone, lean, and fat from each rib were weighed (g) and used to calculate a percent of total rib weight.

2 Ribs respective to animal rib location. Ribs 9V, 10V, 11V, and 12V were collected from the ventral half of ribs 9-12

3 SEM for tissue composition: Fat:15.97; Bone: 5.32; Lean: 14.70.
Figure 2: Cross sectional tracing of ribs two through four on the short rib primals dorsal edge, middle, and ventral edge.

Dorsal Slice

Middle Slice

Ventral Slice

- Bone
- Fat
- Lean
Figure 3: Cross sectional tracing of ribs five through eight on the short rib primals dorsal edge, middle, and ventral edge.
Figure 4: Cross sectional tracing of ribs nine through twelve on the short rib primals dorsal edge, middle, and ventral edge.
Literature Cited


An evaluation of the quality and yield of a 2-rib or 3-rib subprimal

J.J. Hosch, C.R. Calkins, K.A. Varnold, L.S. Senaratne-Lenagala, M.E. Semler, M.D. Chao

Department of Animal Science, University of Nebraska-Lincoln, Lincoln 68583-0908

1A contribution to the University of Nebraska Agricultural Research Division, Lincoln, NE 68583.
1Correspondence: A213 Animal Science: Telephone: 402.472.6314; Fax: 402.472.6362. Email address: ccalkins1@unl.edu (Chris R Calkins, PhD)
ABSTRACT

Forequarter breaks at the third/fourth and fifth/sixth rib junctions were evaluated to create a new chuck subprimal comprised of the cranial rib of the ribeye roll and one or two caudal ribs of the chuck roll. Twelve Choice, YG 3 beef carcasses weighing between 364 and 386 kg were selected for evaluation. In both alternative fabrication methods, the rib primal was fabricated with a division at the sixth/seventh rib junction, making a 3-rib chuck subprimal (third/fourth rib division) containing ribs 4-6, or a 2-rib chuck subprimal (fourth/fifth rib division) containing ribs five and six. These chuck subprimals from both alternative fabrication methods were collected and further processed into single muscle cuts. Bone, lean trim, fat, and all muscles were weighed from each subprimal. A Warner-Bratzler Shear Force (WBS) assessment was conducted on Longissimus dorsi (LD) steaks from both fabrication methods. Three steaks (2.54 cm) were cut from the 3-rib subprimal (anterior, middle and posterior) and two steaks (2.54 cm) were cut from 2-rib subprimal (anterior and posterior); both perpendicular to muscle orientation. The 3-rib subprimal weighed 1.5 kg more than the 2-rib subprimal, yet both subprimals had greater than 60% lean yield. There were no differences in WBS among steaks from 2-rib or 3-rib subprimals ($P=0.49, 0.39$, respectively). All LD steaks from both subprimals had shear force values $<3.7$, associating them as tender product (WBS $<3.9$ kg); steaks from the anterior end had a tendency for lower WBS values. Given this alternative forequarter subprimal could offer a quality, consistently tender, and steakable product to consumers as opposed to offering a chuck roast.

Key words: beef, chuck, rib subprimal
Introduction

The beef forequarter accounts for approximately 52% of total carcass side weight. Marketability of cuts from the forequarter, primarily within the chuck primal, have been suppressed due to high variability of cut-out yields and muscle palatability characteristics (Johnson et al., 1988). Numerous muscle profiling studies have focused on muscles in the forequarter (Ramsbottom and Strandine, 1948; Choi et al. 1987; Johnson et al., 1988; Von Seggern et al., 2005). In work by Johnson et al. (1988) the *Longissimus dorsi* (LD) was considered one of the most tender muscles in the beef forequarter, suggesting whole muscle fabrication of this muscle.

The separation of the chuck and rib between the fifth and sixth ribs is somewhat arbitrary and bound by tradition. Today with the technology to remove the thoracic limb prior to chuck/rib separation, this primal break no longer necessitates to remain. In a study by Reuter et al. (2002) there were no significant \( P < 0.05 \) differences in Warner Bratzler shear force (WBS) among rib locations four through six, suggesting the chuck/rib break could be moved cranially.

It is important to recognize steaks from the sixth rib location are currently marketed as ribeye steaks. In a study by Pfieffer et al. (2005), a ribeye roll produced by a fourth/fifth rib break was more \( P < 0.001 \) valuable; a result of higher saleable yield, and forequarter values compared to traditional fabrication methods. By moving the chuck/rib break anterior to the fourth/fifth rib junction, four additional 2.5 cm ribeye steaks would be included on the ribeye roll.

Due to similarities in tenderness among steaks from the LD, consideration should be given to move the chuck/rib break anterior to augment the availability of tender LD
steaks. This could be achieved by extending the length of the ribeye roll, or more importantly developing a 2-rib or 3-rib subprimal analogous in muscle composition.

**Materials & Methods**

*Subprimal Collection*

Twelve Choice, YG 3 beef carcasses weighing between 364 and 386 kg were evaluated for alternative forequarter fabrication methods. In both cases the rib primal started at the seventh rib.

Two alternative forequarter fabrication methods were evaluated based on the location of the chuck/rib break. Method A resulted in a 3-rib subprimal: a division between ribs three and four. Method B resulted in a 2 rib subprimal: a division between ribs four and five. Six right sides were fabricated as Method A and six right sides as Method B. All fabrication occurred while the carcass was suspended from an “S” hook through the 12th rib.

Irregardless of break location, fabrication commenced with the removal of the *Latissimus dorsi* (lifter meat) exposing the cartilaginous tip of the scapula. The thoracic limb was removed from the forequarter. The chuck/rib break location (third/fourth or fourth/fifth) was then identified respective to treatment. A band saw was utilized to cut the thoracic vertebrae; and the brisket primal was removed. The chine bone was removed from the ribeye subprimal using a band saw and feather bones on the dorsal side of the subprimal were removed. A division was then created using a knife, corresponding to treatment, between ribs to create a respective 2-rib or 3-rib subprimal. In both treatments the knife cut was flush to the caudal rib at the end of the alternative subprimal.
The 2-rib and 3-rib subprimals were then vacuum packaged and transported to the University of Nebraska-Lincoln Loeffel Meat Laboratory under refrigeration. Both 2-rib and 3-rib subprimals were aged at 2°C for 21 days.

2-rib and 3-rib Subprimal Fabrication

All 2-rib and 3-rib subprimals were removed from packaging and weighed (kg). The length and width of the subprimals were measured for both fabrication styles using a measuring tape. Both the 2-rib and 3-rib subprimals were fabricated similarly to obtain individual muscles. Exterior fat was first removed. Using a knife to follow the natural curvature of the ribs, the back ribs were removed. Each muscle was excised from the subprimal and labeled with tags keeping muscle orientation apparent: cranial and caudal ends. Weights for the following components were collected (g): *Longissimus dorsi* (LD), *Longissimus costarum*, *Complexus*, *Spinalis/Multifidus dorsi* (MD), *Serratus ventralis*, *Intercostales interni*, ligamentum nuchae, backribs, fat, connective tissue, and lean trim. The *Longissimus dorsi*, *Longissimus costarum*, and *Complexus* were packaged, vacuum sealed, and frozen at -20°C.

Subprimal WBS Evaluation

To objectively test variation in tenderness of both subprimals, steaks (2.54 cm) from the LD were prepared for WBS assessment. The LD was selected as a result of its significant size and shape when compared to all other encompassed muscles.

All LD muscles from Method A and Method B fabrication were placed in a 4°C cooler to thaw for 24 hrs. Once thawed, three LD steaks were cut from Method A and two LD steaks were cut from Method B, both perpendicular to muscle fiber orientation. Method A steaks were obtained from anterior, medial and posterior locations within the
muscle, whereas Method B only had an anterior and posterior steak. Anterior steaks were fabricated first and consisted of the most cranial 2.54 cm of the LD. The posterior steaks were then cut as the most caudal 2.54 cm. Medial steaks from Method A were taken from the middle 2.54 cm of the remaining LD. Steaks were identified according to location and pre-cook weights and temperatures were recorded.

Steaks were cooked on a Hamilton Beach Indoor- Outdoor Grill (Model 31605A, Proctor-Silex Inc., Washington, NC) to an internal temperature of 71 °C. A Type T, copper constant, Precision Fine Wire Thermocouple (OMEGA Engineering, Inc., Stamford, CT) was inserted into the geometric center of every LD steak. Internal temperature was monitored using an OMEGA 450 ATT thermometer with a type T thermocouple (OMEGA Engineering, Inc., Stamford, CT). Cooked steak weight was recorded to determine cooking loss. Cooked steaks were placed on a plastic tray and overwrapped with oxygen permeable film. Steaks were stored at 4°C for 24 hrs prior to being sheared.

Cooked steaks were retrieved from the cooler and had cores prepared. Due to size, four 1.3 cm cores were retrieved from anterior Method A steaks, whereas all other steaks from both Method A and B had six cores each. These cores were sheared using a tabletop WBS machine following AMSA guidelines (AMSA, 1995). Results were recorded for each core sheared.

**Statistical Analysis**

Yield measurements were analyzed independently using LS Means in PROC GLIMMIX in SAS (SAS 2009, Version 9.2. Cary, NC) as completely randomized designs. A significance value of $P \leq 0.05$ was utilized.
The WBS results were also analyzed, according to steak location, using PROC GLIMMIX in SAS (SAS 2009, Version 9.2. Cary, NC), as a completely randomized designs. Cutting style and animal were considered as main and random effects, respectively. Separation of means was carried out using LSMEANS at $P \leq 0.05$.

**Results & Discussion**

The 3-rib subprimal had an added 1.5 kg of total subprimal weight when compared to that of the 2-rib subprimal. However, both alternative rib subprimals had lean yield values greater than 60% (Figure 1 and 2). In a study by Reuter et al. (2002), steak weights tended to increase from 2nd rib steak through the 10th rib steak.

The *Longissimus dorsi*, *Spinalis dorsi*, and *Complexus* comprised the largest proportion of muscles present in both subprimals; muscles present in ribeye steaks closer to the cranial end. In a consumer preference study, ribeye steaks from ribs 6 and 7 spent longer time in the retail case and resulted in a greater amount of pulls when compared to steaks from ribs 8-12 (Sweeter et al., 2005). Similarly, in a study by Pfieffer et al. (2005), consumers exhibited a visual preference ($P<0.05$) for steaks from the posterior rib end (5-12) as opposed to steaks from the anterior end (2-4). These results were attributed to the increased number of muscles present in ribeye steaks from these locations. Providing a subprimal that is similar in visual appearance to ribeye steaks, specifically the number of muscles present, has potential value for the industry.

There were no differences (Table 1) in WBS among steaks from 2-rib or 3-rib subprimals (P=0.59, 0.39, respectively). The WBS results also did not vary between fabrication methods (2-rib vs 3-rib). When considering tenderness in cranial LD steaks varied results exist in the literature. Although fabricated and sold as steaks, the LD and
MD were somewhat less tender at the anterior ends of the muscles compared to the posterior end of the muscles (Ramsbottom, 1944; Reuter et al., 2002; Sullivan, 2011). However, Johnson et al. (1988) found LD steaks from the chuck primal as the most tender muscle from the beef forequarter, similar to WBS results from Paterson and Parrish (1986).

Although steaks from ribs four through six had higher weighted-average shear force values when compared to all other ribs, animal-to-animal variation was 36% greater than rib-to-rib variation in WBS (Reuter et al., 2002). All LD steaks from the 2-rib and 3-rib subprimals had WBS values less than 3.7 kg. Tenderness classifications have been recommended for application in the industry: very tender (WBS < 3.2 kg), tender (3.2 < WBS < 3.9 kg), intermediate (3.9 < WBS < 4.6 kg), and tough (WBS > 4.6 kg) (Belew et al., 2003). Providing a product that is consistently tender from ribs 3 through 6 provides additional quality to offering a 2-rib or 3-rib subprimal.

Ultimately the incorporation of 2-rib and 3-rib subprimal offerings can ultimately provide a value-added product for producers, versatility to processors, while providing consistent tenderness for consumers.
Figure 1: Least square means of tissue composition yields from 2-rib subprimal.

Bone & Connective Tissue 23%
Fat Trim 21%
Spinalis/Multifidus Complex 17%
Longissimus dorsi 19%
Complexus 8%
Lean Trim 6%
Intercostales externi 3%
Fat Trim 21%

2-rib (fourth/fifth rib through sixth/seventh rib) subprimal muscles were obtained by single muscle fabrication methods. Percentage calculated on a per weight basis.
Figure 2: Least square means of tissue composition percentages from 3-rib subprimal.

3-rib (third/fourth rib through sixth/seventh rib) subprimal muscles were obtained by single muscle fabrication methods. Percentage calculated on a per weight basis.
Table 1: Warner-Bratzler shear force of *Longissimus dorsi* steaks from 2-rib and 3-rib subprimals

<table>
<thead>
<tr>
<th>Steak Location²</th>
<th>Subprimal Fabrication Style¹</th>
<th>2-rib</th>
<th>3-rib</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td></td>
<td>2.92</td>
<td>3.31</td>
</tr>
<tr>
<td>Middle</td>
<td></td>
<td>.</td>
<td>3.68</td>
</tr>
<tr>
<td>Posterior</td>
<td></td>
<td>2.82</td>
<td>3.60</td>
</tr>
<tr>
<td><em>P</em>-value</td>
<td></td>
<td>0.49</td>
<td>0.39</td>
</tr>
<tr>
<td>SEM</td>
<td></td>
<td>0.19</td>
<td>0.26</td>
</tr>
</tbody>
</table>

¹ Two subprimal fabrication styles were utilized: 2-rib (ribs 5-6) and 3-rib (ribs 4-6). In both cases the rib primal was split at the sixth/seventh rib.

² Steaks (2.54 cm) were cut from the *Longissimus dorsi* at the listed locations. No middle steak was obtained from the 2-rib subprimal.
Literature Cited


MANUSCRIPT 4

An evaluation of the extended sirloin cap coulotte

J.J. Hosch, K.A. Varnold, L.S. Senaratne-Lenagala, M.E. Semler, M.D. Chao, and C.R. Calkins

Department of Animal Science, University of Nebraska-Lincoln, Lincoln 68583-0908

A contribution to the University of Nebraska Agricultural Research Division, Lincoln, NE 68583.
1Correspondence: A213 Animal Science: Telephone: 402.472.6314; Fax: 402.472.6362. Email address: ccalkins1@unl.edu (Chris R Calkins, PhD)
ABSTRACT

Fabrication methods for the beef carcass are based strongly on tradition although muscle properties suggest alternative cutting procedures to add value. To evaluate alternative hindquarter fabrication, the right sides of 30 Low Choice YG 3 beef carcasses weighing 364 to 386 kg were selected. The cranial portion of the Biceps femoris, extended sirloin cap, was removed from the carcass using an imaginary line from the dorsal tip of the aitch bone to the lateral side of the carcass. The extended sirloin cap from each carcass was weighed (kg) whole untrimmed and trimmed, and cap dimensions (cm) were measured. Caps were vacuum packaged and aged for 25 d at 2˚C. Steaks (2.54 cm) were cut perpendicular (n=10) and parallel (n=10) to cap muscle fiber direction. Steaks were identified according to primal location and anatomical orientation was maintained throughout the evaluation. Steaks were vacuum sealed, and frozen at -20˚C. Data were analyzed according to steak location, and steaks were grouped into anatomical regions within the extended sirloin cap. Data were analyzed using PROC GLIMMIX function in SAS. Cranial steaks, regardless of fabrication method, were juicier, more tender, and had less connective tissue when compared to caudal steaks (P < 0.0001). According to steak region steaks from the cranial portion of the cap were rated as most tender (6.48), followed by steaks that lie on the ventral edge of the sirloin cap (P < 0.0001). Steaks from the dorsal side of the cap were rated least tender (5.35 and 4.91, respectively) and had greater concentrations of connective tissue detected (4.75 and 3.79, respectively) than the ventral side. There was an interaction (P = 0.04) apparent in the dorsal-caudal corner of the cap; steaks fabricated in a parallel fashion were less tender (P < 0.0001) when compared to perpendicular steaks. There were no differences in cooking loss or off-flavor
between regions \( (P > 0.05) \). Using the results of this study, an extended sirloin cap could be produced if steaks are cut perpendicular to muscle fiber direction.

Key words: beef, coulotte, sirloin cap
Introduction

Under normal U.S. beef carcass fabrication methods, the point of round-sirloin separation results in a portion of the *Biceps femoris* (BF) remaining on the sirloin. Tenderness mapping of the round (Reuter et al., 2002; Senaratne et al. 2010) has indicated that the two most proximal BF steaks are from the most tender region of the muscle. Warner Bratzler Shear Force (WBS) values have indicated these steaks tender and thus they could potentially be marketed as premium to other round steaks.

Aside from adding value to the round, modifications to the round/sirloin break could include these tender proximal steaks on the sirloin subprimal. The beef sirloin butt is already considered a profitable cut offering portion flexibility and moderately priced beef (NCBA, 2001). Reducing the effects of moving the primal break, the cranial portion of the BF could be excised prior to round/sirloin separation. This could be achieved by following the natural seam of the BF (NCBA, 2001; Reuter et al., 2002).

By removing this portion of the BF steaks could be produced. A result of the bipennate muscle fiber orientation in the BF, thought should be given to steak cutting method utilized. It has been suggested once the cap is separated to cut steaks on the distal end across the grain or perpendicular to muscle fiber direction (Reuter et al., 2002; Senaratne et al., 2010). However, in a study by McKenna (2003), beef round outside round (IMPS #171B) steaks fabricated perpendicular to muscle fibers resulted in decreased yields and increased processing time.

To evaluate the feasibility of an extended sirloin cap, the objectives of this study were to determine the point of round/sirloin separation to produce an extended sirloin
cap, as well as evaluate different steak fabrication styles, both parallel and perpendicular to muscle fiber orientation.

**Materials & Methods**

The right side of USDA Choice, YG 3 beef carcasses weighing 364 to 386 kg were selected and railed off for hindquarter evaluation. An imaginary line was made from the dorsal tip of the aitch bone to the lateral side of the carcass. From this a cut was made parallel to the spinal column, following the natural curvature of the pelvic bone. This cut came forth cranially to the origin of the BF. Again from the lateral landmark, a cut was made at a 45° angle to the long axis of the carcass towards the ventral edge of the BF. The BF was then pulled down until the insertion point of the muscle was visible, and could be removed.

Each extended sirloin cap was weighed (kg) whole both untrimmed and trimmed. Length, width, and height (cm) of the cap was measured. The thirty extended sirloin caps were vacuum packaged and transported to the University of Nebraska-Lincoln Loeffel Meat Laboratory under refrigeration and were aged for 25 d at 2°C prior to steak fabrication.

To analyze the effect of extended sirloin cap removal, the remainder of the BF (bottom round) was removed from ten carcasses. The untrimmed and subsequently trimmed weight of the bottom round was recorded. The length from the cut surface to the ischiatic head was measured to determine anatomical location of the cut.

*Extended Sirloin Cap Fabrication*

To evaluate steak cutting method, and its effect on tenderness in the extended sirloin cap, two steak fabrication styles were utilized: parallel (n=10) and perpendicular
(n=10) to muscle fiber direction (Figure 1). These fabrication styles were conceived after mapping the fiber direction of the extended sirloin cap (Figure 1). All steaks were cut 2.54 cm thick. In both cutting methods a divisional cut was made dorsal to ventral approximately 7.6 cm cranial from the caudal cut surface. This divisional cut was marked by a fat seam on the dorsal side, as well as the end to a slight bulge in the BF.

Steaks fabricated parallel to fiber direction originated from two locations: cranial to the divisional cut (E steaks) and caudal from the divisional cut (D steaks). Typically five steaks were derived from section E, and three steaks from section D. The most caudal steak from location E was labeled as E1, the steak cranial from it was labeled as E2 and so on. The most cranial steak from location D was labeled as D1, the steak caudal from it was labeled D2 and so on.

Steaks fabricated perpendicular to fiber direction came from three locations: A, B, C, again created by two knife cuts ventral to dorsal. During steak location development, fiber direction was imperative. Steaks from location A came from the cranial third of the cap. Steaks from location B came from the middle portion of the cap, and cranial to the divisional cut. Steaks from the C location were from the caudal third of the cap, and caudal to the divisional cut. Within each of these three locations steaks were then cut perpendicular to fiber direction, or via a cranial to caudal cut. Steaks were identified numerically within their location 1-5, starting with 1 on the ventral edge.

Aside from numerical classification, anatomical orientation was identified on steak’s cut from both methods. After steak fabrication, steaks were packaged in nylon-polyethylene vacuum pouched, vacuum sealed, and frozen at -20°C.
**Extended Sirloin Cap Sensory Panel**

Within 24 hrs prior to sensory panel preparation, steaks were placed in a 4°C cooler to thaw. Steaks were cooked on a Hamilton Beach Indoor/Outdoor grills (Model 31605A, Proctor-Silex Inc., Washington, NC) to an internal temperature of 71°C; after being flipped once at 35°C. Internal temperature was monitored using a Type T, copper constant, Precision Fine Wire Thermocouple (OMEGA Engineering, Inc., Stamford, CT). All steaks prepared for sensory panel were weighed before and after grilling to determine cooking loss via the equation: “cooking loss % = ((fresh weight – cooked weight) / fresh weight) x 100”.

Cooked steaks were cut into 1.27 x 1.27 x 1.27 cm individual cubes and kept warm in a preheated countertop warmer at the 4 temperature level (Model TMPT, WELL BLOOMFIELD, LLC, Verdi, NV) for no longer than 15 minutes prior to serving.

The steaks were served to five trained panelists while still warm. Panelists evaluated at most seven samples per session. Serving order was designed so that paired samples were served from the same region of the extended cap (Figure 1), regardless of cutting style. With this serving manner, attributes could be analyzed according to steak location and cutting style. Sensory panels were conducted in a positive-pressure ventilated room with lighting and cubicles designed for objective meat sensory analysis. Each sample was evaluated for tenderness (8 = extremely tender; 1 = extremely tough), juiciness (8 = extremely juicy; 1 = extremely dry), connective tissue (8 = no connective tissue; 1 = abundant amount) and off-flavor (8 = strong off-flavor; 1 = no off-flavor).
Extended Sirloin Cap WBS Evaluation

Steaks from ten extended sirloin caps, five from both steak fabrication method, were placed in a 4°C cooler to thaw for 24 hrs. The steaks respective anatomical orientation was maintained throughout the cooking and shearing process. Steaks were grilled on Hamilton Beach Indoor/Outdoor grills (Model 31605A, Proctor-Silex Inc., Washington, NC) with a Type T, copper constant, Precision Fine Wire Thermocouple (OMEGA Engineering, Inc., Stamford, CT) inserted into the geometric center of every beef steak. Internal temperature was monitored using an OMEGA 450 ATT thermometer with a type T thermocouple (OMEGA Engineering, Inc., Stamford, CT) and steaks were cooked on one side until the center temperature reached 35°C. Steaks were turned over, and removed from the grill when the internal temperature reached 71°C. Steaks were placed on a tray and covered with oxygen-permeable film and placed in a 4°C cooler. Twenty hours later, the cooked steaks were cored into 1.3 cm cores and sheared to determine WBS following AMSA guidelines (AMSA, 1995).

Statistical analysis

Data from WBS was analyzed independently using the PROC GLIMMIX procedure of SAS (Version 9.2, Cary, NC, 2002 – 2008). Data was analyzed one of two ways: by steak location and region within the extended sirloin cap. When analyzing WBS based on steak location, animal was considered the random effect with steak location as the main effect. When data was analyzed according to steak region within the cap animal was considered the random effect with fabrication style (parallel or perpendicular) and region as main effects. Interaction between fabrication style and steak region was also
assessed. Separation of means was carried out using LSMEANS with DIFF and LINES options in SAS at $P \leq 0.05$.

Sensory data (tenderness, juiciness, connective tissue and off-flavor intensity) and cooking loss of extended sirloin cap steaks were analyzed independently using ANOVA in PROC GLIMMIX in SAS as completely randomized designs. Data was analyzed similarly to WBS data, except both animal and panelist were considered random effects.

**Results & Discussion**

Differences existed within extended sirloin caps regardless of cutting style, for tenderness, juiciness, connective tissue, and WBS results. Steaks fabricated parallel to muscle fiber direction were rated more tender ($P < 0.001$) towards the cranial end of the cap (Table 1) when compared to all other parallel steaks. These steaks were also more juicy and had less connective tissue. Steaks locations E (E2 and E1) and D (D1 – D3) that had been fabricated into dorsal and ventral halves had a tendency for steaks on the dorsal side to be less tender and less juicy ($P < 0.001$). Steaks from these dorsal locations also had greater ($P < 0.001$) amounts of connective tissues. There were no differences in off-flavor among steaks fabricated parallel to muscle fiber direction ($P = 0.98$).

Steaks fabricated perpendicular to the grain had more desirable traits towards the cranial portion of the extended cap (Table 2). Steaks from location A were juicier, more tender, and had less connective tissue when compared to steak locations B and C ($P < 0.0001$). Steaks from location B and C were rated similar and intermediate for juiciness. Steaks from location B and C on the dorsal edge of the cap (steaks 4-5) were less tender and had significantly ($P < 0.05$) more connective tissue when compared to steaks from
the ventral side of the cap (steaks 1-3). These results parallel those found when analyzing sensory data based on apparent region within the extended cap.

Steaks fabricated parallel to muscle fiber direction had lower overall WBS values when compared to steaks fabricated perpendicular to muscle fiber direction. Similar to Senaratne et al. (2010) the BF had its lowest WBS values at the origin. Parallel steaks cranial to the divisional cut had lower ($P < 0.05$) WBS values when compared to steaks caudal to the divisional cut. Steaks fabricated perpendicular to muscle fiber direction had similar results: steaks cranial to the divisional cut had lower WBS values than those caudal. Steak C5, the most dorsal and caudal steak had the highest ($P < 0.05$) WBS value (9.64 kg). These results again parallel Senaratne et al. (2002) as intermediate WBS values were reported at the insertion, with highest WBS values in a middle region 7 to 10 cm caudal to the separation point between the sirloin and round.

To evaluate the overall tenderness distribution across the extended sirloin cap, all data were combined and analyzed according to region (Table 3). Steaks from region 1 were rated as most tender (6.48), followed by steaks from regions 2 and 4; those that lie on the ventral edge of the sirloin cap ($P < 0.0001$). Steaks from region 3 and 5 were rated least tender (5.35 and 4.91, respectively) and had greater concentrations of connective tissue detected (4.75 and 3.79, respectively) when compared to the other three regions. Conversely in a study by Reuter et al. (2002) the BF had lower WBS values toward the *Semitendinosus* (dorsal side) than toward the *Vastus lateralis* (ventral side), but no consistent WBS differences from the superficial side to the deep side.

There was an interaction ($P = 0.04$) apparent in region 5; steaks fabricated in a parallel fashion were less tender ($P < 0.0001$) when compared to steaks fabricated
perpendicular to muscle fiber direction. Steaks from all regions became less juicy as movement towards the dorsal and posterior end progressed. There were no differences in off-flavor between regions.

Cooking loss for WBS and sensory panel steaks ranged from 10.9 – 36.8%. There were no differences ($P > 0.05$) between the regions from which the steaks were derived ($P = 0.28$) or the specific steak location ($P = 0.07$).

A slight rotation of the point of separation between the sirloin and round on its midpoint axis would allocate more of the tender portion of the BF to the sirloin, yielding more sirloin steaks (Reuter et al., 2002). After assessing the sensory panel data and WBS a susceptible extended sirloin cap could be excised from the carcass prior to fabrication of the sirloin/round. With lower WBS results and higher sensory panel ratings cranial to the divisional cut, it is recommended to produce a cap from this point forward. To do so, the same anatomical landmarks for extended sirloin cap can be utilized-dorsal tip of the aitch bone to the lateral side of the carcass-but an adjustment of 7.6 cm cranial from that line is recommended. Steaks should be fabricated perpendicular to muscle fiber direction to maintain tenderness in this alternative cut.
Figure 1: Steak fabrication methods for extended sirloin caps.

Top left: Location and designation of steaks fabricated parallel to muscle fiber direction.
Top right: Location and designation of steaks fabricated parallel to muscle fiber direction.
Bottom left: Muscle fiber direction map of extended sirloin cap.
Bottom right: Extended sirloin cap regions were utilized to analyze both WBS and sensory results from 2.54 cm steaks cut perpendicular and parallel to muscle fiber direction. Region 1 steaks: E5, E4, E3, A1, A2, A3, A4, A5; Region 2 steaks: E2A, E1A, B1, B2; Region 3 steaks: E2B, E1B, B3, B4, B5; Region 4 steaks: D1A, D2A, D3A, C1, C2; Region 5 steaks: D1B, D2B, D3B, C3, C4, C5.
Table 1: Sensory attributes and connective tissue of steaks fabricated parallel to muscle fiber direction.

<table>
<thead>
<tr>
<th>Steak</th>
<th>Juiciness</th>
<th>Tenderness</th>
<th>Connective Tissue</th>
<th>Off-flavor</th>
<th>WBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>E5</td>
<td>5.74&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>6.71&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>6.49&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.37</td>
<td>2.83&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>E4</td>
<td>5.89&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.79&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.35&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.24</td>
<td>3.45&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>E3</td>
<td>5.51&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>6.26&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>6.22&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.32</td>
<td>3.29&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>E2A</td>
<td>5.59&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>6.15&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>5.76&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>3.44</td>
<td>3.44&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>E2B</td>
<td>4.71&lt;sup&gt;de&lt;/sup&gt;</td>
<td>5.32&lt;sup&gt;g&lt;/sup&gt;</td>
<td>4.81&lt;sup&gt;de&lt;/sup&gt;</td>
<td>3.20</td>
<td>2.75&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>E1A</td>
<td>5.73&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>6.01&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>5.70&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>3.27</td>
<td>4.83&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>E1B</td>
<td>5.25&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>5.27&lt;sup&gt;e&lt;/sup&gt;</td>
<td>4.43&lt;sup&gt;ef&lt;/sup&gt;</td>
<td>3.32</td>
<td>2.86&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>D1A</td>
<td>5.23&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>5.97&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>5.76&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>3.21</td>
<td>5.16&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>D1B</td>
<td>4.73&lt;sup&gt;de&lt;/sup&gt;</td>
<td>5.38&lt;sup&gt;g&lt;/sup&gt;</td>
<td>4.75&lt;sup&gt;def&lt;/sup&gt;</td>
<td>3.39</td>
<td>3.36&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>D2A</td>
<td>4.82&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>5.53&lt;sup&gt;de&lt;/sup&gt;</td>
<td>5.27&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>3.45</td>
<td>4.69&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>D2B</td>
<td>5.21&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>4.71&lt;sup&gt;f&lt;/sup&gt;</td>
<td>4.23&lt;sup&gt;f&lt;/sup&gt;</td>
<td>3.32</td>
<td>4.12&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>D3A</td>
<td>5.55&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>5.97&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>5.31&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>3.26</td>
<td>5.54&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>D3B</td>
<td>4.61&lt;sup&gt;e&lt;/sup&gt;</td>
<td>5.34&lt;sup&gt;g&lt;/sup&gt;</td>
<td>4.91&lt;sup&gt;de&lt;/sup&gt;</td>
<td>3.15</td>
<td>5.47&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>P-value</sup> <0.001  <0.001  <0.001  0.98  <0.0001

<sup>SEM</sup> 0.29  0.33  0.39  0.54  0.64

<sup>a, b, c, d, e, f, g, h</sup> Means in the same row having different superscripts are significant at P < 0.05.

<sup>1</sup> Sensory attributes rated by a trained sensory panel on tenderness (8 = extremely tender; 1 = extremely tough), juiciness (8 = extremely juicy; 1 = extremely dry), connective tissue (8 = no connective tissue; 1 = abundant amount) and off-flavor (8 = strong off-flavor; 1 = no off-flavor).
Table 2: Sensory attributes, connective tissue, and WBS results of steaks fabricated perpendicular to muscle fiber direction.

<table>
<thead>
<tr>
<th>Steak</th>
<th>Sensory Attribute&lt;sup&gt;1&lt;/sup&gt;</th>
<th>WBS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Juiciness</td>
<td>Tenderness</td>
</tr>
<tr>
<td>A1</td>
<td>5.80&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.67&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>A2</td>
<td>5.25&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>6.41&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>A3</td>
<td>5.08&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>6.21&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>A4</td>
<td>5.06&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>6.06&lt;sup&gt;bcd&lt;/sup&gt;</td>
</tr>
<tr>
<td>A5</td>
<td>4.84&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>5.42&lt;sup&gt;edf&lt;/sup&gt;</td>
</tr>
<tr>
<td>B1</td>
<td>4.80&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>6.41&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>B2</td>
<td>5.03&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>5.32&lt;sup&gt;ef&lt;/sup&gt;</td>
</tr>
<tr>
<td>B3</td>
<td>4.90&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>5.70&lt;sup&gt;dde&lt;/sup&gt;</td>
</tr>
<tr>
<td>B4</td>
<td>4.93&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>4.95&lt;sup&gt;fg&lt;/sup&gt;</td>
</tr>
<tr>
<td>B5</td>
<td>5.20&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>4.78&lt;sup&gt;fg&lt;/sup&gt;</td>
</tr>
<tr>
<td>C1</td>
<td>4.62&lt;sup&gt;ed&lt;/sup&gt;</td>
<td>5.99&lt;sup&gt;bcd&lt;/sup&gt;</td>
</tr>
<tr>
<td>C2</td>
<td>4.90&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>5.76&lt;sup&gt;cde&lt;/sup&gt;</td>
</tr>
<tr>
<td>C3</td>
<td>4.86&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>5.15&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>C4</td>
<td>4.58&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4.54&lt;sup&gt;gh&lt;/sup&gt;</td>
</tr>
<tr>
<td>C5</td>
<td>4.75&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>4.02&lt;sup&gt;h&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a, b, c, d, e, f, g, h, i</sup> Means in the same row having different superscripts are significant at $P < 0.05$.

<sup>1</sup>Sensory attributes rated by a trained sensory panel on tenderness (8 = extremely tender; 1 = extremely tough), juiciness (8 = extremely juicy; 1 = extremely dry), connective tissue (8 = no connective tissue; 1 = abundant amount) and off-flavor (8 = strong off-flavor; 1 = no off-flavor).
Table 3: Sensory attributes, connective tissue, cooking loss, and Warner Bratzler Shear Force results in extended sirloin cap steaks by region.

<table>
<thead>
<tr>
<th>Trait</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Fabrication Method</th>
<th>Region</th>
<th>Fabrication Method x Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenderness</td>
<td>6.48a</td>
<td>6.02b</td>
<td>5.35c</td>
<td>5.85b</td>
<td>4.91d</td>
<td>0.06</td>
<td>&lt;0.0001</td>
<td>0.41</td>
</tr>
<tr>
<td>Juiciness</td>
<td>5.45a</td>
<td>5.21ab</td>
<td>4.97bc</td>
<td>4.94bc</td>
<td>4.73c</td>
<td>0.002</td>
<td>&lt;0.0001</td>
<td>0.10</td>
</tr>
<tr>
<td>Off-Flavor</td>
<td>3.36</td>
<td>3.26</td>
<td>3.26</td>
<td>3.27</td>
<td>3.29</td>
<td>0.89</td>
<td>0.89</td>
<td>0.26</td>
</tr>
<tr>
<td>Connective Tissue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perpendicular</td>
<td>6.13a</td>
<td>5.51b</td>
<td>4.84c</td>
<td>5.51b</td>
<td>4.66dA</td>
<td>0.12</td>
<td>&lt;0.0001</td>
<td>0.04</td>
</tr>
<tr>
<td>Parallel</td>
<td>6.43a</td>
<td>5.82b</td>
<td>4.75c</td>
<td>5.49b</td>
<td>3.79cB</td>
<td>0.12</td>
<td>&lt;0.0001</td>
<td>0.04</td>
</tr>
<tr>
<td>Cooking Loss</td>
<td>24.78ab</td>
<td>22.79b</td>
<td>25.00ab</td>
<td>24.93ab</td>
<td>25.79a</td>
<td>0.37</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>WBS</td>
<td>3.07c</td>
<td>3.53c</td>
<td>3.55c</td>
<td>4.74b</td>
<td>6.09a</td>
<td>0.12</td>
<td>&lt;0.0001</td>
<td>0.23</td>
</tr>
</tbody>
</table>

A, B Means in the same column having different superscripts are significant at \( P < 0.05 \).
a, b, c, d Means in the same row having different superscripts are significant at \( P < 0.05 \).

1 Sensory attributes rated by a trained sensory panel on tenderness (8 = extremely tender; 1 = extremely tough), juiciness (8 = extremely juicy; 1 = extremely dry), connective tissue (8 = no connective tissue; 1 = abundant amount) and off-flavor (8 = strong off-flavor; 1 = no off-flavor).

2 Extended sirloin cap regions were utilized to analyze both WBS and sensory results from 2.54 cm steaks cut perpendicular and parallel to muscle fiber direction. Region 1 steaks: E5, E4, E3, A1, A2, A3, A4, A5; Region 2 steaks: E2A, E1A, B1, B2; Region 3 steaks: E2B, E1B, B3, B4, B5; Region 4 steaks: D1A, D2A, D3A, C1, C2; Region 5 steaks: D1B, D2B, D3B, C3, C4, C5.
Literature Cited


MANUSCRIPT 5

The effects of freezing and thawing rates on tenderness, sensory quality and retail display of Beef Subprimals\textsuperscript{1,2,3}

J. E. Hergenreder, J. J. Hosch, K. A. Varnold, A. L. Haack, L. S. Senaratne, S. Pokharel, C. Beauchamp\textsuperscript{3}, B. Lobaugh\textsuperscript{4}, and C. R. Calkins\textsuperscript{5}

Animal Science Department\textsuperscript{1}, University of Nebraska-Lincoln, Lincoln, Nebraska 68583-0908

\textsuperscript{1}A contribution of the University of Nebraska Agriculture Research Division.

\textsuperscript{2}This project was funded in part by the Beef Checkoff.

\textsuperscript{3}This project was funded in part by Colorado Premium.

\textsuperscript{4}iQ Foods

\textsuperscript{5}Correspondence: [A213 Animal Science; (Telephone (402) 472-6314; Fax (402) 472-6362)] email address: ccalkins1@unl.edu (Chris R. Calkins).
ABSTRACT

The objective of the study was to evaluate processing methods for frozen beef subprimals, the effects of freezing and thawing rates on tenderness, sensory properties and retail display were evaluated. Six treatments: fresh-never-frozen 14-day wet aged (14D), fresh-never-frozen 21-day wet aged (21D), blast frozen–fast thawed (BF), blast frozen–slow thawed (BS), conventionally frozen–fast thawed (CF), and conventionally frozen–slow thawed (CS) (all frozen beef subprimals were aged for 14d prior to freezing). Three beef subprimal cuts; ribeye roll (n = 90), strip loin (n = 90), and top sirloin butt (n = 90) - were utilized with three replications of five samples per treatment per week (total of 9 weeks, n = 270). Blast freezing occurred by placing spacers between the boxes of meat on pallets at -28 °C with high air velocity for 3 – 5 d. Conventional freezing occurred with boxes of meat stacked on pallets and placed in a -28 °C freezer with minimal air movement for at least 10 d. Fast thawing of subprimals (to an internal temperature of -2 ° to 0 °C) occurred by immersion in a circulating water bath (< 12 °C) for 21 hrs, and slow thawing of subprimals occurred over a two week period by placing individual subprimals on tables at 0 °C. Steaks (2.5 cm thick) were cut from the longissimus thoracis (LT), longissimus lumborum (LL), and gluteus medius (GM) for Warner-Bratzler shear force (WBS), trained sensory evaluation, and retail display. For LL and GM beef steaks, frozen treatments were equal or lower in WBS values to 14D and 21D beef steaks. No differences were detected in WBS among the treatments applied to GM beef steaks (P = 0.08). There were no differences in sensory tenderness among the LL, LT, and GM (P > 0.05). All LL and LT beef steaks had approximately 4 d to 40% discoloration, and all GM steaks had over 3 d to 40% discoloration. Steaks from
the LL and LT began to discolor at about 3 d, and the GM began to discolor after 1 d. For all beef subprimals, purge loss during storage/thawing was significantly higher for the slow-thawed subprimals ($P < 0.01$), and all fast-thawed subprimals were equal or superior to 14D and 21D ($P < 0.01$) in storage/thawing purge. During retail display, the greatest purge loss occurred in fast-thawed treatments ($P < 0.01$). Overall, freezing rate did not affect purge loss, and neither freezing nor thawing rates had significant meaningful effects on WBS and sensory and were comparable to fresh-never-frozen subprimals.

Key words: beef, freezing method, thawing method
Introduction

Inconsistency in tenderness and palatability among steaks is a concern for today’s beef industry. The 2006 National Beef Tenderness Survey showed the average length of aging for steaks in restaurant settings to be 30 d (Savell et al., 2007), with a range of aging from 7 – 136 d. In addition, 29% of steaks had less than 14 d of aging. This can lead to inconsistency and considerable tenderness variation between products. Supply and demand is a reason for variation in aging time. Seasonal effect and time of year plays a role in consumer demand: beef steaks are mostly consumed in the summer months, and beef roasts are in higher demand during the winter months (Namken et al., 1994), helping account for a reason why consumers may encounter a beef steak with little aging.

A potential solution in reducing aging variations could include freezing and storing beef subprimals immediately once the optimal day of aging (14 d) is reached. Studies have shown the freezing process in meat increases tenderness due to cellular disruption (Hiner et al., 1945 and Shanks et al., 2002). Freezing meat at faster rates decreases purge loss because the majority of ice crystal are intramuscular and the cells do not experience as much damage and can still maintain the moisture (Grujic et al., 1993; Petrovic et al., 1993; Hiner et al., 1945; Ramsbottom and Koonz, 1939; Paul and Child, 1937).

The objectives of this study were to evaluate freezing and thawing procedures in beef subprimals. Objectives include: 1) determine if freezing method had significant effects on purge loss, tenderness and sensory attributes, and 2) determine if thawing
methods had significant effects on purge loss, tenderness and sensory attributes when compared to fresh, never-frozen subprimals aged for 14- and 21-days.

**Materials and Methods**

There were 6 treatments: blast frozen – slow thaw (BS), blast frozen – fast thaw (BF), conventionally frozen – slow thaw (CS), conventionally frozen – fast thaw (CF), fresh, never frozen 14 d aged (14D), and fresh, never frozen 21 d aged (21D). Three beef subprimals; ribeye roll, lip-on (IMPS #112A; NAMP, 2010) (n = 90), strip loin, boneless (IMPS #180; NAMP 2010) (n = 90), and top sirloin butt, boneless (IMPS #184; NAMP, 2010) (n = 90) were utilized with three replications of five samples per treatment per week (total of 9 weeks, n = 270). All beef subprimals were purchased from Colorado Premium (Greeley, CO). Beef subprimals were USDA Choice except for (n = 5) 21D top sirloin butts were USDA Select. At 14 d postmortem, 60 ribeye rolls (*Longissimus Thoracis*, LT), 60 strip loins (*Longissimus Lumborum*, LL), and 60 top sirloin butts (*Gluteus Medius*, GM) were frozen in a -28°C freezer at a warehouse in Denver, CO. Of the 60 beef subprimals, 30 of the three beef subprimals were blast frozen at -28°C using high air velocity for 3 – 5 d. Boxed beef were placed on wooden pallets, stacked on top of each other using plastic spacers between layers. After 3 – 5 d, beef subprimals were transferred to a -28°C freezer until shipped. The remaining 90 beef subprimals (n = 30/subprimal) were conventionally frozen at -28°C using low air velocity for at least 10 d. Boxed beef was left packed tightly on wooden pallets and remained in the freezer until shipping.
The beef subprimals were then shipped under refrigerated conditions to Loeffel Meat Laboratory at the University of Nebraska Lincoln, NE. The subprimals were then unloaded and moved to a -23 °C freezer with minimal air movement for storage. All LT, LL, and GM were frozen for a minimum of 14 d following the freezing treatments. The fresh, never frozen subprimals were collected from Colorado Premium throughout the study.

Colorado Premium would obtain beef subprimals from cattle slaughtered 14 and 21 d prior to processing. Beef subprimals were then placed in coolers with ice packs and shipped next day delivery through FedEx to Loeffel Meat Laboratory at the University of Nebraska Lincoln, NE. The 21D subprimals were shipped the week prior to processing beef subprimals into steaks. The 21D subprimals were placed on a table in a -1 to 2°C cooler. Because of shipping conditions, 14D beef subprimals arrived the day of processing. Each wk for 9 wk, 5 blast frozen and 5 conventionally frozen subprimals were taken from the freezer numbered, weighed on a Weigh-Tronix scale (Model WI-110, Avery Weigh-Tronix, Fairmont, MN) still in the package, and then placed on a table in a -1 to 2°C cooler in the Loeffel Meat Laboratory for 14 d to allow for a slow thaw period. An additional 5 blast and 5 conventionally frozen subprimals were removed from the freezer, numbered, weighed, and placed in a water bath (76.2 x 76.2 x 88.9 cm, 522.39 liters) with air agitation (120 psi) starting at 12°C and decreasing in temperature 0°C in 5°C room in the Loeffel Meat Laboratory for 21 hr prior to cutting each wk for 9 wk. Water bath temperature dropped as subprimals were added, and the surface of the beef subprimals did not exceed 7°C following Loeffel Meat Laboratory Hazard Analysis Critical Control Plan.
Steaks from each muscle group were cut after purge loss data had been collected for beef subprimals each wk for 9 wk. *Gluteus medius* subprimals were cut into 2.54-cm steaks (IMPS #1184B; NAMP, 2010), the dorsal half of 3 middle steaks were used for WBS, cooking loss, and sensory evaluation, and retail display. *Longissimus Lumborum* subprimals were trimmed to an external fat thickness of 0.3-cm then 3, 2.54-cm steaks (IMPS #1180A; NAMP, 2010) were cut from the anterior portion of the LL for WBS, cooking loss, and sensory evaluation, and retail display. *Longissimus Thoracis* subprimals were trimmed to an external fat thickness of 0.3-cm, and cut into 3, 2.54-cm steaks (IMPS #1112; NAMP, 2010) from the posterior portion of the LT for WBS, cooking loss, and sensory evaluation, and retail display.

All WBS steaks were cooked the day of processing. Sensory evaluation steaks were vacuum-packaged and placed in a 4°C cooler until needed. Sensory evaluation steaks were cooked within 3 d of being cut. Steaks placed in retail display were individually weighed, placed on a white foam tray, packaged in oxygen-permeable film, and placed in retail display case using continuous fluorescent lighting at 2°C for 8 d.

**Purge Loss**

Fifty eight out of 270 vacuum bags were damaged during the handling. A total of 21.5% of the vacuum bags were broken. Out of the broken vacuum bags the LT accounted for the majority of broken of bags totaling 30 broken vacuum bags (slow thaw = 10, fast thaw = 19, fresh, never frozen = 1). The GM had the least amount of vacuum bag failure with a total of 8 (slow thaw = 3, fast thaw = 5, fresh, never frozen = 0). The LL accounted for 20 of the broken vacuum bags (slow thaw = 7, fast thaw = 10, fresh,
never frozen = 3). Out of all the broken vacuum bags 21 of them were in the slow thaw treatment, 34 of them were in the fast thawing treatment, and 3 of them were in the fresh, never frozen treatment.

Purge loss was calculated on every beef subprimal with the exception of broken bags in fast thaw treatments (n = 34) and its respective steak in retail display. Frozen weights in the bag were recorded prior to thawing. Prior to processing, all thawed and fresh, never frozen beef subprimals were weighed still in the bag. The beef subprimals were then opened, removed from their vacuum-packaging bags and all purge was dried off using paper towels, and were weighed again. The purge was then emptied into the drain out of the vacuum-package bag. The bag was washed out, dried off with paper towels, and re-weighed. Beef subprimal purge loss was calculated using the following equation: “purge loss % = ((frozen weight - (dried weight + vacuum bag weight)) / frozen weight – vacuum bag weight) x 100”.

Beef steak weights were recorded prior to packaging and placed in retail display case. After 8 d of retail display steaks were removed from packaging, dried with a paper towel and re-weighed. Retail purge loss was calculated by the equation: “purge loss % = (D0 weight – D8 weight) / D0 weight x 100”. Total purge loss was calculated by the equation “purge loss” % = retail purge loss % + storage/thawing purge loss %.

Color Measurement/Retail Display

Packaged beef steaks were placed in retail display under continuous fluorescent lighting at 2°C for 8 d. Color and discoloration scores were obtained with a Minolta Chromameter CR-400 (Minolta Camera Company, Osaka, Japan, illuminant D65 and a
The recorded measurements included L* (psychometric lightness), a* (redness) and b* (yellowness). The Minolta was calibrated every day by normal standards with a white calibration plate that came with the machine from the manufacturer. Six readings per beef steak were taken daily.

Percent surface discoloration was evaluated by a trained five-member panel. Discoloration data were analyzed for the time at which a steak reached 40% discoloration, a value at which consumers begin to refuse to purchase product (Siegel, 2010).

Warner-Bratzler Shear Force and cooking loss

Beef steaks were grilled on Hamilton Beach Indoor/Outdoor grills (Model 31605A, Proctor-Silex Inc., Washington, NC). A Type T, copper constant, Precision Fine Wire Thermocouple (OMEGA Engineering, Inc., Stamford, CT) was inserted into the geometric center of every beef steak. Internal temperature was monitored using an OMEGA 450 ATT thermometer with a type T thermocouple (OMEGA Engineering, Inc., Stamford, CT). Beef steaks were cooked on one side until the center temperature reached 35°C and then turned over. Cooking continued until the temperature reached 71°C. Beef steaks were weighed before and after grilling. Cooking loss was calculated with the equation: “cooking loss % = ((fresh weight – cooked weight) / fresh weight) x 100”.

Beef steaks were placed on a tray and covered with oxygen-permeable film and placed in a 4°C cooler. Twenty hours later, the cooked steaks were cored into of six 1.3-cm cores and sheared to determine WBS following AMSA guidelines (AMSA, 1995).

Sensory Panel
One beefsteak per treatment was prepared and cooked in the same manner described for WBS following AMSA guidelines (AMSA, 1995). Upon reaching 71°C steaks were removed from the grill and cut into 1.27 cm³ cubes and kept warm (not more than 15 min) prior to being evaluated.

The steaks were served to 4-7 trained panelists while still warm. Panelists evaluated six samples (one per treatment) per session. Sensory panels were conducted in a positive-pressure ventilated room with lighting and cubicles designed for objective meat sensory analysis. Each sample was evaluated for tenderness (8 = extremely tender; 1 = extremely tough), juiciness (8 = extremely juicy; 1 = extremely dry), connective tissue (8 = no connective tissue; 1 = abundant amount) and off-flavor (4 = strong off-flavor; 1 = no off-flavor).

Statistical Analysis

Data from each subprimal type was analyzed independently. Purge loss (subprimal and steak), cooking loss, Warner-Bratzler shear force, trained sensory panel and retail display data were analyzed using the PROC GLIMMIX procedure of SAS (Version 9.2, Cary, NC, 2002 – 2008). When significance ($P < 0.05$) was indicated by ANOVA, mean separations were performed using the LSMEANS and PDIF functions of SAS. CONTRAST statements were used to test for differences ($P < 0.05$) between blast frozen and conventionally frozen as well as slow thaw and fast thaw subprimals.

Results and Discussion

There were differences ($P < 0.0001$) in storage/thawing purge loss among treatments for each subprimal group (Table 1). Fast-thawed beef subprimals had equal or
less purge loss compared to the fresh, never-frozen subprimals among all three subprimals. Slow-thawed beef subprimals had the most storage/thawing purge loss ($P < 0.001$). There were no differences in storage/thawing purge loss between blast frozen and conventionally frozen subprimals ($P > 0.05$) (Table 2); fast and slow thawing treatments differed ($P < 0.0001$) (Table 2). Differences in storage/thawing purge loss between thawing treatments are likely because fast-thawed beef subprimals were thawed to -2 to 0°C. Thawed beef subprimals from the fast-thaw treatments had a colder internal temperature than the slow-thawed beef subprimals upon cutting (0°C vs. -2 - 0°C). Slow-thawed beef subprimals were thawed to 0°C, and had reached 0°C a few days prior to processing instead of a few hrs prior to processing. During retail display, the greatest amount of purge loss occurred in fast-thawed treatments ($P < 0.0001$) (Table 1). Overall, total purge loss (moisture loss during storage/thaw and retail display) when compared to 14D product was about 5% higher for slow thawed LT and GM and about 1.8% higher for slow thawed LL (Table 1).

Beef steaks from the 14D treatment always had the best color stability ($P < .02$) (Table 3, Figures 1, 2, and 3). All frozen treatments for the LL and GM steaks were equal or had more days to 40% discoloration to 21D, except for the CS LL steaks, which discolored more rapidly.

Steaks from the GM for all treatments were equal in WBS values ($P = 0.08$). Steaks from the LL frozen treatments were all equal or lower WBS values compared to 14D and 21D beef steaks ($P < 0.01$). Slow-thawed beef steaks were equal in WBS to 14D and 21D beef steaks (Table 4). All slow-thawed beef steaks for the LT and LL were equal or lower ($P < 0.01$) in WBS when compared to fast-thaw beef steaks. Differences
in WBS value are suspected to be a result of the thawing treatments because all slow thawed treatments were thaw 4 d prior to processing resulting in a duel period for increased aging. There were no differences in WBS between blast frozen and conventionally frozen beef steaks for all beef muscles \((P > 0.05)\) (Table 5); fast and slow thawing treatments did not affect WBS in the LT and GM \((P > 0.05)\) (Table 5). Fast and slow thawing treatments did affect WBS for the LL \((P < 0.001)\) (Table 5). Wheeler et al., (1996) found *Longissimus* beef steaks thawed to -2°C before cooking had higher WBS values than beef steaks thawed to 12°C. Fast-thaw beef subprimals were thawed to -2 to 0°C before steaks were cut and cooked. Slow-thawed beef subprimals were thawed to 0°C before beef steaks were cut and cooked. All beef steaks were similar in temperature when placed on the grill. Slow-thawed treatments were thawed in 7 – 11 d instead of 14 d. So, slow-thawed treatments had a dwell period prior to processing allowing for more days of aging. Beef frozen at 1 d postmortem, thawed, and then aged, tenderness is improved (Crouse and Koohmaraie, 1990). Whipple and Koohmaraie (1992) stated that freezing temperature and rate as well as thaw rate may affect the extent to which aging meat after freezing improves tenderness, because of possible detrimental or beneficial effects of freezing itself. No differences were detected in WBS among treatments within the GM \((P = 0.08)\) (Table 4).

There were few differences found in the sensory evaluation (Table 6). No differences were found in sensory tenderness among the LT, LL and GM \((P > 0.05)\). There were no differences in juiciness between LL and GM beef steaks \((P > 0.05)\). The 14D and 21D LT steaks were juicier than all LT frozen steaks \((P < 0.001)\). The 14D and 21D LT steaks also experienced less or equal cooking loss compared to all frozen steaks
This may account for the differences in juiciness between the LT steaks from the fresh-never-frozen and the frozen treatments. The fresh, never frozen LT steaks had less cooking loss, so they ended up being juicier. There were no differences in cooking loss between the LL and GM ($P > 0.05$). For the LT, LL, and GM steaks, all treatments were equal to 14D beef steaks in connective tissue. Differences in connective tissue were not detected in LT and GM beef steaks ($P > 0.05$). Slow-thawed beef steaks for the LL had less detectable connective tissue than the fast-thawed and 21D beef steaks ($P = 0.02$). The difference in connective tissue in the samples did not affect overall tenderness ratings because the panelists did not detect a difference in tenderness between all treatments in the LL. There were no differences detected in off-flavor among the treatments for the LT and LL ($P > 0.05$). The CF had the strongest presence of an off-flavor ($P = 0.02$) in the GM compared to all the GM steaks from the other treatments. There were no differences in tenderness, juiciness, off-flavor, and cooking loss between blast frozen and conventionally frozen treatments of beef steaks for all beef muscles ($P > 0.05$) (Table 7); there was a difference in connective tissue in the LT between blast frozen and conventionally frozen beef steaks ($P = 0.02$). There was no difference in connective tissue for the LL and GM between blast frozen and conventionally frozen beef steaks ($P > 0.05$) (Table 7). There were no differences in off-flavor and cooking loss between fast and slow thawing treatments of beef steaks for all beef muscles ($P > 0.05$) (Table 7). There was a difference in tenderness and connective tissue in the LT between fast and slow thawed beef steaks ($P \leq 0.01$), and there was no difference in tenderness and connective tissue for the LL and GM between fast and slow thawed beef steaks ($P > 0.05$) (Table 7). Juiciness was different in the GM between fast and slow thawed beef
steaks \((P = 0.01)\), and there was no difference in juiciness for the LT and LL between fast and slow thawed beef steaks \((P > 0.05)\) (Table 7).

Neither freezing nor thawing rates had significant meaningful effects on WBS or sensory tenderness. Our finding is supported by Paul and Child’s (1937) research done on freezing and thawing roasts, in that total moisture, drip loss and tenderness of cooked beef were unaffected by freezing or by different thawing temperatures. Lee et al., (1950) also found no significant effects on palatability due to freezing. Conversely, Hiner et al. (1945) found less resistance to shear as freezing temperature decreased, and Shanks et al. (2002) found that frozen steaks had lower WBS values than fresh steaks. However, both studies (Shanks et al. 2002; Hiner et al. 1945) were done on beef steaks and not large pieces of meat or beef subprimals. Steaks and subprimals freeze at different rates because of the difference in thickness and mass, which changes cellular disruption from freezing (Ramsbottom and Koonz, 1939).

Freezing rate did not affect purge loss, which was also found by Ramsbottom and Koonz (1939). Many previous studies have used beef steaks instead of beef subprimals. When freezing beef steaks or smaller pieces of meat freezing temperature does affect drip loss. Several papers reported that faster and colder freezing rates of steaks resulted in less drip loss because the ice crystals form intracellular causing less damage to cell allowing it to maintain moisture (Grujic et al., 1993; Petrovic et al., 1993; Hiner et al., 1945; Ramsbottom and Koonz, 1939; Paul and Child, 1937). The colder the temperature the less time there is for water to transfer out of the cell (Hiner et al., 1945).
When thaw rates were properly managed (the meat is thawed slowly or quickly and the outer surface of the meat does not exceed 7°C), tenderness and sensory attributes were comparable to fresh product. These data suggest that subprimals can be purchased at opportune times, frozen and thawed as needed, and steaks will be equal in quality to fresh, never-frozen product.
Table 1. Percent purge loss in the *longissimus thoracis*, *longissimus lumborum*, and *gluteus medius* for the subprimal, steak and total purge loss.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Treatments</th>
<th>14d</th>
<th>21d</th>
<th>BF</th>
<th>BS</th>
<th>CF</th>
<th>CS</th>
<th>SEM</th>
<th><em>P</em>-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Longissimus Thoracis</strong></td>
<td>Subprimal</td>
<td>0.68b</td>
<td>1.01b</td>
<td>0.98b</td>
<td>5.30a</td>
<td>0.72b</td>
<td>4.49a</td>
<td>1.18</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Steak</td>
<td>2.89b</td>
<td>3.27b</td>
<td>4.52a</td>
<td>3.58b</td>
<td>4.36a</td>
<td>3.47b</td>
<td>0.27</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>3.57b</td>
<td>4.28b</td>
<td>5.50b</td>
<td>8.88a</td>
<td>5.08b</td>
<td>7.96a</td>
<td>1.20</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Longissimus Lumborum</strong></td>
<td>Subprimal</td>
<td>1.78b</td>
<td>1.88b</td>
<td>0.88c</td>
<td>3.53a</td>
<td>0.78c</td>
<td>3.53a</td>
<td>0.30</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Steak</td>
<td>3.35b</td>
<td>3.07b</td>
<td>4.42a</td>
<td>3.44b</td>
<td>3.60b</td>
<td>3.32b</td>
<td>0.37</td>
<td>0.0037</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>5.13b</td>
<td>4.95b</td>
<td>5.30b</td>
<td>6.97a</td>
<td>4.38b</td>
<td>6.86a</td>
<td>0.48</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Gluteus Medius</strong></td>
<td>Subprimal</td>
<td>1.25bc</td>
<td>1.56b</td>
<td>0.79cd</td>
<td>6.17a</td>
<td>0.53d</td>
<td>6.23a</td>
<td>0.35</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Steak</td>
<td>3.95b</td>
<td>4.63b</td>
<td>6.60a</td>
<td>3.99b</td>
<td>6.56a</td>
<td>3.87b</td>
<td>0.57</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>5.20c</td>
<td>6.18bc</td>
<td>7.39b</td>
<td>10.16a</td>
<td>7.08b</td>
<td>10.10a</td>
<td>0.60</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

*a, b, c, d* Means in the same row having different superscripts are significant at *P* < 0.05.

1 B = Blast Frozen = spacers placed between boxes of meat and placed in a -28°C freezer with high air velocity, C = Conventional Frozen = boxes of meat placed in a -28°C freezer with minimal air movement, S = Slow Thaw = subprimals set on a table in a 0°C room for 14 days, F = Fast Thaw = subprimals immersed in a circulating water bath (< 12°C) for 21 hrs 14d = Aged for 14d and fresh, never frozen, 21d = Aged for 21d and fresh, never frozen.
Table 2. Contrast between the freezing process and thawing process of purge loss in the *longissimus thoracis*, *longissimus lumborum*, and *gluteus medius*.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>SEM</th>
<th>Blast Frozen vs. Conventional Frozen</th>
<th>Slow Thaw vs. Fast Thaw</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Longissimus Thoracis</em></td>
<td>0.016</td>
<td>0.5431</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><em>Longissimus Lumborum</em></td>
<td>0.12</td>
<td>0.8171</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><em>Gluteus Medius</em></td>
<td>0.16</td>
<td>0.7060</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Blast Frozen = spacers placed between boxes of meat and placed in a -28°C freezer with high air velocity, Conventional Frozen = boxes of meat placed in a -28°C freezer with minimal air movement, Slow Thaw = subprimals set on a table in a 0°C room for 14 days, Fast Thaw = subprimals immersed in a circulating water bath (< 12°C) for 21 hrs.

Table 3. Days-to-40% discoloration of steaks from the *longissimus thoracis*, *longissimus lumborum*, and *gluteus medius* under continuous fluorescent lighting.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>14d</th>
<th>21d</th>
<th>BF</th>
<th>BS</th>
<th>CF</th>
<th>CS</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Longissimus Thoracis</em></td>
<td>5.80a</td>
<td>5.12b</td>
<td>4.37c</td>
<td>3.85c</td>
<td>3.99c</td>
<td>4.07c</td>
<td>0.23</td>
<td>.02</td>
</tr>
<tr>
<td><em>Lumborum</em></td>
<td>5.47a</td>
<td>4.99abc</td>
<td>4.76abc</td>
<td>4.42bc</td>
<td>4.81bc</td>
<td>4.26c</td>
<td>0.28</td>
<td>.0001</td>
</tr>
<tr>
<td><em>Gluteus Medius</em></td>
<td>4.41a</td>
<td>3.56c</td>
<td>3.45c</td>
<td>4.19bc</td>
<td>3.02c</td>
<td>3.37c</td>
<td>0.25</td>
<td>.0011</td>
</tr>
</tbody>
</table>

* Values within the same row having different superscripts are significant at $P < 0.05$.

1 B = Blast Frozen = spacers placed between boxes of meat and placed in a -28°C freezer with high air velocity, C = Conventional Frozen = boxes of meat placed in a -28°C freezer with minimal air movement, S = Slow Thaw = subprimals set on a table in a 0°C room for 14 days, F = Fast Thaw = subprimals immersed in a circulating water bath (< 12°C) for 21 hrs 14d = Aged for 14d and fresh, never frozen, 21d = Aged for 21d and fresh, never frozen.
Table 4. Warner-Bratzler shear force of the steaks from the longissimus thoracis, longissimus lumborum, and gluteus medius.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Treatments</th>
<th>14d</th>
<th>21d</th>
<th>BF</th>
<th>BS</th>
<th>CF</th>
<th>CS</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longissimus Thoracis</td>
<td></td>
<td>3.44&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.10&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.45&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.70&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>4.21&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.53&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.33</td>
<td>0.001</td>
</tr>
<tr>
<td>Longissimus Lumborum</td>
<td></td>
<td>3.55&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.32&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>3.55&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>2.93&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>3.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.83&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.32</td>
<td>0.01</td>
</tr>
<tr>
<td>Gluteus Medius</td>
<td></td>
<td>3.35</td>
<td>3.21</td>
<td>4.08</td>
<td>3.48</td>
<td>3.51</td>
<td>3.54</td>
<td>0.32</td>
<td>0.08</td>
</tr>
</tbody>
</table>

<sup>a, b, c, d</sup> Means in the same row having different superscripts are significant at P < 0.05.

1 B = Blast Frozen = spacers placed between boxes of meat and placed in a -28°C freezer with high air velocity, C = Conventional Frozen = boxes of meat placed in a -28°C freezer with minimal air movement, S = Slow Thaw = subprimals set on a table in a 0°C room for 14 days, F = Fast Thaw = subprimals immersed in a circulating water bath (< 12°C) for 21 hrs 14d = Aged for 14d and fresh, never frozen, 21d = Aged for 21d and fresh, never frozen.
Table 5. Contrast between freezing process and thawing process of Warner-Bratzler shear force of the steaks from the *longissimus thoracis, longissimus lumborum,* and *gluteus medius.*

<table>
<thead>
<tr>
<th>Muscle</th>
<th>SEM</th>
<th>Blast Frozen vs. Conventional Frozen</th>
<th>Slow Thaw vs. Fast Thaw</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Longissimus Thoracis</em></td>
<td>0.12</td>
<td>0.4825</td>
<td>0.2897</td>
</tr>
<tr>
<td><em>Longissimus Lumborum</em></td>
<td>0.002</td>
<td>0.5177</td>
<td>0.0004</td>
</tr>
<tr>
<td><em>Gluteus Medius</em></td>
<td>0.002</td>
<td>0.2411</td>
<td>0.1845</td>
</tr>
</tbody>
</table>

Blast Frozen = spacers placed between boxes of meat and placed in a -28°C freezer with high air velocity, Conventional Frozen = boxes of meat placed in a -28°C freezer with minimal air movement, Slow Thaw = subprimal set on a table in a 0°C room for 14 days, Fast Thaw = subprimal immersed in a circulating water bath (< 12°C) for 21 hrs.
Table 6. Sensory attributes, connective tissue, and cooking loss in steaks from the *longissimus thoracis, longissimus lumborum*, and *gluteus medius*.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Trait</th>
<th>Treatments¹</th>
<th>14d</th>
<th>21d</th>
<th>BF</th>
<th>BS</th>
<th>CF</th>
<th>CS</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Longissimus Thoracis</strong></td>
<td>Tenderness</td>
<td>5.80</td>
<td>5.94</td>
<td>5.12</td>
<td>5.30</td>
<td>5.55</td>
<td>5.67</td>
<td>0.30</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juiciness</td>
<td>5.08</td>
<td>5.07</td>
<td>4.12</td>
<td>4.34</td>
<td>4.48</td>
<td>4.30</td>
<td>0.31</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Connective</td>
<td>5.04</td>
<td>5.48</td>
<td>4.68</td>
<td>4.85</td>
<td>5.14</td>
<td>5.32</td>
<td>0.30</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Off-Flavor</td>
<td>2.10</td>
<td>2.14</td>
<td>1.88</td>
<td>1.97</td>
<td>2.05</td>
<td>2.02</td>
<td>0.12</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cooking Loss</td>
<td>17.36</td>
<td>16.53</td>
<td>21.24</td>
<td>19.41</td>
<td>22.31</td>
<td>20.51</td>
<td>1.50</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td><strong>Longissimus Lumborum</strong></td>
<td>Tenderness</td>
<td>6.03</td>
<td>5.90</td>
<td>6.07</td>
<td>6.31</td>
<td>5.79</td>
<td>6.37</td>
<td>0.23</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juiciness</td>
<td>5.63</td>
<td>5.24</td>
<td>4.99</td>
<td>5.03</td>
<td>5.32</td>
<td>5.19</td>
<td>0.26</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Connective</td>
<td>5.61ab</td>
<td>5.55b</td>
<td>5.77ab</td>
<td>6.04a</td>
<td>5.37b</td>
<td>6.02a</td>
<td>0.23</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Off-Flavor</td>
<td>1.93</td>
<td>1.92</td>
<td>1.89</td>
<td>2.04</td>
<td>1.81</td>
<td>1.86</td>
<td>0.12</td>
<td>0.49</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cooking Loss</td>
<td>20.95</td>
<td>16.51</td>
<td>17.21</td>
<td>19.33</td>
<td>19.36</td>
<td>17.67</td>
<td>1.50</td>
<td>0.41</td>
<td></td>
</tr>
<tr>
<td><strong>Gluteus Medius</strong></td>
<td>Tenderness</td>
<td>5.43</td>
<td>5.88</td>
<td>5.54</td>
<td>5.89</td>
<td>5.59</td>
<td>5.52</td>
<td>0.21</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Juiciness</td>
<td>5.01</td>
<td>5.36</td>
<td>5.33</td>
<td>4.70</td>
<td>5.04</td>
<td>4.55</td>
<td>0.32</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Connective</td>
<td>4.92</td>
<td>5.38</td>
<td>5.22</td>
<td>5.17</td>
<td>5.07</td>
<td>5.22</td>
<td>0.23</td>
<td>0.46</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Off-Flavor</td>
<td>1.90b</td>
<td>2.01ab</td>
<td>1.84b</td>
<td>1.96ab</td>
<td>2.10a</td>
<td>1.85b</td>
<td>0.085</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cooking Loss</td>
<td>23.44</td>
<td>25.03</td>
<td>26.11</td>
<td>27.79</td>
<td>27.49</td>
<td>25.67</td>
<td>1.50</td>
<td>0.40</td>
<td></td>
</tr>
</tbody>
</table>

¹ B = Blast Frozen = spacers placed between boxes of meat and placed in a -28°C freezer with high air velocity, C = Conventional Frozen = boxes of meat placed in a -28°C freezer with minimal air movement, S = Slow Thaw = subprimals set on a table in a 0°C room for 14 days, F = Fast Thaw = subprimals immersed in a circulating water bath (< 12°C) for 21 hrs 14d = Aged for 14d and fresh, never frozen, 21d = Aged for 21d and fresh, never frozen.

Means in the same row having different superscripts are significant at *P* < 0.05.

Tenderness (8 = extremely tender; 1 = extremely tough), Juiciness (8 = extremely juicy; 1 = extremely dry), Connective tissue (8 = no connective tissue; 1 = abundant amount), Off-flavor (4 = strong off-flavor; 1 = no off-flavor).
Table 7. Contrast between freezing process and thawing process of sensory attributes, connective tissue, and cooking loss in steaks from the *longissimus thoracis*, *longissimus lumborum*, and *gluteus medius*.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Trait</th>
<th>SEM</th>
<th>Blast Frozen vs. Conventional Frozen</th>
<th>Slow Thaw vs. Fast Thaw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longissimus Thoracis</td>
<td>Tenderness</td>
<td>0.074</td>
<td>0.0613</td>
<td>0.4692</td>
</tr>
<tr>
<td></td>
<td>Juiciness</td>
<td>0.064</td>
<td>0.4384</td>
<td>0.8965</td>
</tr>
<tr>
<td></td>
<td>Connective Tissue</td>
<td>0.086</td>
<td>0.0268</td>
<td>0.3961</td>
</tr>
<tr>
<td></td>
<td>Off-Flavor</td>
<td>0.028</td>
<td>0.1356</td>
<td>0.6648</td>
</tr>
<tr>
<td></td>
<td>Cooking Loss</td>
<td>2.62</td>
<td>0.3511</td>
<td>0.1230</td>
</tr>
<tr>
<td>Longissimus Lumborum</td>
<td>Tenderness</td>
<td>0.064</td>
<td>0.5327</td>
<td>0.0194</td>
</tr>
<tr>
<td></td>
<td>Juiciness</td>
<td>0.091</td>
<td>0.1977</td>
<td>0.8044</td>
</tr>
<tr>
<td></td>
<td>Connective Tissue</td>
<td>0.069</td>
<td>0.1842</td>
<td>0.0032</td>
</tr>
<tr>
<td></td>
<td>Off-Flavor</td>
<td>0.019</td>
<td>0.0751</td>
<td>0.1722</td>
</tr>
<tr>
<td></td>
<td>Cooking Loss</td>
<td>3.71</td>
<td>0.8728</td>
<td>0.8882</td>
</tr>
<tr>
<td>Gluteus Medius</td>
<td>Tenderness</td>
<td>0.087</td>
<td>0.6811</td>
<td>0.8198</td>
</tr>
<tr>
<td></td>
<td>Juiciness</td>
<td>0.091</td>
<td>0.3217</td>
<td>0.0108</td>
</tr>
<tr>
<td></td>
<td>Connective Tissue</td>
<td>0.11</td>
<td>0.7670</td>
<td>0.7689</td>
</tr>
<tr>
<td></td>
<td>Off-Flavor</td>
<td>0.023</td>
<td>0.2296</td>
<td>0.2505</td>
</tr>
<tr>
<td></td>
<td>Cooking Loss</td>
<td>3.71</td>
<td>0.8005</td>
<td>0.9612</td>
</tr>
</tbody>
</table>

Blast Frozen = spacers placed between boxes of meat and placed in a -28°C freezer with high air velocity, Conventional Frozen = boxes of meat placed in a -28°C freezer with minimal air movement, Slow Thaw = subprimals set on a table in a 0°C room for 14 days, Fast Thaw = subprimals immersed in a circulating water bath (< 12°C) for 21 hrs.
Figure 1. Percent discoloration of steaks from the *longissimus thoracis* under continuous fluorescent lighting from days 0 - 7.
Figure 2. Percent discoloration of steaks from the *longissimus lumborum* under continuous fluorescent lighting from days 0 - 7

![Graph showing percent discoloration of steaks from the longissimus lumborum under continuous fluorescent lighting from days 0 - 7. The graph includes data for 14 Day Aged, 21 Day Aged, Blast Frozen, Fast Thaw, Blast Frozen, Slow Thaw, Conventional Frozen, Fast Thaw, and Conventional Frozen, Slow Thaw.](image-url)
Figure 3. Percent discoloration of steaks from the *gluteus medius* under continuous fluorescent lighting from days 0 – 7

- 14 Day Aged
- 21 Day Aged
- Blast Frozen, Fast Thaw
- Blast Frozen, Slow Thaw
- Conventional Frozen, Fast Thaw
- Conventional Frozen, Slow Thaw


Appendix 1: Variation in round fabrication methods.
Appendix 2: Beef carcass fabrication mandated by Office of Price Administration.
Appendix 3: Photographs of pelvic bones from a fabricated beef steer carcass weighing 888 lbs (404 kg).

Aitch bone piece from various angles.

Hip bone pieces from various angles.
Appendix 4: Examining splitting accuracy and its effect on aitch bone size and shape.

Lateral to midpoint

Split at midpoint

Medial to midpoint
Appendix 5: Locations of short rib linear measurements.

Clockwise from top left: chuck short rib ventral length, chuck short rib dorsal length, chuck short rib width at rib 2 location, and chuck short rib width at rib 5 location.

Clockwise from top left: rib short ventral length, chuck short rib dorsal length, chuck short rib width at rib 6 location, and chuck short rib width at rib 6 location.
Appendix 6: Individual short ribs (2-12) utilized during the yield assessment.
Appendix 7: Short rib slice (2-12) used to prepare 6mm taste panel serving size.
Appendix 8: Anatomical location of 2 and 3-rib subprimals.
Appendix 9: Diagram supporting anatomical locations of 2 and 3-rib subprimal measurements.
Appendix 10: Single muscle fabrication technique utilized during 2 and 3-rib subprimal fabrication.
Appendix 11: Removal of the extended sirloin cap.

An imaginary line was made from the dorsal tip of the aitch bone to the lateral side of the carcass. From this landmark, a cut was made adjacent to the spinal column, following the curvature of the pelvic bone. This cut came anterior toward the origin of the Biceps femoris. Again from the lateral landmark a cut was made at a 45° angle to the long axis of the carcass to the ventral edge of the Biceps femoris. The Biceps femoris was then pulled down until the anterior insertion point of the muscle was visible, and could be removed.
Appendix 12: Location and designation of steaks fabricated perpendicular to muscle fiber direction.
Appendix 13: Location and designation of steaks fabricated parallel to muscle fiber direction.
Appendix 14: Muscle fiber map of extended sirloin cap.
Appendix 15: Extended sirloin cap regions utilized to analyze WBS and sensory results from 2.54 cm steaks cut perpendicular and parallel to muscle fiber direction.
Appendix 16: Trained sensory panel consent form.

INVITATION TO PARTICIPATE
You are invited to participate in a taste panel assessing the acceptability of beef from alternative fabrication methods.

BASIS FOR SUBJECT SELECTION
Participants must be 19 years or older.

PURPOSE OF THE STUDY
This study is being conducted to determine the acceptability of new cuts resulting from alternative fabrication.

EXPLANATION OF PROCEDURES
You will be required to be at the training sessions, and 80% of the taste panels. You will then be given a sample of steak from 5 treatments and asked to assess the differences, rating the sample on tenderness, juiciness and connective tissue.

POTENTIAL RISKS AND DISCOMFORTS
There will be no risks other than those normally associated with eating of meat products. The food will be prepared under sanitary conditions.

POTENTIAL BENEFITS
Your recognition of the importance of sensory panels, and your contribution to them, is one benefit. Society in general benefits from the production of meat products with improved consumer acceptance.

ASSURANCE OF CONFIDENTIALITY
Any information obtained in connection with this project and which could be identified with you will be kept confidential. Summary results and statistical data may be reported in scientific journals or presented at scientific meetings; however, individual panelist responses will be maintained in confidence.
WITHDRAWAL FROM THE STUDY

Participation in this study is voluntary. Your decision whether or not to participate will not affect your present or future relationship with the investigator or the University of Nebraska. If you decide to participate, you are free to withdraw your consent and to discontinue participation at any time without penalty.

COMPENSATION FOR PARTICIPATION

Individuals participating in this panel will receive $10 for every training session and $10 for every taste panel session. The panelists will also receive a small treat after every session, once consent to participate in this study is given.

OFFER TO ANSWER QUESTIONS

If you have any questions, please do not hesitate to ask. If you think of questions later, please feel free to contact Chris Calkins, Ph.D. (402-472-6314). If you have any additional questions concerning the rights of research subjects, you may contact the University of Nebraska-Lincoln Institutional Review Board (IRB), telephone 402-472-6965.

YOU ARE VOLUNTARILY MAKING A DECISION WHETHER OR NOT TO PARTICIPATE IN THIS RESEARCH TODAY. YOUR SIGNATURE CERTIFIES THAT YOU HAVE DECIDED TO PARTICIPATE HAVING READ THE INFORMATION PRESENTED. YOUR SIGNATURE ALSO CERTIFIES THAT YOU HAVE HAD AN ADEQUATE OPPORTUNITY TO DISCUSS THIS STUDY WITH THE INVESTIGATOR AND YOU HAVE HAD ALL YOUR QUESTIONS ANSWERED TO YOUR SATISFACTION. YOU WILL BE GIVEN A COPY OF THIS CONSENT FORM TO KEEP.

_________________________________________________  _______________________
SIGNATURE OF SUBJECT  DATE

IN MY JUDGEMENT THE SUBJECT IS VOLUNTARILY AND KNOWINGLY GIVING INFORMED CONSENT AND POSSESESSE THE LEGAL CAPACITY TO GIVE INFORMED CONSENT TO PARTICIPATE IN THIS RESEARCH STUDY.

_________________________________________________  _______________________
SIGNATURE OF INVESTIGATOR  DATE

Chris Calkins, Ph.D.
Appendix 17: Trained sensory panel evaluation form.

Trained Taste Panel Form

Panelist #: __________________

Please evaluate each sensory attributes of the sample by using the rating scale (1-8) and then identify the flavor associated with the sample.

Rating scales:

<table>
<thead>
<tr>
<th>TENDERNESS</th>
<th>CONNECTIVE TISSUE</th>
<th>JUICINESS</th>
<th>OFF-FLAVOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Extremely Tender</td>
<td>8 No Connective Tissue</td>
<td>8 Extremely Juicy</td>
<td>8 Very Strong</td>
</tr>
<tr>
<td>7 Very Tender</td>
<td>7 Trace Amount</td>
<td>7 Very Juicy</td>
<td>7 Strong</td>
</tr>
<tr>
<td>6 Moderately Tender</td>
<td>6 Slight Amount</td>
<td>6 Moderately Juicy</td>
<td>6 Moderate</td>
</tr>
<tr>
<td>5 Slightly Tender</td>
<td>5 Small Amount</td>
<td>5 Slightly Juicy</td>
<td>5 Modest</td>
</tr>
<tr>
<td>4 Slightly Tough</td>
<td>4 Modest Amount</td>
<td>4 Slightly Dry</td>
<td>4 Small</td>
</tr>
<tr>
<td>3 Moderately Tough</td>
<td>3 Moderate Amount</td>
<td>3 Moderately Dry</td>
<td>3 Slight</td>
</tr>
<tr>
<td>2 Very Tough</td>
<td>2 Slightly Abundant</td>
<td>2 Very Dry</td>
<td>2 Little</td>
</tr>
<tr>
<td>1 Extremely Tough</td>
<td>1 Abundant Amount</td>
<td>1 Extremely Dry</td>
<td>1 None</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Tenderness</th>
<th>Connective Tissue</th>
<th>Juiciness</th>
<th>Off-flavor Intensity</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 18: Sensory panel ranking form – tenderness.

Ranking Test

Tenderness

Name:_____________________  Panel #:______________  Date:__________

Rank the following samples:

<table>
<thead>
<tr>
<th>Tenderness</th>
<th>Sample #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most tender</td>
<td></td>
</tr>
<tr>
<td>Least tender</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tenderness</th>
<th>Sample #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most tender</td>
<td></td>
</tr>
<tr>
<td>Least tender</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tenderness</th>
<th>Sample #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most tender</td>
<td></td>
</tr>
<tr>
<td>Least tender</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 19: Sensory panel ranking form – connective tissue.

Ranking Test

Connective Tissue

Name:_____________________  Panel #:______________  Date:__________

Rank the following samples:

<table>
<thead>
<tr>
<th>Connective Tissue</th>
<th>Sample #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most connective tissue</td>
<td></td>
</tr>
<tr>
<td>Least connective tissue</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Connective Tissue</th>
<th>Sample #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most connective tissue</td>
<td></td>
</tr>
<tr>
<td>Least connective tissue</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Connective Tissue</th>
<th>Sample #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most connective tissue</td>
<td></td>
</tr>
<tr>
<td>Least connective tissue</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 20: Sensory panel ranking form – juiciness.

Ranking Test

Juiciness

Name:_____________________

Panel #:______________

Date:__________

Rank the following samples;

<table>
<thead>
<tr>
<th>Juiciness</th>
<th>Sample #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most juicy</td>
<td></td>
</tr>
<tr>
<td>Least juicy</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Juiciness</th>
<th>Sample #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most juicy</td>
<td></td>
</tr>
<tr>
<td>Least juicy</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Juiciness</th>
<th>Sample #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most juicy</td>
<td></td>
</tr>
<tr>
<td>Least juicy</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 21: Sensory attributes, connective tissue, and cooking loss of steaks fabricated parallel to muscle fiber direction.

1 Sensory attributes rated by a trained taste panel on tenderness (8 = extremely tender; 1 = extremely tough), juiciness (8 = extremely juicy; 1 = extremely dry), connective tissue (8 = no connective tissue; 1 = abundant amount) and off-flavor (8 = strong off-flavor; 1 = no off-flavor).
Appendix 22: Sensory attributes, connective tissue, and cooking loss of steaks fabricated perpendicular to muscle fiber direction.

Sensory attributes rated by a trained taste panel on tenderness (8 = extremely tender; 1 = extremely tough), juiciness (8 = extremely juicy; 1 = extremely dry), connective tissue (8 = no connective tissue; 1 = abundant amount) and off-flavor (8 = strong off-flavor; 1 = no off-flavor).
Appendix 23: Warner-Bratzler Shear Force results from extended sirloin cap steaks fabricated parallel to muscle fiber direction.

<table>
<thead>
<tr>
<th>Steak</th>
<th>WBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>E5</td>
<td>2.83  cd</td>
</tr>
<tr>
<td>E4</td>
<td>3.45  cd</td>
</tr>
<tr>
<td>E3</td>
<td>3.29  cd</td>
</tr>
<tr>
<td>E2A</td>
<td>3.44  cd</td>
</tr>
<tr>
<td>E2B</td>
<td>2.75  d</td>
</tr>
<tr>
<td>E1A</td>
<td>4.83  ab</td>
</tr>
<tr>
<td>E1B</td>
<td>2.86  cd</td>
</tr>
<tr>
<td>D1A</td>
<td>5.16  ab</td>
</tr>
<tr>
<td>D1B</td>
<td>3.36  cd</td>
</tr>
<tr>
<td>D2A</td>
<td>4.69  ab</td>
</tr>
<tr>
<td>D2B</td>
<td>4.12  bc</td>
</tr>
<tr>
<td>D3A</td>
<td>5.54  a</td>
</tr>
<tr>
<td>D3B</td>
<td>5.47  a</td>
</tr>
</tbody>
</table>

$P$-value <0.0001
SEM 0.64

a, b, c, d Means in the same row having different superscripts are significant at $P < 0.05$. 
Appendix 24: Warner-Bratzler Shear Force results from extended sirloin cap steaks fabricated perpendicular to muscle fiber direction.

<table>
<thead>
<tr>
<th>Steak</th>
<th>WBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>2.37&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>A2</td>
<td>2.75&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>A3</td>
<td>2.99&lt;sup&gt;ef&lt;/sup&gt;</td>
</tr>
<tr>
<td>A4</td>
<td>3.05&lt;sup&gt;ef&lt;/sup&gt;</td>
</tr>
<tr>
<td>A5</td>
<td>3.63&lt;sup&gt;def&lt;/sup&gt;</td>
</tr>
<tr>
<td>B1</td>
<td>2.56&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>B2</td>
<td>3.38&lt;sup&gt;def&lt;/sup&gt;</td>
</tr>
<tr>
<td>B3</td>
<td>3.67&lt;sup&gt;def&lt;/sup&gt;</td>
</tr>
<tr>
<td>B4</td>
<td>4.59&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>B5</td>
<td>4.48&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>C1</td>
<td>3.69&lt;sup&gt;def&lt;/sup&gt;</td>
</tr>
<tr>
<td>C2</td>
<td>5.04&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>C3</td>
<td>6.65&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>C4</td>
<td>7.66&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>C5</td>
<td>9.64&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

| P-value | <0.0001 |
| SEM     | 0.66    |

Means in the same row having different superscripts are significant at $P < 0.05$. 

*a, b, c, d, e, f*
RECOMMENDATIONS FOR FUTURE RESEARCH

From this research, it was determined that new methods of fabrication could be implemented in the industry with minimal impacts on fabrication yields and overall acceptability.

Alternative fabrication in the forequarter should strongly be considered. Divergence of the chuck/rib break cranial would benefit both the short rib offerings, as well as providing a more consistent cut through a 2-rib or 3-rib subprimal. In both cases the *Longissimus dorsi muscle* from both alternative primals had Warner Bratzler Shear Force (WBS) results that would rate them as tender product. Recommendations for implementation in the industry would include a larger study that focuses on the economic effect, as well as yield differences between alternative and traditional forequarter fabrication. Consumer acceptability of the new 2-rib or 3-rib subprimal would need to be evaluated to determine the susceptibility of this innovative cut in the marketplace.

In reference to the evaluation of yield composition and sensory properties of beef short ribs, there has been little to no previous research accomplished. Results from this study have indicated that current short rib offerings would have little to no effect consequent to an alteration of the chuck/rib break. Short rib yield composition was similar cranial to rib 9 as well as in sensory panel ratings. The ventral short ribs evaluated, ribs 9-12, could receive further attention focusing on the economic benefit as well as fabrication time and yield differences. These results could be compared to the production of rib finger meat - the common means for this subprimal. Due to the nature of short rib samples, WBS is difficult to achieve, so another sensory panel—one with panelist fluent with this cut of meat - could be considered.
Finally when assessing alternative fabrication in the hindquarter many advantages were realized. In adding weight to the top sirloin butt, prior to sirloin/round fabrication, the industry would benefit immensely. Results from WBS and the sensory panel evaluation have indicated a more proximal location of extended sirloin cap removal. Again the economics and fabrication times involved with removing this cap could be evaluated. A retail study could also be completed to determine consumer acceptability and willingness to pay for this innovative subprimal cut.