TENDERNESS, CONSISTENCY AND COOKING LOSS OF BEEF LOINS AND

GROUND BEEF FROM TWO DIFFERENT GENETIC TYPES OF CATTLE

by

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**ABSTRACT**

Producing consist quality beef that satisfies the consumers' demand is one of the major challenges in the beef industry. The focus of this study involved two experiments designed to measure two parameters of meat quality, tenderness and cooking loss. Experiment 1 involved dividing loins into 6 (2-2.5 pound) roasts, cooking (smoking), measuring tenderness, and cooking loss by weight. Experiment 2 involved the evaluation of cooking loss and shrinkage in ground beef. Two sources of meat studied were HeartBrand (Akaushi breed), and meat from a commercial grocery store. Each pound package was divided into ¼ pound (118-120g) patties and grilled on a George Foreman Grill, and drippings were collected.

Loin experiment consisted of six HeartBrand loins and one select grade Control loin. No significant differences were found in tenderness, but a significant difference was found in average cooking loss 0.40 lb. ± 0.03 Control:0.56 lb.± 0.03 HeartBrand (p<.05) and tenderness consistency.

Ground beef experiment consisted of 20 pounds of commercial grocery store ground beef, and 20 pounds HeartBrand ground beef. Although there was no significant difference in cooking loss 45.44g± 3.74 Control: 44.98g ± 2.68 HeartBrand, there was a significant difference found in cooking shrinkage in both circumference and thickness of the patties. Differences in circumference measurements between fresh and cooked were 4 cm ± 0.59; Control 3.21cm ± 0.47; HeartBrand (p<.05). An additional significant difference was found in patty thickness which measured 0.221 ± 0.19 cm; Control 0.151

cm ± 0.11; HeartBrand (p<.05).  Total dripping collection values 62.4g ± 4.66; Control

64.3g ± 5.10; HeartBrand were not significantly different, but when the drippings were

separated a significant difference was found in weight of solids 12.3g ± 2.72; Control

18.2g ± 3.11 HeartBrand (p<.05), and in the liquid portion 50g ± 0.61; Control:46.1g ±

0.32 HeartBrand (p<.05).

Both loin and ground beef experiments showed variation in cooking loss,

tenderness, and consistency between commercial grocery store and HeartBrand (Akaushi)

beef.  Quality beef production has made advancements, but continual improvements is

needed to satisfy the consumers demand for consistency in both quality and value.

# I. INTRODUCTION

**Background**

     Quality remains a key demand driver for consumer consumption of beef. Nutritional value is an important contributor to the overall quality of beef meat products. Intramuscular fat level and composition of fatty acids along with the biological value of protein, minerals and vitamin are key factors of nutrition. Along with nutritional value, intramuscular fat deposits are associated with tenderness, juiciness, and flavor (Scollan et al., 2014). Tenderness, consistency and flavor are the major qualities consumers associate with meat quality. Unfortunately, tenderness is a characteristic that is highly variable and depends on many intrinsic and extrinsic factors and the interactions of these factors in the animal (Destefanis, Brugiapaglia, Barge, & Dal Molin, 2008).

     Fat content of food has received focused attention for decades (Kallas, Realini, & Gil, 2014). Red meat is perceived as a "fatty" protein source with health risks linked to its consumption (Garmyn et al., 2011). Fatty acid composition in meat of production animals has received considerable interest in respect to human health and meat quality characteristics (Smet, Raes, & Demeyer, 2004). Due to consumer demand, increased health awareness, and diet preferences, the composition of animal products has been modified through genetic selection of breeding males and females. Animals have been genetically modified for leaner meats, yet flavor is important to the consumer so fat content is highly valued. The animal science discipline has adjusted and refocused goals to meet consumer demand and health considerations. Overall, improvements have been made in genetics, nutrition, and health management which impact beef quality.

However, the quality of meat may be effected by several different parameters, such as marbling and visible fat which are considered by consumers to be important indicators of beef quality (Dixit et al., 2016). Genetics, nutrition, environmental stresses, age, and health of the cattle also effect meat quality. Genetics influence the animals' body composition (marbling), growth potential, environmental adaptations, as well as behavioral and personality disposition. The "breeding out" of undesirable traits in a herd will lead to an increased production of quality meat.

Physiological factors including nutrition and disease management also affect the quality of meat. Lifelong challenges or a short-term stress can have far reaching consequences on animal production and meat quality. Any illness will affect the production and efficiency of animals. Evidence suggests that acute pre-slaughter stress not only affects muscle color, firmness, and water-holding capacity, but also reduces meat tenderness (Gruber et al., 2010). Along with pre-slaughter stress, the pH change and temperature change during harvest along with the marbling, fat content and location of the cut of meat from the carcass are all influencing factors of meat quality (Ngapo et al., 2002). Meat quality factors are addressed through two separate grading evaluations: USDA Quality grades, and USDA Yield grades. If the meat product is not desirable to the consumer in appearance, taste and consistency, various aspects of animal science have failed the consumer.

Producing a consistent, high quality meat is the beef industry's challenge (Jeremiah, Gibson, Aalhus, & Dugan, 2003). Beef producers are continually looking at ways to increase profit through escalations in growth potential and upgraded carcass composition. Research has found that consumers are increasing their willingness to pay

significant premium prices to buy beef directly from producers (Kuo-Liang Chang et al., 2013). Thus, the question is does the quality of beef that consumers purchase fluctuate from source to source?

**Purpose**

Determine the effect of cooking on tenderness and weight loss of beef loins and ground beef along with measuring two quality parameters (tenderness and cooking loss) of a premium cut of meat to the more commonly consumed ground beef.

**Research Questions**

1). Is there a difference in tenderness and cooking loss between commercial grocery store beef loins and HeartBrand beef loins?

2). Is there difference in cooking loss (weight and size) between commercial grocery store ground beef and HeartBrand ground beef?

3). Does quality and consistency of quality differ between commercial grocery store beef and HeartBrand beef?

## II. LITERATURE REVIEW

**Factors Influencing Meat Composition and Quality**

Several components of meta quality need to be understood when discussing fresh meat. Fresh meat studies have been designed to explore changes in water-holding capacity (WHC), functions and structures of proteases, denaturation and degradation of proteins, and oxidation of muscle tissue. (Hughes, Oiseth, Purslow, & Warner, 2014). One major event effecting the quality of fresh meat is the conversion of muscle (living tissue) to meat (edible tissue).

Muscle is a complex structure composed of fibers, a cytoskeleton, an extracellular matrix and water. Most fresh meat is skeletal muscle tissue. Physiological changes of muscle to meat can affect the components of fresh meat.

**Conversion of Muscle to Meat**

Numerous challenges in the meat industry come from the anatomical and physiological changes in the muscle. Immediately after slaughter, the WHC of the muscle proteins are high and the meat is considered to be tender (Tsai & Ockerman, 1981). Part of the slaughter process includes exsanguination (bleeding out). The animal is dead, but muscle cells continue to function for a period of times. Thus, the conversion of muscle to meat is a process that involves proteolysis and oxidation.

Proteolysis can be defined as the hydrolysis or breakdown of protein into smaller peptides or amino acids, usually this process is catalyzed by enzymes (called proteases). Protein disintegration or denaturation is one of the activities in proteolysis. One of the consequences of proteolysis in the muscle is water mobility (Pearce, Rosenvold, Andersen, & Hopkins, 2011). Degradation of key cytoskeleton proteins by the calpain

system influences the ability of meat to retain water and the location of water retention (Huff-Lonergan & Lonergan, 2005).

Muscular contractions continue in the body after death. Muscular contractions require the use of energy (ATP) and oxygen ($O_2$). Oxygen is no longer available for the muscles cells to use. Anaerobic conversion of glycogen by the muscles causes the buildup of lactate. A buildup of $H^+$ ions leads to an increase of acidity, thus decreasing the pH of the muscle. Once the pH of the meat proteins reaches the isoelectric point (positive and negative charges are equal), the proteins (myosin especially) are attracted to each other and will reduce the water held by and attracted to the meat proteins. Net charge changes in meat proteins causes structures to pack more closely together contributing to shrinkage in myofibrillar lattice spacing (Huff-Lonergan & Lonergan, 2005). Patten stated that the reason pH has such a profound effect on WHC is because of the relationship between pH and muscle swelling (Patten et al., 2008). A range of pH (pH >6.3) effects meat causing it to become dark, firm and dry (DFD). DFD meat is a result of limited glycogen stores in the muscle fibers (Lindahl, Henckel, Karlsson, & Andersen, 2006). Accompanying the higher pH level, $O_2$ consuming enzymes in the meat are active thus promoting the formation of reduced muscle pigment deoxymyoglobin resulting in the purple color. Immediate pre and post-slaughter handling practices can effect tissue pH and thus produce either dark, firm and dry (DFD) or pale, soft, and exudative (PSE) carcasses (Brewer & Novakofski, 1999). Animals that experience pre-harvest stress and lack of rest to replenish the glycogen storage in the muscles before harvest produce the DFD meat due to not being at pH of 5.5.-5.7. (Brewer & Novakofski, 1999; Sawyer, Apple, & Johnson, 2008). Glycogen is needed for

lactate production in the muscle and lack of glycogen subsequently causes higher pH in the postmortem muscle as seen in Figure 1.
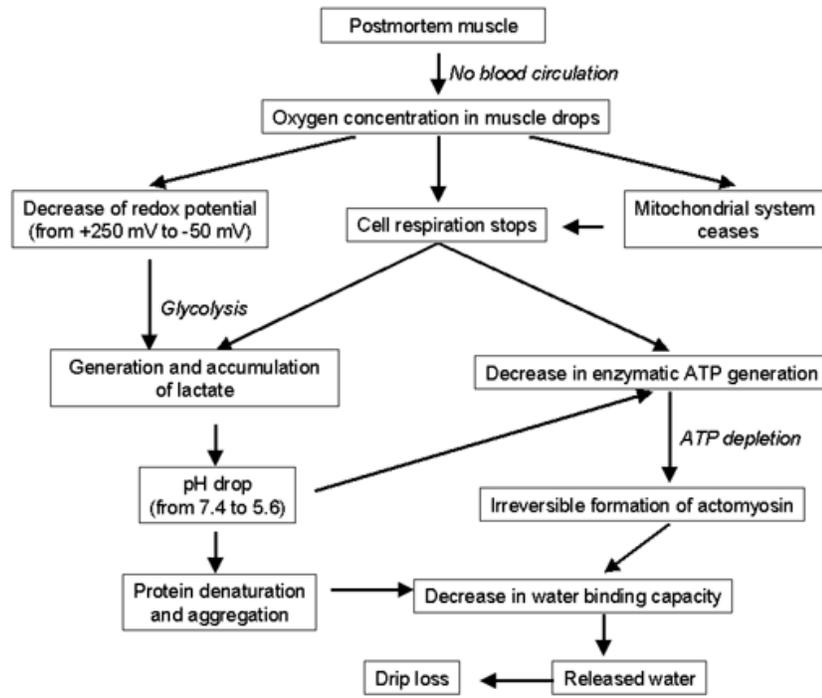


*Figure 1*. Scheme summarizing early post-mortem changes in muscle and its influence on water binding.(Toldra, 2003)

Pale, soft, and exudative (PSE) is a term often used to describe pork, but beef can also be pale in color with moisture exudates on surface have a great drip loss.  High drip loss is associated with an extensive pH decline accompanied by high muscle temperature pre-rigor.  'Heat toughening' or 'heat shortening' are terms used to describe the meat produced.  High rigor temperature increases the toughness of the meat due to excessive muscle contraction at rigor.  Toughness of "heat shortened" meat is not resolved by aging (Warner, Kerr, Kim, & Geesink, 2014).  Low pH and high temperature promotes severe muscle protein denaturation and accelerates the inactivation the of oxygen-consuming mitochondrial enzymes leading to the oxygenation of the muscle pigment to a bright red

oxymyoglobin ($MbO_2$)(Lindahl et al., 2006). Presence of a high level of glycogen in the muscles causes a 5.4-5.3 pH.  Increases in glycogen leads to a longer decline in pH and overall lower pH.  The ultimate pH of meat is 5.6-5.8 (Lonergan, Huff-Lonergan, Rowe, Kuhlers, & Jungst, 2001).  Another hypothesis influencing the pH of muscle is the proximity to bones and the tendinous insertion (Seggern, Calkins, Johnson, Brickler, & Gwartney, 2005).   Both situations caused by a change in pH will decrease the WHC of meat.

Ability of meat to retain water is an essential quality parameter for both the industry and the consumer (Traore et al., 2012).  WHC is influenced by early postmortem pH, temperature decline and naturally accompanying rigor mortis (Li, Li, Li, Hviid, & Lundström, 2011).  Rigor mortis leads to the stiffening of the carcass.  During the conversion of muscle to meat, the key chemical processes are focused on the achievement of rigor mortis (Honikel, 2004).  Conversion of muscle into meat is classified into 3 stages: pre-rigor, rigor, and tenderizing (Ouali et al., 2006). Four basic phases make up the process of rigor:

1).     Delay - muscles are very extensible – glycolysis and mitochondria functioning
        with aerobic metabolism
2)      Onset – muscles lose extensibility – anaerobic glycolysis, increase in lactate,
        increase in $H^+$ ions, decrease in pH
3).     Completion – muscles stiff and rigid – O2 is depleted, mitochondria shut down,
        final pH is reached
4).     Resolution – muscles gain some extensibility as meat is aged

Changes that are initiated at exsanguination of the animal prior rigor mortis include:

- Hormonal stimulation
- Anoxia (lack of $O_2$)
- Glycogen levels drop
- ATP is depleted

- Increase in ion strength ($H^+$)
- Decrease in sarcomere length
- Increase in myofilament spacing
- Microfilament proteins packed closely due to increase electrostatic repulsion
- Increasing intracellular water due to osmotic pressure (Pearce et al., 2011).

Additionally, water movement within the muscle will occur with the disintegration to the cell membrane and an intact cytoskeleton due to:

- Shrinkage of muscle fibers and connective tissue surrounding the muscle fibers
- Perimysium (connective tissue) is broken and water accumulates (4-6 hr post mortem)
- Muscle fibers shrink within the endomysial network
- Accumulation of fluid between the fibers and the endomysial network (Pearce et al., 2011).

Most consumed meats (excluding organs) are composed skeletal muscles. Skeletal muscles have some unique characteristics. Skeletal muscles are the only type of muscle with voluntary control in the body. Muscle cells are multi-nucleated, striated (caused by the Z bands of the sarcomeres) and are arranged in long parallel fibers. Muscle anatomy and physiology determines the development and activity of the muscle fibers (muscle cells are called fibers), muscle bundles and whole muscle. There are different muscle fiber types:

- Slow oxidative (oxidative phosphorylation to generate ATP = more mitochondria, $O_2$ supply, and myoglobin (oxygen binding protein)), or type I (long twitch times, low peak forces and high resistance to fatigue).
- Fast oxido-glycolytic (faster contraction times, maintain force production even after large number of contractions, high in oxidative and glycolytic enzymes and ATPase activity, resistance to fatigue), or type IIA.
- Fast glycolytic (glycolytic fibers have low levels of myoglobin= white fibers) IIX (high contraction rates and extremely large forces, high ATPase and glycolytic activities and low oxidative capacity, fast to fatigue) or IIB.

Muscle fibers are classified generally by contractile and metabolic properties. Fibers are classified into three major types:

- Red (higher activity of oxidative enzymes with slower contractions)
- Intermediate (have alternative metabolic activities)
- White (consumes glucose versus mitochondria respiration and has fast contractions).

Size of the muscle fibers is effected by type of fiber. Slow oxidative fibers have the smallest diameter, fast oxidative fibers have an intermediate size and the fast-glycolytic fibers are the largest diameter. Slow oxidative muscles (high resistant to fatigue) are weight-supporting postural muscles. Generalities have stated that support muscles are more tender than locomotive muscles (Belew, Brooks, McKenna, & Savell, 2003). Intrinsic and extrinsic factors such as gender, age, breed, hormones and physical activity also influence muscle fiber variation. Individual muscle fiber types exhibit different contractile, metabolic, physiological, and chemical morphological characteristics. Muscle metabolic properties are affected by fiber type and influence the conversion of muscle to meat and meat quality (Lee, Joo, & Ryu, 2010).

Composition of beef muscle is 75% water, 22% protein and the other 3% is fat and mineral content. Individual cells (fibers with components) and connective tissue (around different muscle structures) are the main muscle components. Muscle fibers (cells) are made up of myofibrils comprised predominately of proteins: thick filaments myosin), thin filaments (actin) and elastic filaments (titin).

Functional contraction unit of the muscle is called a sarcomere. Three different bands are associated with sarcomeres. Each individual sarcomere is located between two Z bands (darker lines in microscopic view). I bands are the lighter lines (predominately actin filaments) and A band (predominately myosin filaments) as seen in Figure.2.

Bare zone of myosin filament

Actin (thin filament)

Z line

Myosin (thick filament)

Titin
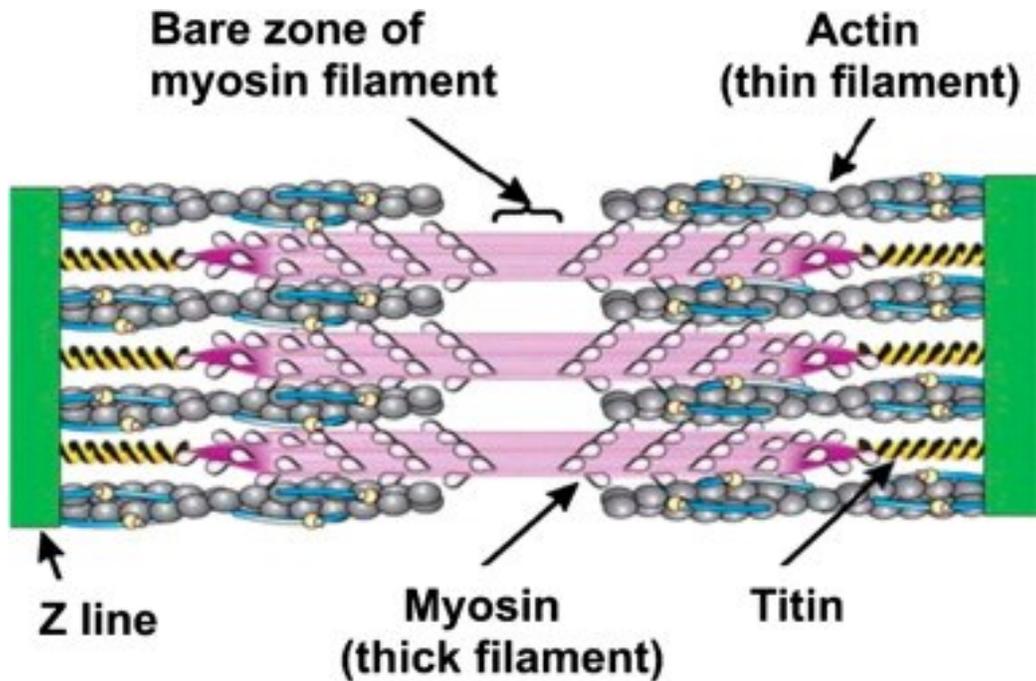
*Figure 2.* Sacromere (Plotnikov, Millard, Campagnola, & Mohler, 2006)

Sarcomere, the contractile unit, is activated when myosin and actin interact (forming actomyosin) causing a shortening in the sarcomere length. Muscle contraction requires $Ca^{2+}$ ions to be present (usually released from the sarcoplasmic reticulum of the cell). $Ca^{2+}$ ions bind with the troponin (troponin and tropomyosin are the regulatory proteins associated with actin) on the actin filaments. Binding causes actin to change its shape and uncover binding sites for the myosin heads (Offer et al., 1989). Myosin heads are triggered when adenosine triphosphate (ATP) binds to it, ATP hydrolyzes, and adenosine diphosphate (ADP) and organic phosphate (Pi) are formed. Energy is released from the conversion of ATP to ADP. Energy then "cocks" the myosin head and forms a cross bridge. Myosin pulls on actin sliding the actin towards the middle of sarcomere. This action shortens sarcomere length and overall muscle fiber.

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The cross-bridge cycle in skeletal muscles has 4 steps. Each cycle involves the hydrolysis of one ATP molecule (calcium is already bonded with troponin on the actin fiber).

1. ATP is hydrolyzed and activates the myosin head.
2. Myosin head changes shape and is "cocked" and binds to the actin filament.
3. Power stroke occurs. Myosin pulls actin filament towards the center of the sarcomere.
4. ATP molecule appears causing the disassociation of myosin and actin.

When there is no ATP for the disassociation of the myosin head and actin, the rigor condition exists. The cross-bridge cycle action continues until there is no $Ca^{2+}$ to bind with troponin on the actin filament or ATP is depleted.

Single muscle fibers have a layer of connective tissue called endomysium. Endomysium lies above the sarcolemma, the muscle cell membrane. Muscle fibers are arranged in bundles called fascicles. Fascicles are covered by a connective tissue called perimysium. Perimysium represents 90% of the total connective tissue in muscles. Muscles vary more in perimysium content than in endomysium content (Lepetit, 2008). Another covering of connective tissue called epimysium covers the whole muscle. Epimysium is continuous with the tendon that attaches the muscle to a bone (Huff-Lonergan & Lonergan, 2005).

The network of connective tissues is called the intramuscular connective tissue (IMCT) (Purslow, 2014). Endomysium, perimysium and the epimysium are part of the IMCT. The IMCT in muscles influences pattern of muscle development, support of nerves and blood vessels of the muscle and how the muscle mechanically integrates with the tissues around it. IMCT content provides the matrix for muscle contraction (Purslow, 2002). Each connective tissue and its degradation directly affect WHC. When pH is low,

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the swelling of connective tissues causes an increase in WHC (Toldra, 2003). Connective tissues determine where the water will accumulate and where the water will be expelled.

Connective tissues are composed of collagen, elastin, and reticulin. Collagen is the predominant fiber type in muscles (Lepetit, 2008; Modzelewska-Kapituła, Kwiatkowska, Jankowska, & Dąbrowska, 2015). Collagen is the most abundant protein in the body.

**Quality and Yield Grading of Meat**

Federal Grading is intended to correlate with market desirability. Carcasses receive both a quality grade and a yield grade. Quality grade indicates the palatability of the lean portions of the carcass. Yield grade represents the amount of edible meat from a carcass.

Relationships between marbling, maturity and carcass quality will determine the USDA Quality Grade. For more than 80 years, the USDA quality grades were determined using visual assessment by graders. In 2006, a 2 camera system was developed to objectively measure the marbling and determine the quality grade. The system improved both accuracy and the precision of beef grading (Emerson, Woerner, Belk, & Tatum, 2013) . Eight different quality grades with 5 maturity groups (A, B, C, D, E) are used during carcass grading. Quality grades for animals under the age of 30 months are Standard, Select, Choice, and Prime. Carcass maturity is determined by examining the skeletal ossification in the top three thoracic vertebra (buttons). An evaluation of rib color and shape helps determine the maturity of the carcass.

Lean flesh color and texture also undergoes progressive changes with age. Lean flesh of the young carcass is very fine in texture and a light grayish red in color. As

carcasses mature, the texture of the lean flesh becomes coarser and becomes a darker red color. A myoglobin increase accompanies maturity, causing a darker red color in the meat (Patten et al., 2008).

In addition to quality grade, the yield grade is also determined on the carcass. Yield grade indicates the percentage of boneless, closely trimmed major retail cuts derived from the carcass. The numbers 1 through 5 are used in grading yield (1 = best yield and 5 = least yield). Yield grade of a carcass is determined by back fat thickness at the $12^{th}$ & $13^{th}$ rib, hot carcass weight, size of ribeye area (at $12^{th}$ rib), and the percent of kidney, pelvic, and heart fat. All these factors together determine the total edible portion of a carcass. Both quality grade and yield grade are critical factors of beef quality and profitability.

**Components of Fresh Meat**

Basic main constituents of skeletal muscle are water, protein, fat, carbohydrate and other soluble compounds (Toldra, 2003). Muscle consists of approximately 75% water, 20% protein, 3% fat and 2% soluble non-protein substances (Tornberg, 2005). The 3 major components of fresh meat are soluble protein (sarcoplasmic), insoluble protein (myofibrillar, cytoskeleton and collagen), and water (Hughes et al., 2014). These components have a direct effect on each other. Patten reported increases in marbling, increases fat content and decreases water content (Patten et al., 2008). Both marbling (fat content in lean portions of meat) and water content of meat have direct relationship with meat quality. Variation in muscle composition are affected by the sex of the animal, yield grade, quality grade, weight of the carcass and function (locomotion or support) of the muscle (Seggern et al., 2005).

**Soluble Proteins**

Soluble proteins in the muscle are made up of sarcoplasmic components including the myoglobin (iron (Fe) and oxygen ($O_2$) binding protein in muscle), the calpain components (protein that binds with $Ca^{2+}$ in muscle), and soluble collagen. Sarcoplasm is the cytoplasm of a myocyte (muscle fiber). Sarcoplasm in muscles contains Golgi apparatus, mitochondria and other cell organelles. Sarcoplasmic reticulum in muscle cells is comparative to the smooth endoplasmic reticulum in other cells. Biochemical changes in the sarcoplasmic proteins that occur early postmortem account partially for variations in meat color and WHC between individual muscles (Li et al., 2011). Studies have reported the formation of protein actomyosin (contractile complex of actin and myosin) would decrease the WHC of the meat (Huff-Lonergan & Lonergan, 2005; Li et al., 2011) . Some muscle collagen is classified as soluble protein. Heat–labile collagen implies an alteration, a change or a destruction of a protein at high temperatures. Heat-labile collagen in bovine skeletal muscle decreases as the animal matures. Decreases in heat-labile collagen are responsible for the age-associated toughness in meat (Patten et al., 2008).

**Insoluble Proteins**

The insoluble protein portion of the muscle includes myofibrillar, cytoskeleton and collagen. Myofibrillar proteins are responsible for the contractile properties of muscle (meat). Myofibrillar components are actin, myosin and titin (also known as connectin). Formation of the protein actomyosin (contractile complex of actin and myosin) decreases the WHC in meat (Huff-Lonergan & Lonergan, 2005; Li et al., 2011).

Actomyosin is formed when the cross-bridges between the actin and myosin

occurs.  Formations of cross-bridges occur during rigor and thus reduce the available space for water to reside. Even though actomyosin decreases WHC of the muscle, early activated proteolytic enzymes degrade cytoskeleton proteins releasing some inter-and/or outer filament space to hold water in muscle fibers (Huff-Lonergan & Lonergan, 2005; Li et al., 2011). So, the effect of actomyosin on the soluble and the insoluble proteins have an offsetting effect on the WHC in the muscle.

While actin and myosin interact to perform contractile functions of muscle, titin functions as a molecular spring and provides the passive elasticity of muscles.  Titin accounts for the muscles' ability to return to the resting state when muscles are stretched and released (titin folds and refolds).  Titin connects the Z band and the M band in the sarcomere limiting sarcomere range of motion and contributing to the passive stiffness of muscle.

Cytoskeletal and regulatory proteins of muscle include vinculin, desmin, nebulin, dystrophin, and troponin T.  Vinculin is involved with the adhesion molecules of the actin cytoskeleton.  Vinculin is the cytoskeletal protein associated with the cell to cell or the cell matrix junctions (anchoring F-actin).  Desmin is a protein that is located in the Z disk of striated muscles.   It connects Z-band to Z-band across the myofilament and play a critical role in the maintenance of structural and mechanical integrity of contractile muscle.  Nebulin is located and associated with actin (thin filament).  The functions of nebulin are regulation of muscle contraction and has a role in calcium homeostasis in muscles.  Dystrophin is the cytoplasmic protein that connects the cytoskeleton of the muscle fiber to the surrounding extracellular matrix through the cell membrane.

Troponin T is part of the troponin complex.  It binds with the tropomyosin and helps position the actin filament during the muscle contraction process.

The percentage of insoluble protein in a muscle will change from one muscle to another.  Skeletal muscle fibers are classified by metabolic and mechanical differences. Collagen is a protein that is unique and specialized.  Primary function of collagen is providing support, strength and helps form an impervious membrane in and around muscle tissue. Collagen content in a muscle is determined by work the muscle is required to do and location as well as proximity to bones and joints (tendons-muscle to bone attachment and ligaments – bone to bone attachment are made of dense compacted collagen fibers= gristle).  Beef muscles are classified as muscles of locomotion or muscles of support (Bratcher, Johnson, Littell, & Gwartney, 2005).  The function of the muscles will have a direct effect on the ratio between the three main components of muscle tissue.

**Water**

The third and major portion of the post-rigor muscle is water (myowater).  Water in the muscle is used for a lubricant and a transport of metabolites to and in the muscle fibers.  Composition of beef muscles is approximately 75% varying with the age of the animal (Kolczak, Krzysztoforski, & Palka, 2007).  WHC in meat is based on the electrostatic forces or osmotic forces, causing swelling of myofibrils (Puolanne & Halonen, 2010).  Water (moisture content) in the muscle can be held either within the myofibrils, between the myofibrils, between the myofibrils and sarcolemma (cell membrane), between the muscle cells or between the muscle bundles (Huff-Lonergan & Lonergan, 2005).

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The majority of water in the muscle is held by capillary forces within the myofibrils (Huff-Lonergan & Lonergan, 2005; Hughes et al., 2014).  Water is a unique dipolar molecule with a V-shape.  Due to structure, water is attracted to charged particles like proteins.  Water directly bound to the surface of proteins have a strong binding through polar and charged groups and form a primary shell.  A weaker interaction is formed when water is located in the second position which forms a secondary shell (Toldra, 2003).

Three type of water are present in muscles; each differing in the degree of its freedom (Kolczak et al., 2007). Free (16-18%), immobilized (74-75%) and bound (7-8%) water comprise muscles.  Water is named by the location in the muscle. Four locations of water in muscle are:

- Intra-myofibrillar (between the myosin and actin)
- Inter-myofibrillar (in sarcoplasm space between myofibrils)
- Inter-fascicular (space within individual fascicles)
- Extra-fascicular (space around individual fascicles)
  As seen in Figure.3.
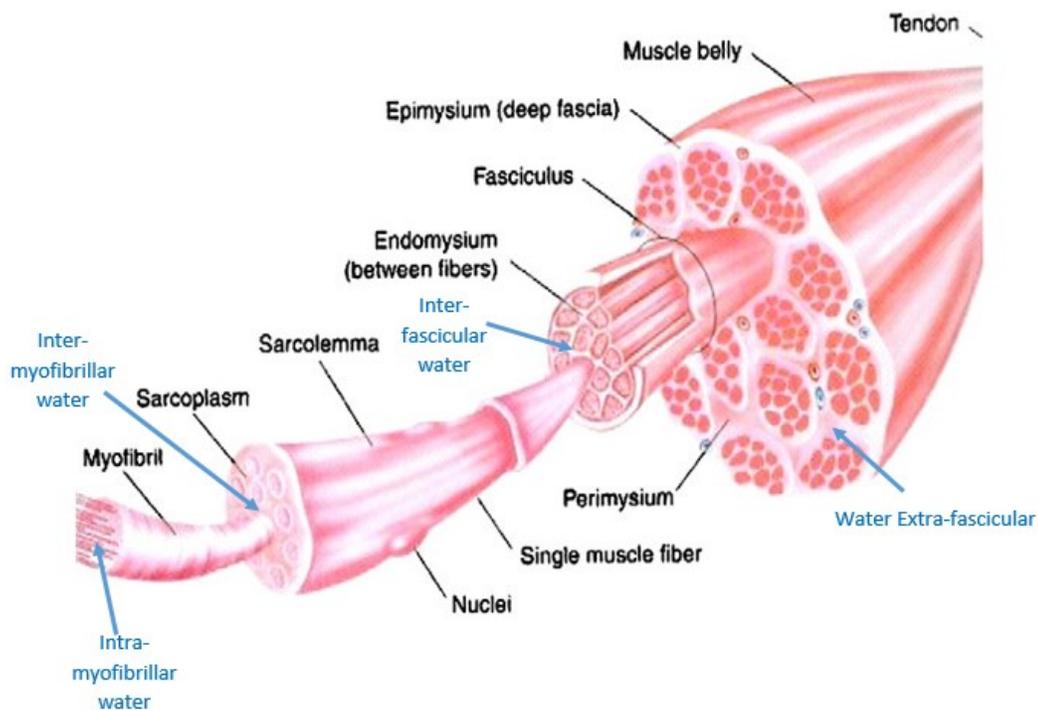
*Figure 3*. The muscle split into components and the locations of muscle water compartments: the intra-myofibrillar component and the extra-myofibrillar component which is comprised of the inter-myofibrillar, inter-fascicular and extra-fascicular water populations (Baechle & Earle, 2008)

Intra-myofibrillar space is reported to contain about 85% of the myowater while the remaining 15% is located outside the myofibrillar network in the extra-myofibrillar (inter and extra-fascicular spaces)(Pearce et al., 2011).

**Free Water**

When meat is cut, fluid (free water) will drain from the surface under gravity if the capillary forces do not retain it (Honikel, 1998). The flow of free water from the tissue is unimpeded. Holding forces of this fraction of water in the meat are weak surface forces. Free water is disassociated from the meat by either gravity, pressure on the tissue, or processing procedures such as cutting. Free water is referred to as 'drip

loss'.  Drip loss is defined as the fluid (containing mainly water and proteins) which can be expelled from meat without mechanical force other than gravity.   Drip loss depends on shortening of sarcomeres regulated by the interaction of muscle temperature and rigor development (Fischer, 2007).

**Immobilized Water**

Immobilized water is called entrapped water.  Immobilized water is "in flux". The amount of immobilized water is dependent on the available space between the myofibrils in the sarcomere (Toldra, 2003).  It is not a permanent part of the muscle protein, but it is held by steric effects or attraction to the bound water (Kolczak et al., 2007).  Immobilized water at times will be sharing an H+ with a closely associated amino acid so that it is trapped.  Immobilized water "falls out" of the muscle tissue when free water amount increases. Immobilized water is held in the structure of the muscle, but is not bound to a protein.  This water doesn't flow freely from the tissue, but can be removed by drying or converted into ice by freezing.

Immobilized water is the highest percentage of water in the muscle and has a bigger influence on WHC.  This portion of water in the muscle is most affected by the processes of rigor and muscle to meat conversion (Huff-Lonergan & Lonergan, 2005). Alteration of muscle cell structures and a decrease in pH can cause a loss of this water resulting in an escape called a purge.

Free water and immobilized water are termed as expressible water content. Expressible water content represents free water in meat tissue, that is held only be capillary forces and can be easily removed from meat using external forces (Huff-Lonergan & Lonergan, 2005).  Movement of the water is mainly due to changes in

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myofibril spacing (Pearce et al., 2011). Expressible moisture is the amount of liquid that can be removed from a sample when force is applied (Patten et al., 2008).

**Bound Water**

Bound water, constitutional water or protein-associated water is the third type of water in meat (Apple & Yancey, 2013; Pearce et al., 2011). Bound water is the smallest faction of total water in the muscle (less than 10%). Polar groups of the side chains of the amino acids in the meat proteins bind the water molecules on surfaces by Van der Waals forces (Puolanne & Halonen, 2010). Bound water strongly interacts with hydrophilic sites of proteins. Bound water has little if any mobility, very resistant to freezing and evaporation by heat. Bound water is called unfreezable water (Kolczak et al., 2007).

WHC is defined as the ability of fresh meat to retain its own water during the various and multiple meat processing procedures of cutting, heating, grinding and pressing and during transport, storage and cooking (Pearce et al., 2011). Release of water from meat can be described as drip, purge, weep, exudate or cook loss (Warner, in press). For the consumer, low WHC has a detrimental impact on appearance in fresh meat cuts for retail and influences the sensory quality of the meat end-product (Offer et al., 1989). Water is the major portion of the muscle tissue and it affects the appearance, color, tenderness and quality of meat.

WHC of meat has a direct correlation with the perceived quality of the meat and the overall profit to the producer. The rate and quantity of drip formation in fresh meat is dependent on the pressure exerted by the weight of the meat cut as well as externally applied pressure (Hughes et al., 2014). Research studies have been conducted where the

carcass is hung from the pelvic girdle versus the Achilles tendon.  Further, smaller animal species have a greater WHC due to less external pressure on the carcass during the hanging and ageing process (Warner et al., 2014).

WHC is effected by many factors.  Factors range from the stress the animal experiences prior to slaughter through the steps in processing meat products.  A few things can be done to help curtail water loss in meat.

One prevention step is to limit the influencing factors of pH, post-mortem muscle metabolism and control post-mortem muscle temperature.  All of these are key factors connected to drip loss (free water) (Traore et al., 2012).  Structurally, drip loss is believed to be principally influenced by:

- Extent of lateral and transverse shrinkage of myofibrils and interfilament spaces at rigor (Offer et al., 1989).
- Permeability of the cell membrane to water (Huff-Lonergan & Lonergan, 2005)
- Development of drip channels, extracellular space (Bertram, Purslow, & Andersen, 2002).
- Post-mortem cytoskeletal protein degradation (Hughes et al., 2014; Kristensen & Purslow, 2001).

It has been noted that as marbling increases, fat content also increases, and water content decreases in a linear fashion.

Storage conditions have a great influence on the WHC of meat.  Storage temperate should be as low as possible without freezing to maintain the WHC.  Freezing and thawing of fresh meat has a profound impact on drip loss of meat moisture.  Physical disruptions caused by ice crystals formed in the meat are part of the increase in drip formation.  Ice formation in the meat begins at $-1^0$C and at $-5^0$C.  Approximately 75% of the water in meat is ice.  Maximum ice formation occurs at $-20^0$C , at which point 92% of the water in meat is ice (bound water is resistant to freezing even as low as $-35^0$C)

(Cooke & Wien, 1971). Freezing rate of meat can have a large impact on the amount of drip lost upon thawing. Freezing quickly (i.e. flash frozen) favors the formation of small ice crystals while slow freezing favors the development of larger ice crystals. The large crystals can actually cause expansion and even rupture of cell membranes and will increase the amount of drip loss (free water) from the meat.(Bevilacqua, Zaritzky, & Calvelo, 1979).

**Interactions of Fresh Meat Components**

Interactions between soluble protein, insoluble protein and water affect the others throughout the transition of living tissue (muscle) to dead tissue (fresh meat). Changes in length, strength and location of structures directly impact other components of muscle. Water loss from the muscle is impacted by myofibrillar lattice spacing, membrane permeability, extracellular space and drip channel formation. Proteins in the muscle are both pH and temperature sensitive and influence the extent of the structural changes (Hughes et al., 2014).

Protein fraction within muscle with the greatest influence on WHC is the water-soluble collagen. More water-soluble collagen content in meat, more WHC within the meat (Modzelewska-Kapituła et al., 2015).

**Effect of Aging on Fresh Meat**

Postmortem conditioning is a term for ageing and has a positive influence on the reduction of the strength of connective tissues in meat (Purslow, 2005). Post-mortem ageing has a significant effect on the microstructure and quality traits, especially texture, tenderness and WHC of meat (Zamora et al., 1996). Ageing assists in the conversion of collagen from insoluble to soluble. In addition, species and age influences collagen

content helping to determine tenderness and toughness of meat (Silva et al., 2015). Main structural changes of ageing tenderization take place in the Z band of the sarcomere (Palka, 2003). Tenderization is caused by proteolysis of myofibrillar and cytoskeletal protein (Modzelewska-Kapituła et al., 2015; Nishimura, Liu, Hattori, & Takahashi, 1998). A variety of enzymes promote tenderization by denaturing intramuscular connective tissues (Purslow, 2014). Degree of cross-linage between collagen molecules affects meat tenderness (Jeremiah, Dugan, Aalhus, & Gibson, 2003; Ngapo et al., 2002). Collagen solubility decreases with age (Jeremiah et al., 2003). Meat from old animals is less tender compared to young animals (Lepetit, 2008; Modzelewska-Kapituła et al., 2015).

One of the methods of improving tenderness and maintaining WHC is postmortem ageing (Modzelewska-Kapituła et al., 2015). During post-mortem ageing of meat, water becomes tightly trapped in the protein networks. (Kolczak et al., 2007). Structural changes in the extracellular matrix takes place after 14-28 days post-mortem (Nishimura et al., 1998). One study noted that ageing a *semitendinosus* muscle at $4C^0$ for 5 days to 12 days caused a twofold increase in collagen solubility and the parameters of toughness had a twofold decrease (Palka, 2003). Furthermore, after ageing for 28 days, beef longissimus muscles display almost double the concentration of free amino acids compared to non-aged muscles, indicative of the degradation of proteins (Hughes et al., 2014). No significant differences in the effect of aging between the different muscles has been reported (Bratcher et al., 2005). According to Farouk (2012), the improvement of WHC during ageing results from the destruction of meat structure and the creation of a "sponge effect"(Farouk, Mustafa, Wu, & Krsinic, 2012).

**Structural Changes in Cooked Meat**

Cooking is essential to ensure meat product preservation, to be palatable and to eliminate pathogenic microorganisms making meat safe for consumption (Tornberg, 2005; Trevisan, Lima, Sampaio, Soares, & Bastos, 2016). Heat solubilizes connective tissues which leads to tenderization, but heat also denatures the myofibrillar proteins causing hardening and toughening of meat (Obuz, Dikeman, Grobbel, Stephens, & Loughin, 2004). Many studies strive to correlate structural and biochemical changes in fresh meat (e.g. due to ageing, animal's maturity, level of nutrition, animal genotype) without considering effect of the cooking processes (Hughes et al., 2014).

Attributes of quality include cooking loss, color, and texture which are closely tied to the chemical and physical characteristics of meat proteins (Niu, Rasco, Tang, Lai, & Huang, 2015). Beef muscle composition including WHC, color and micronutrient content are modified by heating. During the cooking process, water has an important role in the generation of toughness and appears to be influenced not only by collagen, but also by other myofibrillar and cytoskeleton proteins (Hughes et al., 2014).

When proteins in meat are denatured by heating, it affects the WHC. Release (becoming disassociated with proteins) and migration of water in meat is related to the denaturation, contraction, and rigidity of the myofibrillar structures and protein caused by the increase of temperature during cooking (Hughes et al., 2014; Kondjoyan, Oillic, Portanguen, & Gros, 2013). Li observed that the solubility of myofibrillar proteins had no significant correlation to color attributes or WHC of meat (Li et al., 2011).

Proteins on the surface go through denaturation when being cooked and will become hydrophobic. Meat proteins will repel water and release it from the tissue.

Hydrophobicity of the protein surface in the meat increases rapidly after heating. Cooking increased hydrophobicity of surface proteins and was not dependent on the amount of drip loss. (Traore et al., 2012). Traore stated that no matter the amount of free water in a cut of meat, cooking caused the muscle tissue to "push" more water from its surface (Traore et al., 2012).

Physico-chemical processes are occurring during the heating of meat and causes significant changes in microstructures, WHC, and texture (Palka, 2003). Changes occurring during cooking and heating are similar to muscle-meat-conversion. Sarcoplasmic, myofibrillar and connective tissue proteins all undergo denaturation during heating (Kolczak et al., 2007). Denaturation of muscle proteins have been linked to tenderness, juiciness and color (Kondjoyan et al., 2014). Meat proteins denature at different temperatures. Myosin is known to denature at about 54-58$^0$ C (130-136$^0$ F). Actin, actomyosin complex and titin denature around 80$^0$C (176$^0$ F) (Tornberg, 2005). The denaturation of the proteins will cause the following structural changes:

- destruction of cell membrane
- shrinkage of transverse and longitudinal fibers
- aggregation of sarcoplasmic proteins
- shrinkage of connective tissues.

All these events, particularly the connective tissue changes, result in cooking losses in meats (Honikel, 1998). Protein denaturation and contraction of muscle structures due to temperature change during cooking causes the majority of the water loss (Kondjoyan et al., 2013). An increase of myofibrillar structure rigidity accompanies the denaturation of proteins and water loss during cooking (Hughes et al., 2014). Water expelled from the myofibers by heat circulates in channels formed by the shrinkage of the perimysium, endomysium and myofiber bundle network (Bouhrara, Clerjon, Damez,

Kondjoyan, & Bonny, 2012).  Collagen contraction is a factor in meat shrinkage and water transport during cooking, but there is some debate over exactly what the role of collagen is in  muscle shrinkage and fluid expulsion  (Bouhrara et al., 2011; Bouhrara et al., 2012; Hughes et al., 2014).

**Effects of Cooking on Meats**

Many factors need to be considered when cooking meat:  cooking temperature, cooking time, meat pH, collagen content, ageing and even the state of the meat before it is cooked – frozen versus thawed.  It has been expressed that ideally cooking should be carried out from the frozen state, but if thawing is necessary, then it must be specified as thawing will allow further ageing (Honikel, 1998).  Actually, freezing meat has shown to affect the WHC of meat due to the ice crystal formation and the rupture of cell membranes due to freezing expansion. Typically, freezing and thawing meats decrease the WHC and increases free water, except ground beef due to the cellular damage that takes place during the grinding process (Tsai & Ockerman, 1981).

  **Temperature and Time**

Correlation between the WHC of fresh muscle (meat) and cooking loss can be high, but is dependent upon cooking temperature.  While cooking, meats can lose a large quantity of mass in the form of meat juice and the amount of loss is temperature and time dependent (Hughes et al., 2014).   Temperature range from $40^0$ to $60^0$ C ($104 – 140^0$ F) induces transverse shrinkage to occur in the myofibrils as well as the muscle cell (Hughes et al., 2014).  Toughness of the meat has been recorded to increase between $40^0$ to $50^0$C ($104^0 – 122^0$ F) due to contraction of perimysial connective tissue, decreases toughness between $50^0$- $60^0$C ($122^0 – 140^0$F) and increases again between $60^0$-$80^0$C ($140^0 – 176^0$ F)

because of the denaturing of myofibrillar proteins (Bouhrara et al., 2011; Christensen, Purslow, & Larsen, 2000). One study found different percentage loss of WHC was cooking temperature dependent. Cooking loss was 20% at $80^0$C ($176^0$F) and at $60^0$ to $70^0$C ($140$-$158^0$F) cooking loss increased to 55-58%. The explanation for the difference in cooking loss was a different drip loss of fresh meat (Hughes et al., 2014).

Although an increase in WHC is associated with the swelling of muscle fibers during ageing, this is not translated into lower cooking loss (Straadt, Rasmussen, Andersen, & Bertram, 2007). Effect of aging and cooking loss has been an area of conflicting findings. Hughes found higher water loss when cooking aged meat, but the amount of loss was dependent on the length of ageing (Hughes et al., 2014). It was also being reported that cooking loss is not affected by ageing time (Modzelewska-Kapituła et al., 2015). Additionally, it was reported that if the muscles were exposed to higher pre-rigor temperature resulting in myosin denaturation, the cooking loss was high regardless of the ageing period (Hughes et al., 2014; Warner et al., 2014). Even though ageing meat correlates with increased tenderness and juiciness, it does not equate with lower water loss during cooking.

Another aspect of temperature on the tenderness of meat is the effect on the sarcoplasmic proteins and enzymes. Low temperature and long heating time on beef muscles has shown that collagenase remains active until about $60^0$C ($140^0$F). The enzymes are inactive with faster heating and higher end temperatures (Tornberg, 2005).

## pH

In addition to temperature, time and ageing of meat, pH has an influence beyond the conversion of muscle to meat. Strong evidence shows increasing tenderness as the

pH increased from 6 to 7 (Bouton, Shorthose, & Harris, 1971). As early as pre-slaughter stress, pH has played a role in denaturation of proteins, WHC and quality of the meat product. During the cooking process, pH continues to have an effect on water loss. Cooking losses at $90^0$ C ($194^0$ F) were constant with increasing pH of the fresh meat at 42-43% until pH 5.9. Then it decreases linearly to approximately 31% at pH 6.8. Cooking losses at $65^0$ C ($149^0$ F) decreased linearly as fresh pH increased. Relationship between cooking loss and cooked pH were similar to cooking loss and fresh pH, except the values were displaced or shifted due to the rise in pH produced during the cooking process (Bouton et al., 1971).

**Connective Tissue**

Another component of meat that has not been discussed yet with the aspect of cooking is the intramuscular connective tissue (IMCT). Collagen components of the IMCT content of meat has been recognized as the toughness of cooked meats (Ngapo et al., 2002). Epimysium layer of the IMCT is often removed from the meat prior to the cooking process. After removing the epimysium, the main contributors of the IMCT left in the meat are the perimysium and the endomysium. Perimysial network in cooked meat is what determines degree of difficulty in pulling the meat apart (Purslow, 2014). Purslow stated that there are 3 different effects that cooking has on the IMCT in meat that will influence the toughness of the meat:

1). Intrinsic strength on the perimysium and endomysium changes. Collagen becomes soluble and proteins in the insoluble collagen becoming denatured during the heating process.
2). Shrinkage of meat during cooking increases the concentration of perimysium and endomysium in the meat.
3). WHC decreases as the IMCT network shrinks due to the heating of the meat (Purslow, 2014).

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Connective tissues directly influence the WHC of meat. Contraction of the collagen in meat occurs between $58^0$ C ($136^0$ F) and $65^0$ C ($149^0$ F). A significant negative relationship was found between expressible (free and immobilized) water content and water soluble collagen. This indicates that the WHC of fresh meat corresponds with water-soluble collagen content in cooked meat (Modzelewska-Kapituła et al., 2015). No relationship between the WHC attributes and total collagen was found. Part of the collagen when it is heated is soluble, but the degree of solubility will decrease as the age of the animal increases. Additionally, ageing, pH, and other chemical changes affect soluble or insoluble collagen characteristics. It has been reported that the quantity of soluble collagen in meat roasted to $80^0$ C ($176^0$ F) increases (Palka, 2003). Consumption of cooked meat with higher amounts of soluble collagen may have more health benefits than the meat with higher amounts of insoluble collagen. Thus, application of postmortem ageing to beef production may beneficially affect not only sensory quality, but also its nutritional and health –promoting value (Modzelewska-Kapituła et al., 2015).

**Tenderness**

Meat tenderness is described as the most important factor influencing consumer satisfaction (Koohmaraie & Geesink, 2006; Silva et al., 2015). Tenderness is a main factor in the consumers' perception of meat quality, taste and satisfaction. Human perception of palatability is a complex interaction of sensory and physical processes that occur during chewing (Caine, Aalhus, Best, Dugan, & Jeremiah, 2003). A challenge in the beef industry is the high variability of tenderness and being able to supply the tender beef (Van Wezemael, De Smet, Ueland, & Verbeke, 2014). Tenderness of beef muscles

has been linked to breed, nutrition, work demands, age of animal, degree of crosslinking in connective tissue, contractile status of the muscle and intramuscular fat content. These factors contribute to tenderness differences between different muscles from the same carcass (Belew et al., 2003). Crosslinking of collagen in older animals has been correlated with tougher meat (Purslow, 2005; Voges et al., 2007).

Tenderness development is dependent on the architecture and integrity of the muscle cells and biological events that modify the muscle proteins (Huff Lonergan, Zhang, & Lonergan, 2010). Tenderness is known to increase as meat marbling increases. Additionally, it has been found that sex of the animal effects tenderness and marbling relationship due to the differences seen between steers and heifers (Emerson et al., 2013). Perimysium tissue arrangement (which defines the muscle fascicle size or grain size (graininess) of meat) has been used as an indicator of tenderness (Purslow, 2005). A key event in tenderization has been summarized as the weakening of the myofibers. Tenderness of meat is determined by:

1) Amount and solubility of connective tissue (background tenderness)
2). Sarcomere shortening during rigor development (toughening phase)
3). Postmortem proteolysis of myofibrillar and associated proteins (tenderization phase)
 (Koohmaraie & Geesink, 2006)

Three major cytoskeletal structures are degraded in tender meat:

- Z to Z line attachments (desmin main composition)
- Z and M line attachments to the sarcolemma and titin
- Titin (elastic) filament protein (Koohmaraie & Geesink, 2006)

Two factors with direct and cooperative influence on the tenderness of the meat are pH and proteolysis activity. Both initial and final pH effect the tenderness of meat. Postmortem glycolysis has a direct relationship on the pH of meat. Increased tenderness

was observed with a rapid pH decline during the first 10 hours of postmortem (Veiseth-Kent, Hollung, Ofstad, Aass, & Hildrum, 2010). A positive correlation has been observed between Warner Bratzler shear force measurements and pH. Leptit stated no correlations were found between the collagen content of cooked meat and meat tenderness (Lepetit, 2008). Although Ngapo reported a low correlation between the two meat components (Ngapo et al., 2002).

Along with pH, the calpain-mediated proteolysis is the other factor in tenderness. The calpain activities occurs in the myofibril structure of the muscle and leads to increased fragmentation of myofibrils during the storage and aging of meats (Taylor, Geesink, Thompson, Koohmaraie, & Goll, 1995) . Skeletal muscle has at least three proteases (m-caplain, calpain 3, µ-calpain, and calpstatin (inhibitor of µ and m-calpain)) in the calpain system. After activation by calcium, the calpain system degrades substrates and will autolyze. M-caplain and calpain 3 are not involved in the post-mortem tenderization.

Muscle fiber type is known to influence meat tenderness. Muscles mainly composed of Type II fast fibers are more susceptible to early postmortem proteolytic degradation then Type I slow fibers muscles. However, it has also been observed that increasing the proportion of slow-twitch Type I fibers has improved tenderness in cattle. Correlations have not been fully established between muscle fiber type, tenderness and intramuscular fat and meat toughness (Lee et al., 2010).

Another tenderization theory states that part of the conversion of muscle of meat involves the action of cathepsins and apoptosis of the muscle cells (Ouali et al., 2006).

The tenderness of meat is commonly measured by using a Warner-Bratzler Shear

Force (WBSF) machine. Peak force as recorded by a Warner-Bratzler shear test has

traditionally been the instrumental measurement that correlates with toughness of meat

and consumer satisfaction.  Numerous factors can affect the result of WBSF

measurements, but three commonly debated factors are cookery method including

endpoint temperature, steak and core location, and the orientation of the core in respect to

the direction of muscle fibers (Silva et al., 2015).  WBSF has proven to be a valuable tool

to the beef industry not only determining steaks with acceptable palatability to

consumers, but also help to identify cuts that need improvement (Guelker et al., 2013).

**Color**

One of the final issues to discuss is that of the color of the meat after the cooking

process. Solubility of myofibrillar proteins showed no significant correlations with meat

color attributes (Li et al., 2011).  The color change due to temperature increase is initially

due to myoglobin denaturation.  Color change from red to pink occurs at $60-70^0$ C (140-

$158^0$ F).  The color change from pink to grey – light tan occurs between $70-80^0$ C (158 -

$176^0$ F) (Kondjoyan et al., 2014).  Water loss induced by cooking or during ageing could

reduce the myofibrillar lattice space, fiber diameter and impact the osmolality,

contributing to increase in lightness of the meat surface (Hughes et al., 2014).  Although

the cooking process would change the color of the meat, the color still needs to be a

tailored to the consumers' preferences.  Maillard reaction is the browning of the meat as

it cooks.  At the temperature threshold of $85^0$ C ($185^0$ F), the Maillard reaction begins

(Kondjoyan et al., 2014).  This reaction takes place as amino acids (protein building

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blocks) and glucose combine and reacts together with the heat. The result is an eye pleaser for the consumer and has a direct correlation to the enjoyment of eating the meat.

**Cooking in Smoker**

Advantages of using the smoker to cook meat is that the temperature, airspeed, relative humidity, and smoke density are controlled. Sawdust is metered and distributed on a heated surface causing smoldering and smoke (Romans, Costello, Carlson, Greaser, & Jones, 2001). Natural wood smoke has 3 principal phases: solids (ash and tar), noncondensibles (air and combustion gases), condensibles (acids, carbonyls, phenolic and polycyclic hydrocarbons. Condensibles significantly influence flavor, aroma and preservation properties of smoked products. Smoke's phenolic element is the main source of the smoky aroma and flavor. Carbonyl is attributed with producing the consumer pleasing amber-brown color of smoked meats (Romans et al., 2001). Smoking is done at a moderate temperature to prevent case hardening (drying and overcooking product surface).

**Ground Beef**

Ground beef is versatile, economical, easy to prepare and one of the most popular meat products of consumers. Weekly consumption of ground beef has been reported with approximately 25% of every slaughtered steer and heifer becoming ground beef (Moon et al., 2016). Ground beef typically has as fat content between 20-30%. Increasing fat content has a direct correlation with increasing cooking loss and residual juiciness of patties (Troutt et al., 1992). Color stability of ground beef has been observed to change depending on the muscles that are ground together (Raines, Hunt, & Unruh, 2010).

**American Akaushi Beef**

Japanese cattle produce characteristically high quality beef with extreme marbling (Uemoto et al., 2011). Increased marbling in the Japanese breeds has been attributed to the intramuscular adipocytes being smaller indicating immaturity and more proliferation in the cells (Kawachi, 2006). Akaushi beef is higher in monounsaturated fatty acids (MUFA) content and has a lower melting point in intramuscular fat (Scollan et al., 2014). Ruminant animals naturally produce conjugated linoleic acid which has potential health benefits including a reduction in cancer, cardiovascular diseases, diabetes, obesity and helps to boost the immune system (Kallas et al., 2014).

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# III. Materials and Methods:

**Research Design**

Two sources of beef were used in these studies. Control meat was obtained from a commercial grocery store in San Macros, TX. Treatment meat was obtained from HeartBrand beef company (Akaushi breed of cattle). Two shipments (two weeks apart) from HeartBrand of three loins were received at the University on a Tuesday. Loins were stored in the cooler, and one loin was processed each day. Twenty pounds of ground beef for the study was shipped with the second shipment of loins.

Experiment one was conducted on premium cuts of meat – the loin. Roasts of the loin roasts consisted of the *Longissimus* muscle, along with pieces of the *Iliocostalis* and *Spinalis dorsi* muscles attached as shown in Figure 4.
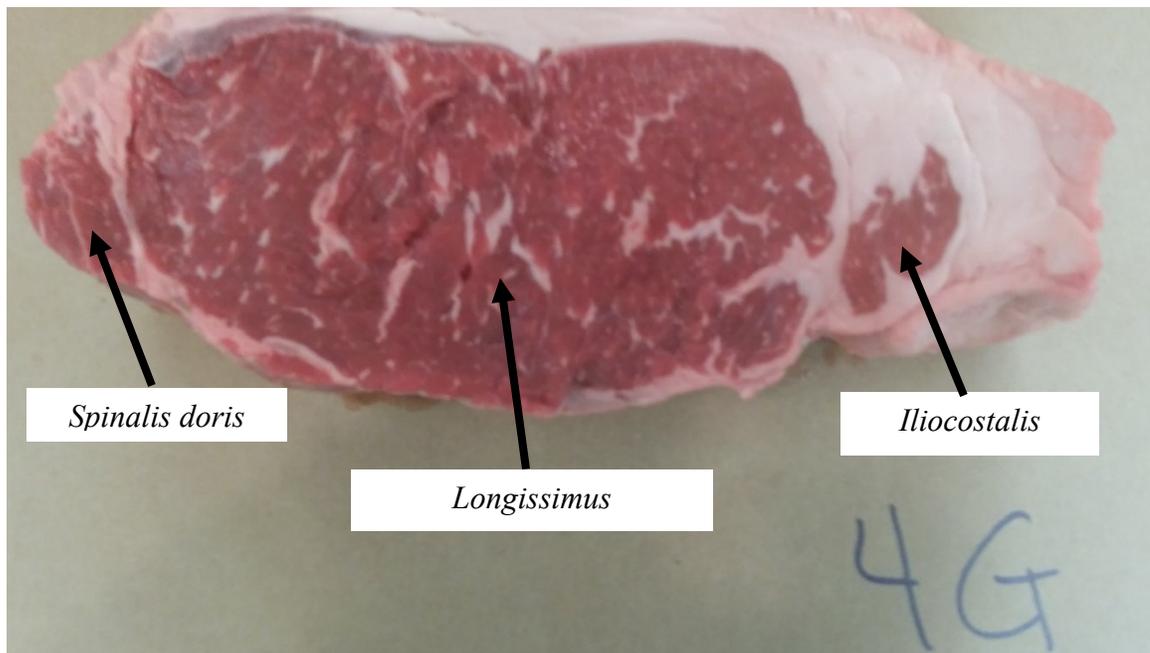


*Figure. 4*. Roast from HeartBrand F loin showing the three muscles present in the roasts. (Only the *Longissimus* muscle was cored to test tenderness)

Experiment two was conducted on a common, less experience meat – ground beef.  Meat was stored in a Bally Thermobalance Refrigeration system (Bally Case and Cooler Inc, Bally, PA) at $33^0$F.

**Procedures for Loin Experiment**

Whole loins were received and cut into 6 roasts weighing approximately 2-2.5 pounds each.  Whole loin and dividing of loins into roasts as shown in Figures 5 and 6.



*Figure 5*. Whole loin before division



*Figure 6*.  Dividing whole loin into six roasts weighing approximately 2 to 2.5 pounds

Loins were weighed, placed into an UltraSource smoker (Model # 350003) and cooked at $220^0$F to an internal temperature of $165^0$F.  The internal temperaure of $165^0$F was selected because between $140^0$F and $176^0$F an increase in both soluble collagen and toughness of meat (due to the denaturing of myofibrillar proteins) has been reported (Bouhrara et al., 2011; Christensen et al., 2000; Palka, 2003).  Internal temperature of the thickest roast of the loin was tracked by the internal thermometer probe of the smoker which shuts the smoker off when the desired temperature of $165^0$F is reached.  Hickory sawdust was used in the smoking and cooking process.  Smoker and arrangement of roasts on tray to be put in the smoker are seen in Figure 7.

7(a)                                          7(b)

*Figure 7*.  UltraSource Smoker (Model # 350003) 7(a) and the arrangement of the loin roasts for cooking on the tray placed in the smoker 7(b):  Roast #1 was placed at the front of the tray and Roast #6 at the back of the tray

Internal thermometer of the smoker was placed in the thickest portion of heaviest roast. Thermometer was placed in roast #2 of the loin as seen in Figure 8.



*Figure 8*. Picture of the 6 roasts of a loin after being cooked and smoked. The internal thermometer probe as shown placed in Roast # 2

Roasts were then weighed. Temperature was taken in 3 locations of the roasts (small end, large end and middle all on the face surface of the roast). Roasts were then allowed to cool for 30 minutes at room temperature (57-59$^0$F). It has been observed that during the air cooling of meat, energy accumulates in the meat close to the surface and can increase the temperature at the center of the meat. Liquid expulsion often seen during cooling of meat is due to protein denaturation and tissue contraction caused during the cooking process. These processes continue until the temperature throughout the meat falls below 30-40$^0$C (86 – 104$^0$ F). Water evaporation during air cooling has also been observed to be an added factor to cooking loss in meat (Kondjoyan et al., 2013).

After the cooling time, temperatures of the roast were taken again at same

locations. The roasts were placed in gallon size, freezer Ziploc bags and placed in the

cooler (30-32$^0$ F) for overnight.

After 20 -28 hours, the roasts were removed from the cooler one at a time.

Temperatures of each roast were taken in three locations and recorded.  Process of taking

the meat temperature in three locations of the roasts is presented in Figure 9.



*Figure 9*.  Temperature of the roasts were taken in 3 locations of the roast on the face surface of
the roasts.  The procedure was conducted four times: after cooking and weighing the roasts, after
the 30 minutes at room temperature cooling of the roasts, the next day before the coring of the
roasts, and after the coring of the roasts

Roasts (only *Longissimus* muscle) were then cored and tenderness tested.

Tenderness of each core was measured by the Warner-Bratzler Shear Force Device

(WBSF), Model # GR-151, (G-R Manufacturing, Tall Grass Solutions, Manhattan, KS).

After the roasts have been in the cooler overnight, six cores were taken from each roast

and tested.  Cores were taken in different locations in the roast, but approximately the

same regional area from roast to roast.  Each core was sheared once in the center of the

core.  Coring instrument along with the Warner-Bratzler Shear Device are pictured in

Figure 10 and a picture of two cored roasts with the location of the cores labeled in the

roast is pictured in Figure 11.
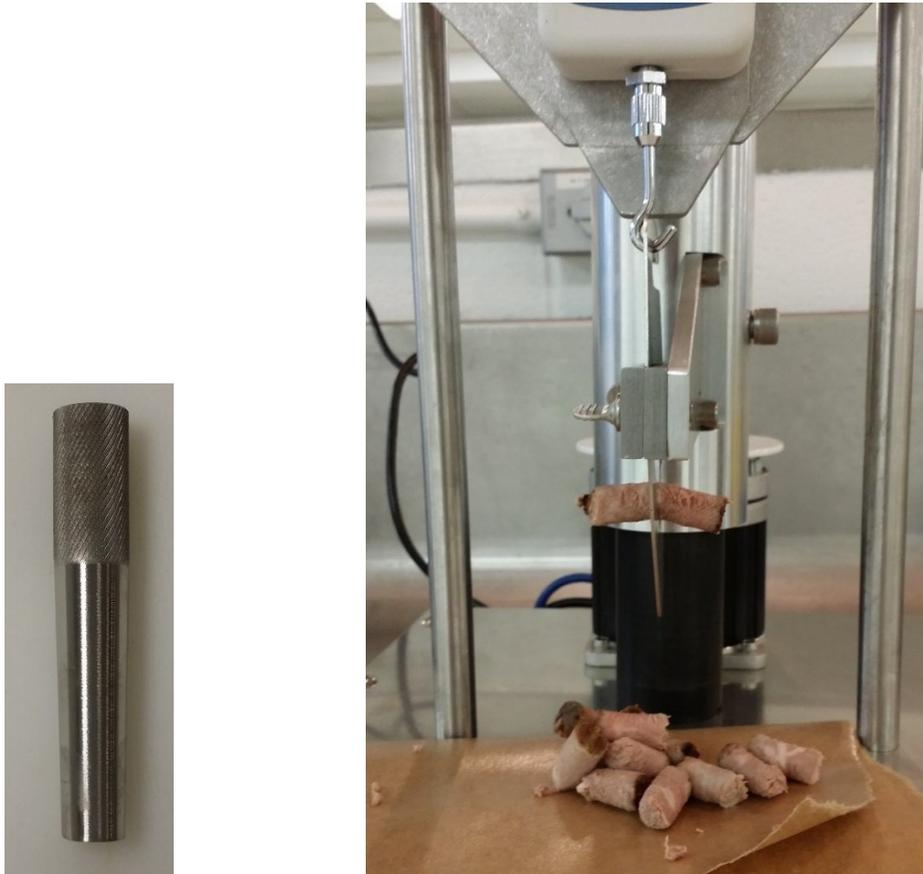


*Figure 10.* The hand corer used to obtain 5/8-inch diameter core. The Warner-Bratzler Shear Force measurement being taken on a core of a roast. Previously tested (cut in half) cores are on the freezer paper.

*Figure 11.* Two roasts that have been cored and tested for tenderness with the Warner-Bratzler Shear Force device. The roast on the right shows the locations and identification of the cores and a core before tenderness test.

After tenderness measurements were taken, roast and cores were placed back in the Ziploc freezer bag and placed in the freezer. Time the roasts came out of the cooler until the time the roasts were put in the freezer was recorded. Average time the roasts were out of the cooler was 13.71 ±2.33 minutes. Temperatures were also recorded in three areas at the beginning of the coring process and again and the end of the coring process. No significant difference was observed in the temperature of the loins or in the time that the loins were out for tenderness measurement.

**Procedures for Ground Beef Experiment**

Experiment 2 was conducted on ground beef. Twenty (one pound) packages of 80:20 ground chuck (71:29 as calculated from the nutritional label) and twenty (one

pound) packages of HeartBrand ground beef (75:25 as calculated from the nutritional label) were used. Each pound package was unwrapped, weighed, labeled and photographed as shown in Figure 12.



*Figure 12*.  Two sources of ground beef in packages and the ground beef unwrapped for weighing and dividing into patties

Each package was weighed and divided in to 4 patties (118-120 g) and grilled on a George Foreman Grill (Model GR2080R).  Prior to grilling, the patties were weighed (g), circumference measured (inches converted to cm) as seen in Figure 13, thickness measured (inches converted to cm) also seen in Figure 13, photographed, and temperature taken on patty #1 (back left side of the grill) and patty #4 (front right side of the grill) as seen in Figure 14.

13(a)                                          13(b)

*Figure 13.*  Circumference measurement 13(a) and thickness measurement 13(b) of the ground beef patties

*Figure 14.* Placement of ground beef patties on the grill with thermometers recording the starting temperatures

Patties were grilled to an internal temperature of $165^0$F. Thermometers were placed in patty #1 and 4 (back left, front right). Average cooking time for the patties was $7.86 \pm .75$ minutes. Cooking temperatures of patty #1 and patty #4 were recorded at minute intervals until both thermometers read at least $165^0$F as seen in Figure 15.

*Figure 15*.  George Foreman Grill closed and temperature of patty #1 and patty #4 are observed and recorded every minute until both thermometers have reached the desired temperature of $165^0$ F

After patties reached $165^0$ F, the patties were removed and weighed (g), circumference measured (cm), thickness measured (cm), photographed, and placed in Ziplocs and in the freezer.  Drippings from the patties were collected in a grease tray under the grill.  Drippings were collected from off the grill for 30 minutes following the completion of cooking.  Plastic spatulas were used to remove the additional grease and solids from the grill.  Tray containing drippings was weighed (g) as seen in Figure 16.

*Figure 16.*  Weighing the dripping collected from a pound of ground beef

Values for drippings were calculated by weighing the contents in the tray and then subtracting the weight of the tray (62g).  Contents of the drippings were poured in a labeled glass jar and placed in the freezer for possible future needs.  Each jar contained the drippings from one pound of grilled ground beef.

It was observed that there appeared to be more solids in the drippings from the HeartBrand patties.  We separated and measured the solid and liquid portion of collected drippings.  Drippings were taken from the freezer, lids of the jars were removed, and jars were placed on a metal rack and for heating in the smoker ($170^0$F) for 15 minutes (until all the drippings were in a liquid form) as seen in Figure 17.

17(a)
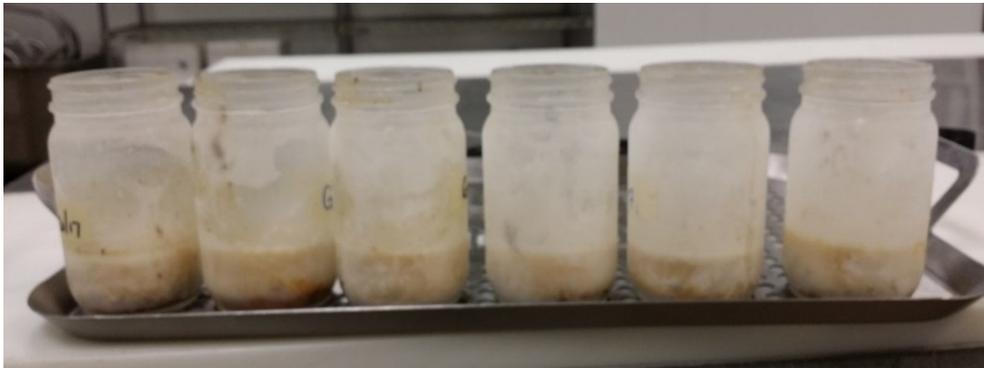


17(b)



17(c)

*Figure 17.* Removal of the jars containing ground beef drippings from the freezer 17(a), caps removed from the jars of drippings and placed on a metal tray 17(b), and jars of drippings in a liquid state after being in the smoker set at $170^0F$ for 15 minutes 17(c)

Ten jars were processed at a time. After heating the drippings, each jar was weighed and recorded for total weight of drippings. Liquid was partially decanted off into another jar. Remaining content of the jar was poured through a strainer. Strainer as shown in Figure 18.



*Figure 18*. Wire strainer used to separate the ground beef drippings. The strainer contains solids from the separation process

Liquid portion of the drippings was re-captured in a jar. Jar of only the liquid (after straining) was weighed and recorded. Liquid was again poured through the strainer back into its original jar. Jar of liquid was weighed and recorded one final time. Weight of dripping solids was calculated by subtracting the strained liquid (minus the solids) weight from the original weight of the liquid. Lids were placed back on the jars and the jars were placed back in the freezer.

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Statistical evaluations were performed on both loins and ground beef by entering the data into the SPSS database. Statistical analysis done on the loins included one-way ANOVA with a Post Hoc (Tukey) on any findings that showed a significance difference ($p< .05$). Regression linear analysis and a Pearson correlation were run to discovery any relationship that might exist between cooking loss and tenderness of the loins. These tests resulted in R values that were not significant, and revealed that water loss is not the only predictor of tenderness of meat. Frequency of variables was also run on the core values of all the loins. Ground beef statistical analysis involved performing a paired T-test on the data collected. Findings of the paired T-test were considered significant if $p<.05$.

## IV. EVALUATION

**Individual Loin Results**

Loin experiment did not show differences that might be expected when comparing a prime quality grade meat with a select quality grade meat. Each loin was divided into 6 roasts and each roast was cored in 6 locations. Tenderness of the total loin was determined by the 6 roasts and each roast with 6 cores (36 tenderness measurements/ loin). Core locations were the same from one roast to the next roast. When taking cores from the *Longissimus* muscle, if there appeared to be any abnormality in the surface texture of the meat (connective tissue), the position of the core sample was slightly adjusted to avoid coring the abnormality in the meat. Tenderness value units from the WBSF of the roasts were recorded in lb./f (pounds of force). As values from the WBSF increase, the tenderness of the meat decreases, i.e. lower the value, the more tender the meat.

**Control**

Control loin was purchased at a commercial grocery store in San Marcos, TX and was a select quality grade. The select quality grade for the Control loin was used due to the display shelves at the grocery stores having predominantly select quality grade meats for consumers to buy. Unless a consumer is educated about quality grades of meat, research has shown that they will buy what is convenient such as select quality grade. Cooking time at $220^0$F for the Control loin was completed at 2 hours and 56 minutes when the internal thermometer probe in Roast #5 reached $165^0$F. In overall tenderness, the control loin ranked third (4.18 lb./f) out of the seven loins and had the least amount of cooking loss. Cooking loss for the control loin was 2.4 pounds or 20.4% of total loin

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weight. WBSF values on the six roasts from the control loin and the cores taken from

each of the roasts are shown in Table 1, Figure 19 and Figure 20.

Table 1.  Warner-Bratzler values for Cores in the six roasts in the Control loin

| ID | 1 | 2 | 3 | 4 | 5 | 6 | Mean | STD |
|---|---|---|---|---|---|---|---|---|
| | | | **Roasts[1]** | | | | | |
| Core A | 2.66 | 6.64 | 4.64 | 3.70 | 6.48 | 3.50 | 4.60 | 1.499 |
| Core B | 5.38 | 3.48 | 3.88 | 3.58 | 6.20 | 6.80 | 4.89 | 1.312 |
| Core C | 2.24 | 3.24 | 3.68 | 6.72 | 4.38 | 4.12 | 4.06 | 1.373 |
| Core D | 8.38 | 2.94 | 3.16 | 4.06 | 3.90 | 3.52 | 4.33 | 1.854 |
| Core E | 4.96 | 3.65 | 3.38 | 3.50 | 4.26 | 3.48 | 3.87 | 0.565 |
| Core F | 3.66 | 4.22 | 2.86 | 3.50 | 2.64 | 2.94 | 3.30 | 0.544 |
| | | | | | | | | |
| Mean | 4.55 | 4.03 | 3.60 | 4.18 | 4.64 | 4.06 | | |
| STD | 2.050 | 1.232 | 0.571 | 1.153 | 1.328 | 1.272 | | |

**Loin Total Mean**  4.18

**Loin Total STD**  1.383

[1] Units are lb./f
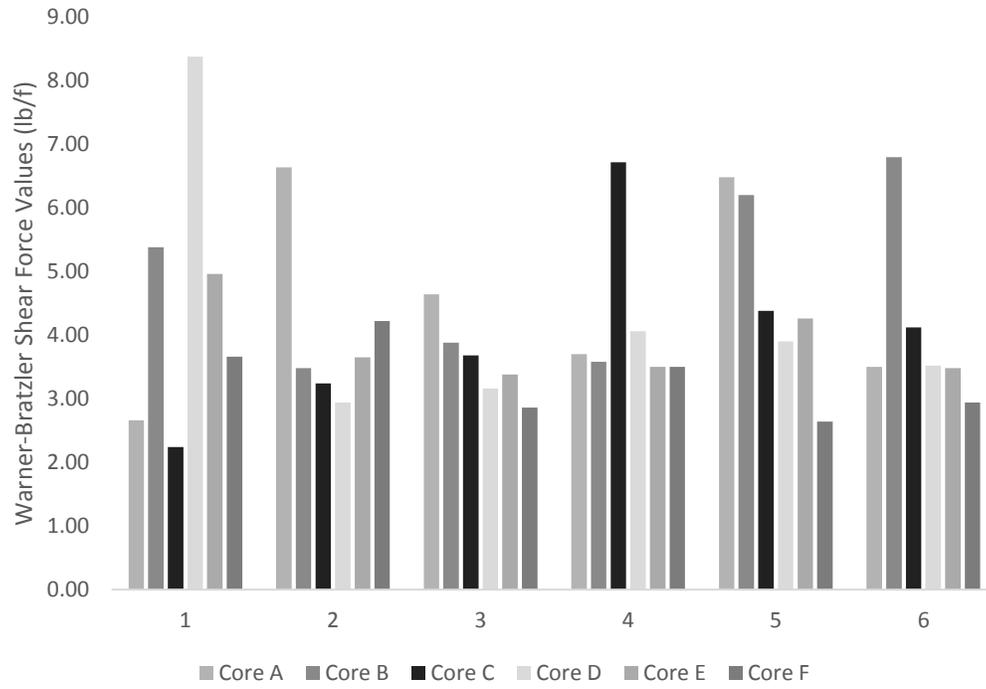
*Figure 19*. Six roasts and the 6 cores from each roast of the Control loin
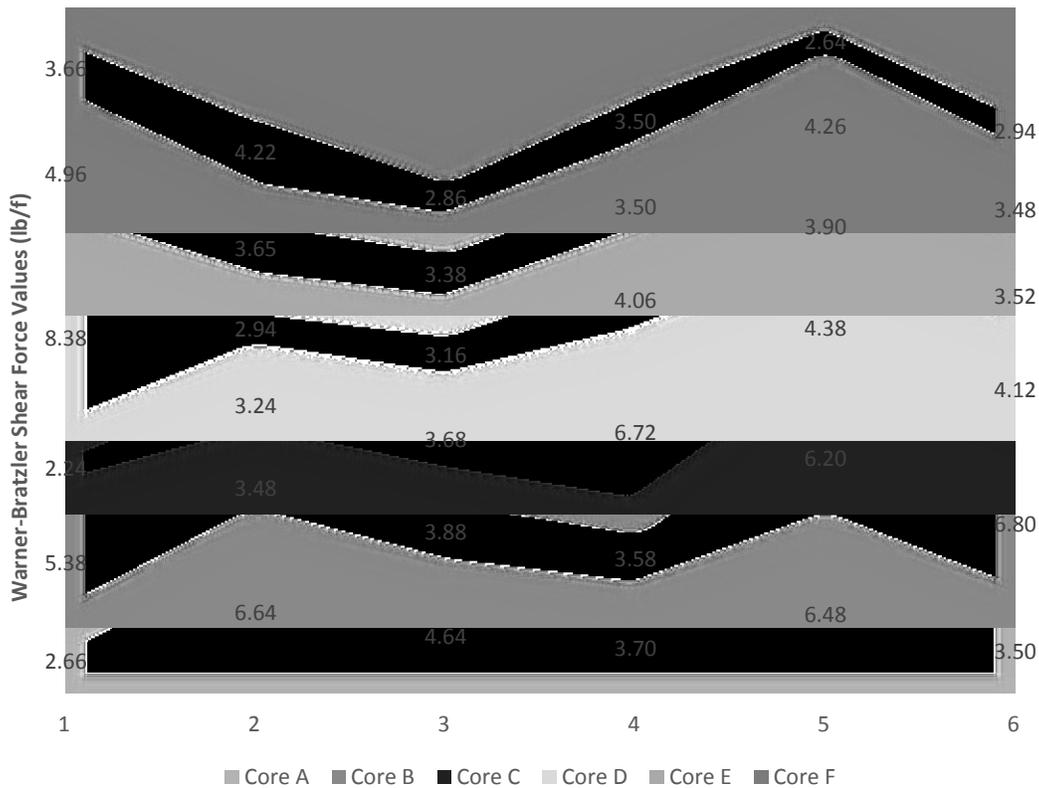
*Figure 20.* Six roasts and an accumulative display of the 6 cores from each roast of Control loin

**HeartBrand A**

HeartBrand A loin was cooked for 3 hours and 23 minutes at $220^0$F when the internal thermometer in Roast #4 reached $165^0$F. HeartBrand Loin A ranked fourth (4.48 lb./f) out of the seven loins in total tenderness and second in cooking loss. Cooking loss for HeartBrand A was 3.1 pounds or 24% of total loin weight. WBSF values for the six roasts of loin HeartBrand A and the cores taken from each of the roasts are shown in Table 2, Figure 21 and Figure 22.

Table 2.  Warner-Bratzler values for Cores in the six roasts in the HeartBrand A loin

| | | | Roasts[1] | | | | | |
| ID | 1 | 2 | 3 | 4 | 5 | 6 | Mean | STD |
|---|---|---|---|---|---|---|---|---|
| **Core A** | 2.30 | 4.60 | 5.54 | 3.70 | 4.98 | 3.76 | 4.15 | 1.049 |
| **Core B** | 4.90 | 4.80 | 4.26 | 4.68 | 5.66 | 4.66 | 4.83 | 0.422 |
| **Core C** | 5.94 | 4.52 | 3.86 | 3.78 | 3.20 | 3.02 | 4.05 | 0.973 |
| **Core D** | 3.82 | 3.56 | 4.26 | 5.14 | 4.66 | 5.22 | 4.44 | 0.624 |
| **Core E** | 5.32 | 5.22 | 5.54 | 4.22 | 3.64 | 4.54 | 4.75 | 0.674 |
| **Core F** | 4.48 | 4.68 | 4.88 | 3.48 | 4.62 | 5.68 | 4.64 | 0.647 |
| | | | | | | | | |
| **Mean** | 4.46 | 4.56 | 4.72 | 4.17 | 4.46 | 4.48 | | |
| | | | 0.65 | | 0.82 | | | |
| **STD** | 1.169 | 0.502 | 0 | 0.585 | 0 | 0.883 | | |

**Loin Total Mean**      4.48
**Loin Total STD**      0.816

[1]Units are lb./f
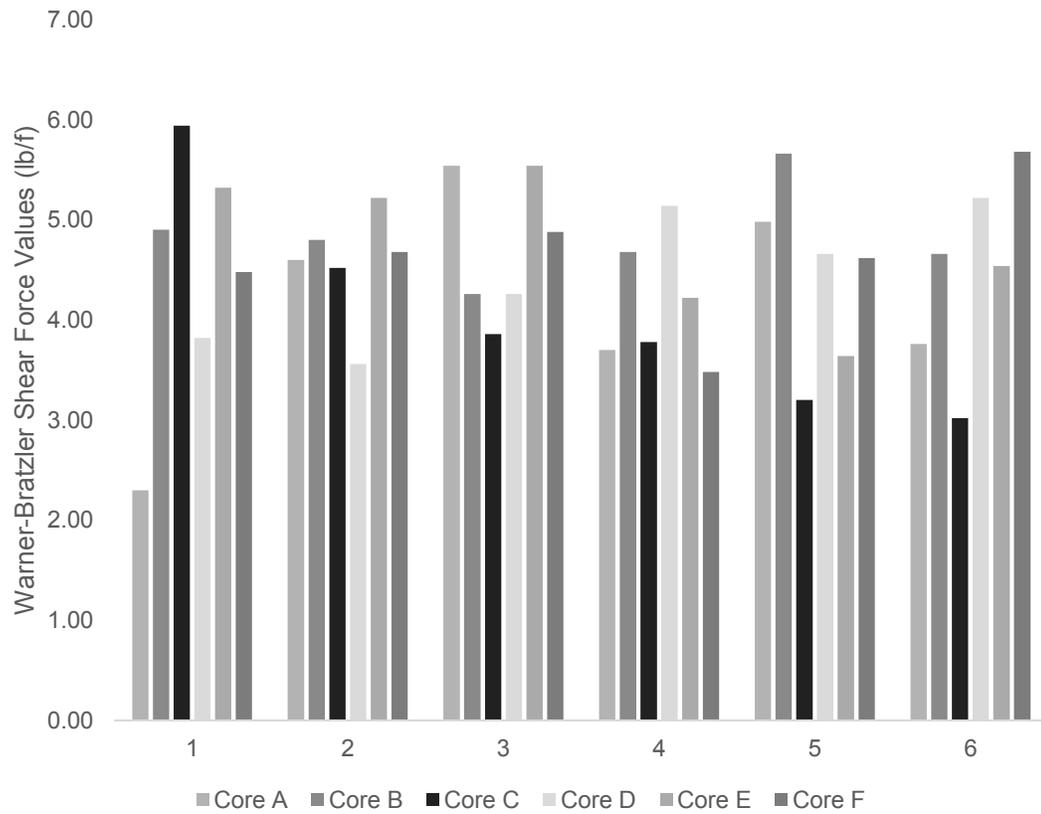
*Figure 21.* Six roasts and the 6 cores from each roast of HeartBrand A loin
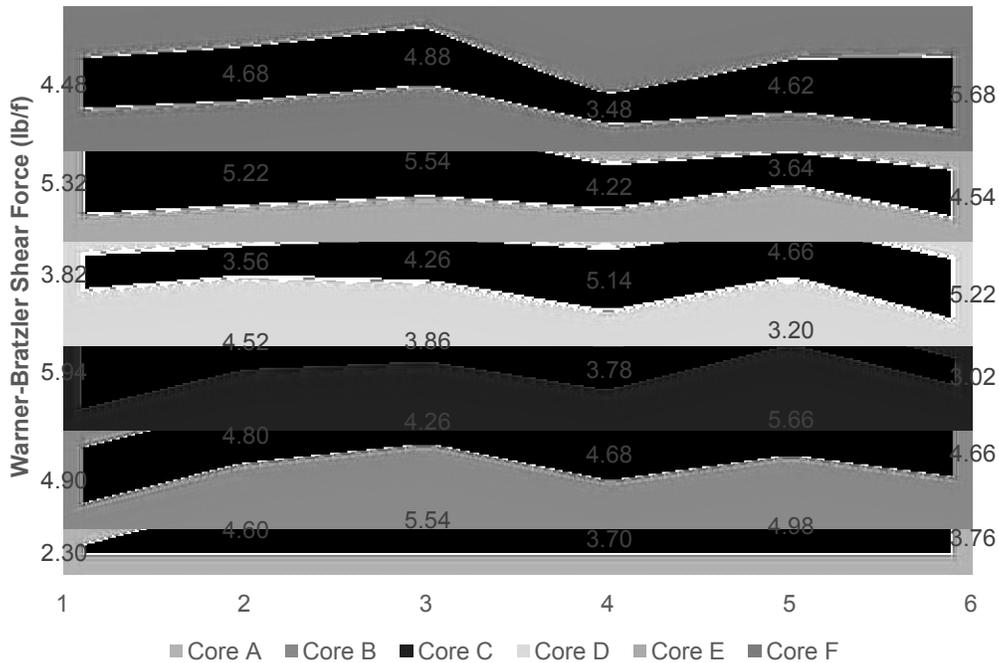
*Figure 22*. Six roasts and an accumulative display of the 6 cores from each roast of HeartBrand A loin

**HeartBrand B**

HeartBrand B loin was cooked at $220^0$F for 2 hours and 45 minutes when the internal thermometer probe in Roast #6 reached $165^0$F. HeartBrand B loin was the most tender loin (3.72 lb./f) of the seven loins and cooking loss ranked sixth out of the seven loins. Cooking loss for the HeartBrand B was 3.24 pounds or 27% of total loin weight. WBSF values of the six roasts of loin HeartBrand B and the cores taken from each of the roasts are shown in Table 3, Figure 23 and Figure 24.

Table 3. Warner-Bratzler values for Cores in the six roasts in the HeartBrand B loin

| ID | | | Roast[1] | | | | Mean | STD |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | | |
| Core A | 4.18 | 4.24 | 3.34 | 3.28 | 4.68 | 3.94 | 3.94 | 0.498 |
| Core B | 4.16 | 3.64 | 3.96 | 4.72 | 5.18 | 4.48 | 4.36 | 0.506 |
| Core C | 2.48 | 4.58 | 3.38 | 3.98 | 3.12 | 2.20 | 3.29 | 0.819 |
| Core D | 3.54 | 2.52 | 3.38 | 3.34 | 4.38 | 3.56 | 3.45 | 0.543 |
| Core E | 4.06 | 3.42 | 3.24 | 2.64 | 4.48 | 4.60 | 3.74 | 0.701 |
| Core F | 2.64 | 4.06 | 5.10 | 3.64 | 2.70 | 3.18 | 3.55 | 0.852 |
| Mean | 3.51 | 3.74 | 3.73 | 3.60 | 4.09 | 3.66 | | |
| STD | 0.706 | 0.666 | 0.654 | 0.644 | 0.880 | 0.817 | | |

| | |
|---|---|
| **Loin Total Mean** | 3.72 |
| **Loin Total STD** | 0.756 |

[1]Units lb./f
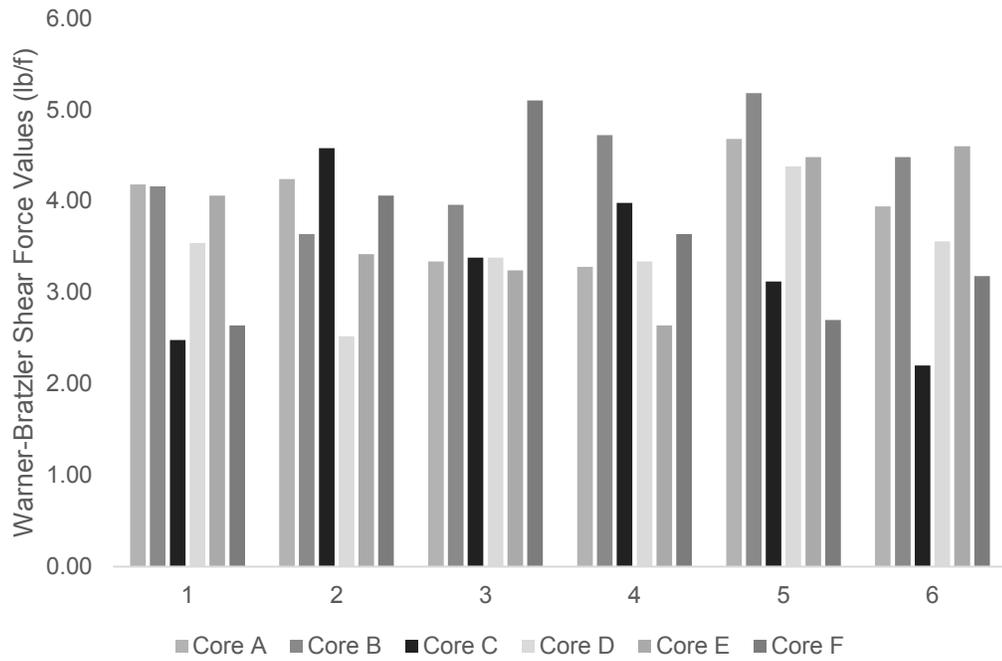
*Figure 23.* Six roasts and the 6 cores from each roast of HeartBrand B loin
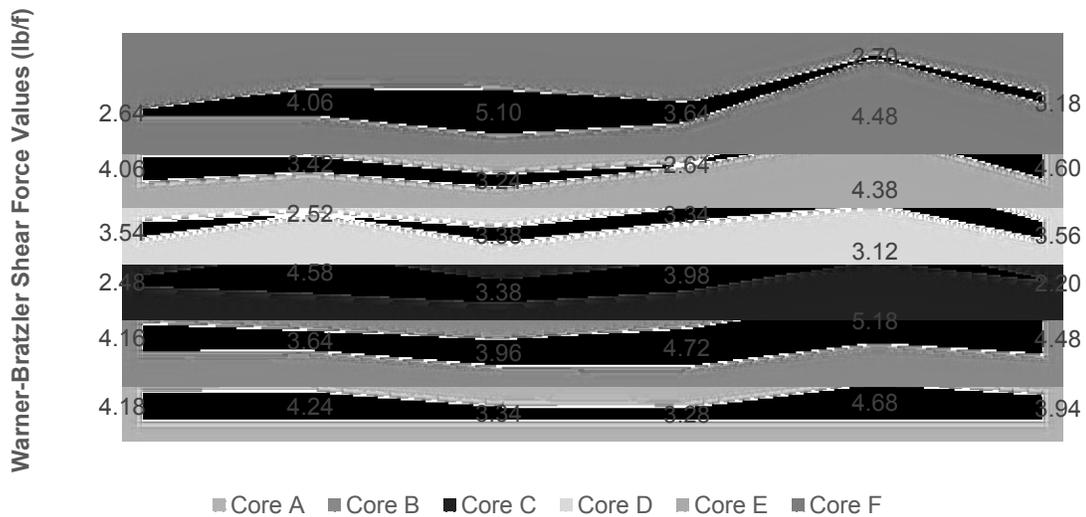
*Figure 24.* Six roasts and an accumulative display of the 6 cores from each roast of HeartBrand B loin

**HeartBrand C**

HeartBrand C loin was cooked at $220^0$F for 2 hours and 30 minutes until the internal thermometer probe in Roast #2 reached $165^0$F. HeartBrand C ranked sixth (4.74 lb./f) out of the seven loins when measuring tenderness and cooking loss was fourth out of the seven. Cooking loss for the HeartBrand C was 3.48 pounds or 26% of total loin weight. WBSF values of the six roasts of loin HeartBrand C and the cores taken from each of the roasts are shown in Table 4, Figure 25 and Figure 26.

Table 4. Warner-Bratzler values for Cores in the six roasts in the HeartBrand C loin

| ID | 1 | 2 | 3 | 4 | 5 | 6 | Mean | STD |
|---|---|---|---|---|---|---|---|---|
| | | | Roasts[1] | | | | | |
| Core A | 6.50 | 6.10 | 3.74 | 3.06 | 4.34 | 4.98 | 4.79 | 1.223 |
| Core B | 3.58 | 5.88 | 4.32 | 4.84 | 4.60 | 4.20 | 4.57 | 0.703 |
| Core C | 2.78 | 4.64 | 4.66 | 4.66 | 5.92 | 5.74 | 4.73 | 1.021 |
| Core D | 6.02 | 5.04 | 4.24 | 3.06 | 4.12 | 4.46 | 4.49 | 0.903 |
| Core E | 6.48 | 4.38 | 3.98 | 4.22 | 6.08 | 3.32 | 4.74 | 1.141 |
| Core F | 5.30 | 5.84 | 4.76 | 5.42 | 4.44 | 4.96 | 5.12 | 0.458 |
| | | | | | | | | |
| Mean | 5.11 | 5.31 | 4.28 | 4.21 | 4.92 | 4.61 | | |
| STD | 1.440 | 0.660 | 0.356 | 0.886 | 0.780 | 0.752 | | |

| | |
|---|---|
| Loin Total Mean | 4.74 |
| Loin Total STD | 0.966 |

[1]Units lb./f
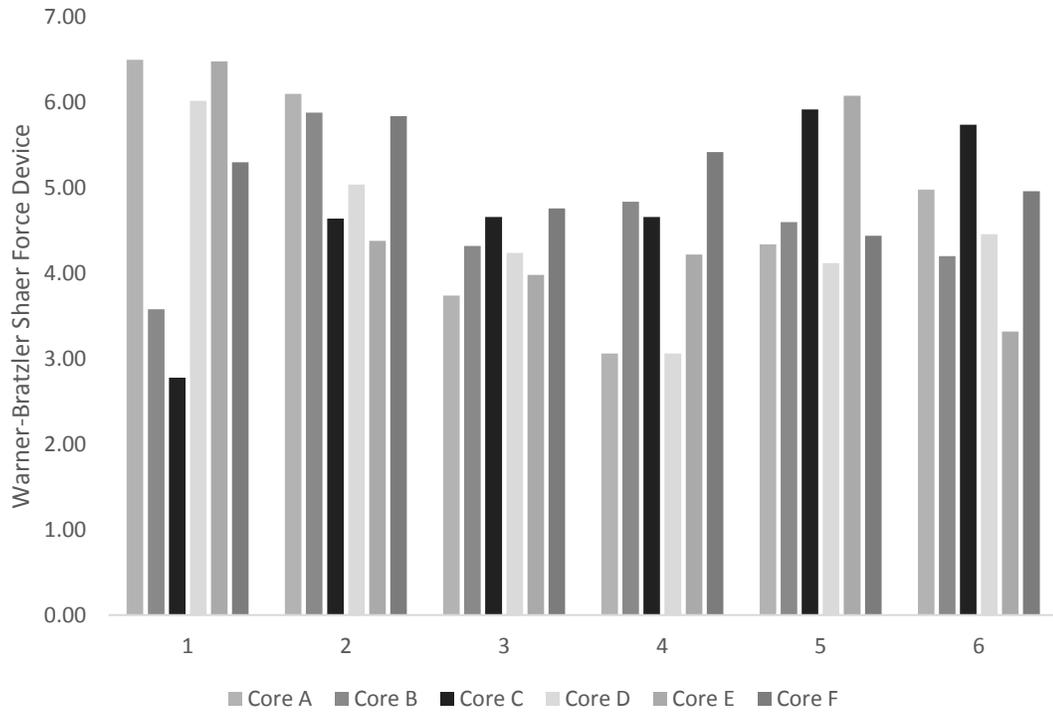
*Figure 25.* Six roasts and the 6 cores from each roast of HeartBrand C loin
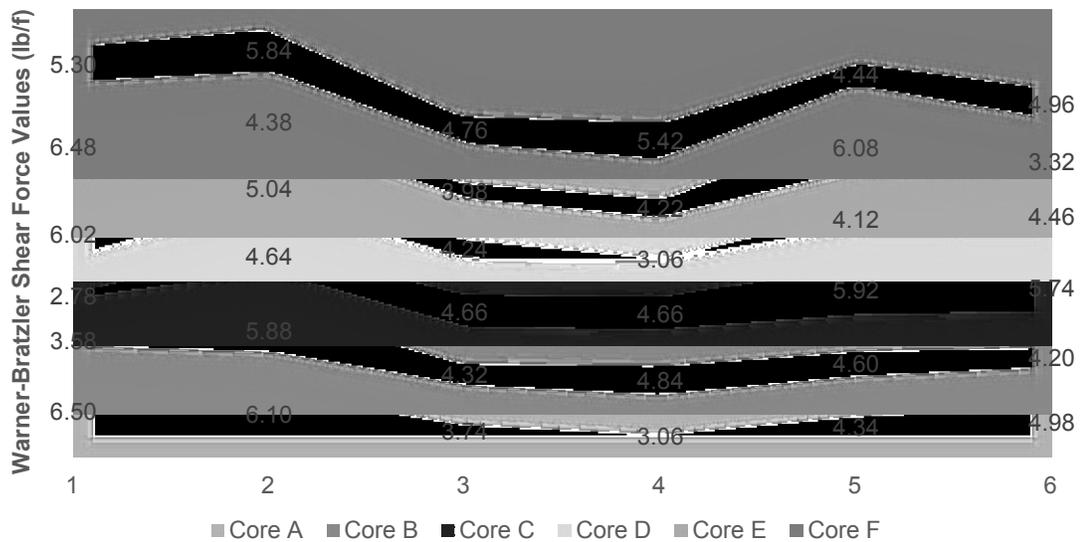
*Figure 26.* Six roasts and an accumulative display of the 6 cores from each roast of HeartBrand C loin

### HeartBrand D

HeartBrand D loin was cooked at $220^0$F for 3 hours and 33 minutes until the internal thermometer probe in Roast #3 reached $165^0$F. HeartBrand D was the toughest loin (4.90 lb./f) in the loin study. Loin HeartBrand D also had the greatest amount of cooking loss. Cooking loss for HeartBrand D was 3.67 pounds or 27.5% of total loin weight. WBSF values of the six roasts of loin HeartBrand D and the cores taken from each of the roasts are shown in Table 5, Figure 27 and Figure 28.

Table 5.  Warner-Bratzler values for Cores in the six roasts in the HeartBrand D loin

| | Roasts[1] | | | | | | | |
| ID | 1 | 2 | 3 | 4 | 5 | 6 | Mean | STD |
|---|---|---|---|---|---|---|---|---|
| **Core A** | 5.76 | 4.30 | 4.22 | 6.72 | 4.18 | 6.98 | 5.36 | 1.187 |
| **Core B** | 6.36 | 3.96 | 3.86 | 4.24 | 4.88 | 4.30 | 4.60 | 0.852 |
| **Core C** | 2.94 | 5.64 | 4.58 | 4.22 | 5.76 | 5.48 | 4.77 | 0.994 |
| **Core D** | 4.20 | 3.38 | 4.68 | 5.40 | 5.40 | 5.26 | 4.72 | 0.740 |
| **Core E** | 4.56 | 6.02 | 4.06 | 5.62 | 5.90 | 4.38 | 5.09 | 0.780 |
| **Core F** | 6.98 | 4.70 | 5.26 | 4.50 | 4.28 | 3.36 | 4.85 | 1.110 |
| | | | | | | | | |
| **Mean** | 5.13 | 4.67 | 4.44 | 5.12 | 5.07 | 4.96 | | |
| **STD** | 1.373 | 0.919 | 0.462 | 0.900 | 0.674 | 1.138 | | |

**Loin Total**
**Mean**          4.90
**Loin Total STD**  0.992

[1]Units lb./f
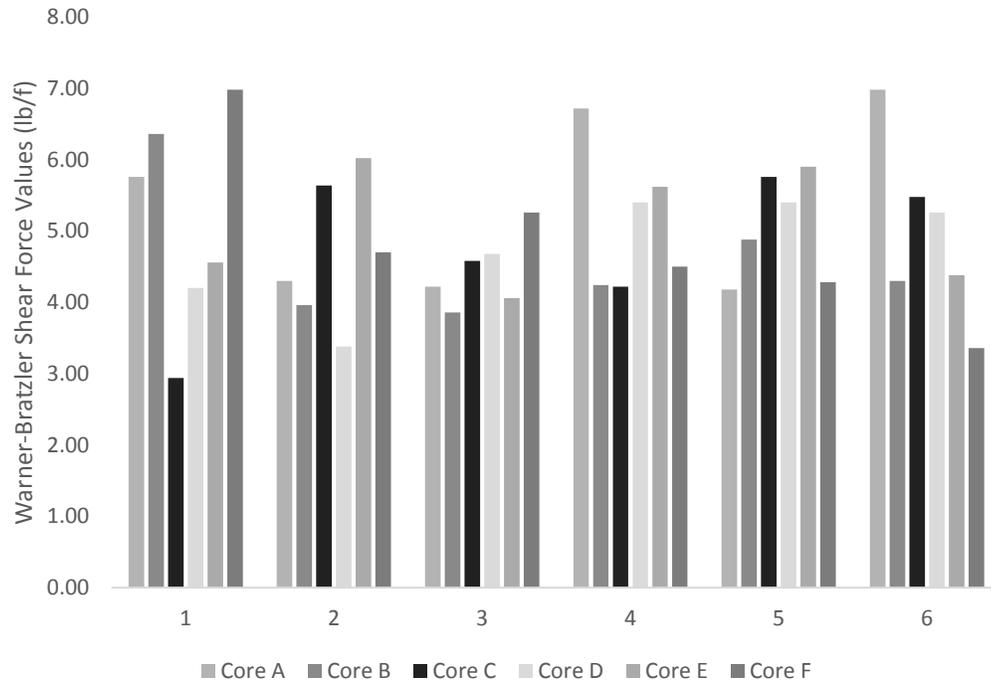
*Figure 27.* Six roasts and the 6 cores from each roast of HeartBrand D loin
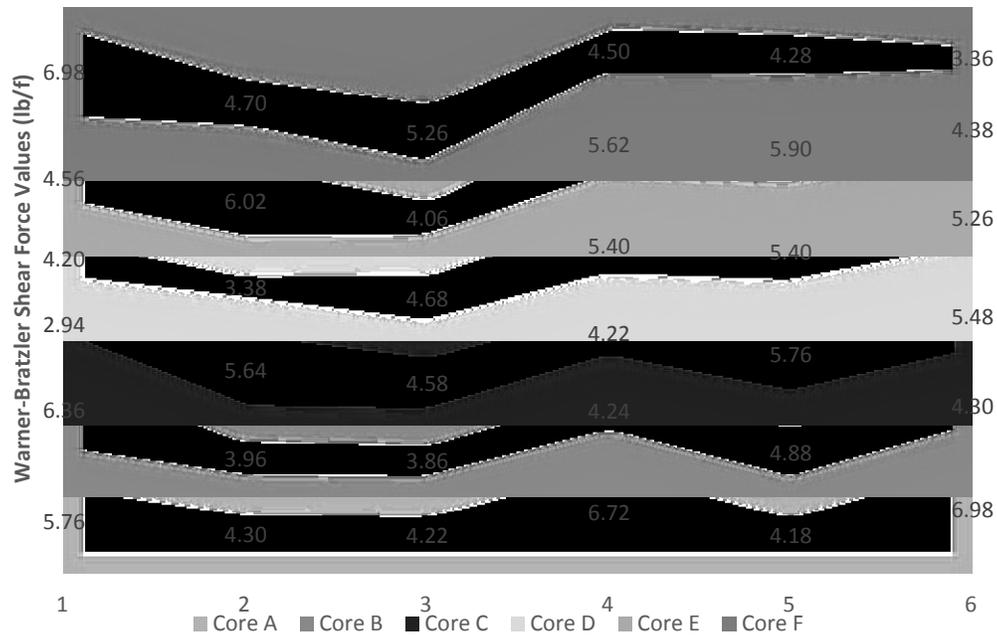
*Figure 28.* Six roasts and an accumulative display of the 6 cores from each roast of HeartBrand D loin

**HeartBrand E**

HeartBrand E loin was cooked at $220^0$F for 3 hours and 36 minutes until the internal thermometer probe in Roast #6 reached $165^0$F. HeartBrand E was second (4.12 lb./f) in tenderness of the seven loins and ranked third out of the seven in cooking loss. Cooking loss of HeartBrand E was 3.72 pounds or 24.7% of total loin weight. WBSF values for the six roasts of loin HeartBrand E and the cores taken from each of the roasts are shown in Table 6, Figure 29 and Figure 30.

Table 6.  Warner-Bratzler values for Cores in the six Roasts in the HeartBrand E loin

| ID | 1 | 2 | 3 | 4 | 5 | 6 | Mean | STD |
|---|---|---|---|---|---|---|---|---|
| | | | Roasts[1] | | | | | |
| **Core A** | 4.82 | 5.00 | 5.32 | 3.74 | 4.78 | 3.16 | 4.47 | 0.761 |
| **Core B** | 5.32 | 3.70 | 4.38 | 4.98 | 6.02 | 2.34 | 4.46 | 1.192 |
| **Core C** | 2.56 | 2.68 | 3.34 | 4.42 | 5.06 | 2.86 | 3.49 | 0.937 |
| **Core D** | 3.60 | 2.44 | 5.58 | 3.62 | 4.22 | 4.34 | 3.97 | 0.948 |
| **Core E** | 3.02 | 4.18 | 4.78 | 3.96 | 6.00 | 4.26 | 4.37 | 0.900 |
| **Core F** | 4.98 | 3.88 | 3.84 | 2.50 | 4.02 | 4.62 | 3.97 | 0.778 |
| | | | | | | | | |
| **Mean** | 4.05 | 3.65 | 4.54 | 3.87 | 5.02 | 3.60 | | |
| **STD** | 1.045 | 0.872 | 0.786 | 0.764 | 0.781 | 0.852 | | |

**Loin Total**
**Mean**               4.12
**Loin Total STD**     0.995

[1]Units lb./f
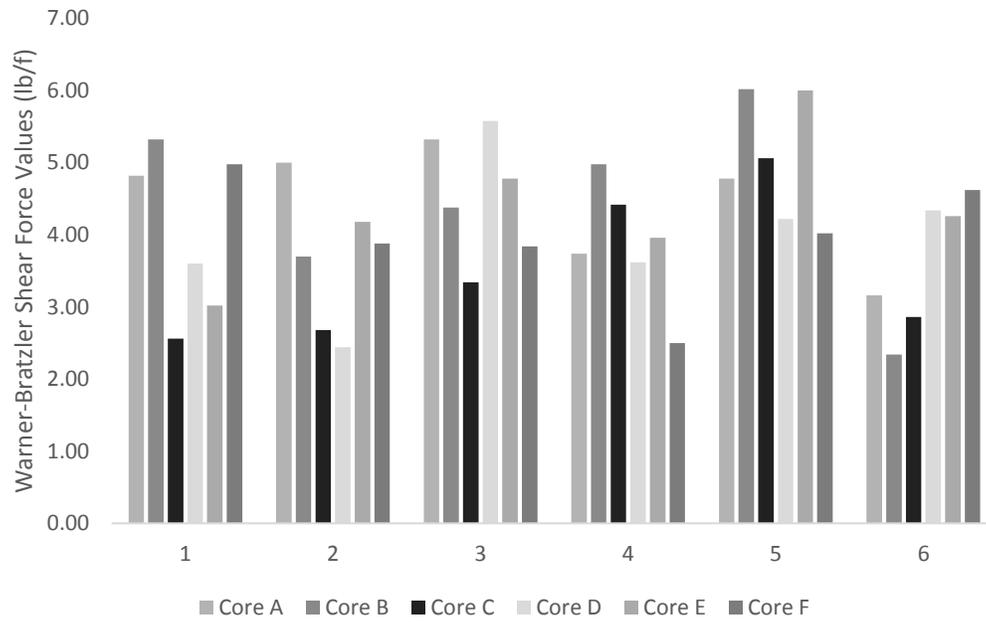
*Figure 29*.  Six roasts and the 6 cores from each roast of HeartBrand E loin
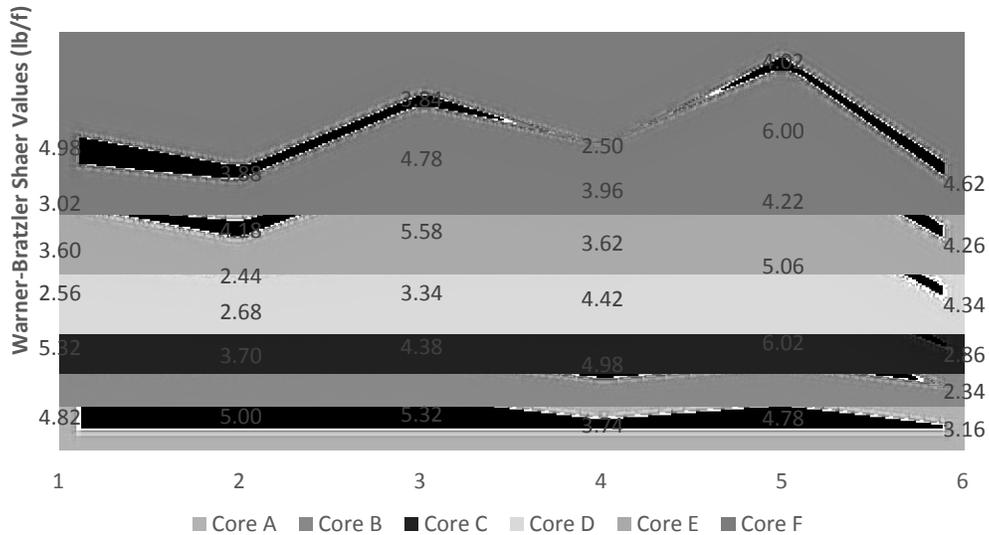
*Figure 30.* Six roasts and an accumulative display of the 6 cores from each roast of HeartBrand E loin

### HeartBrand F

HeartBrand F loin was cooked at $220^0$F for 3 hours and 24 minutes until the internal thermometer probe in Roast #3 reached $165^0$F. HeartBrand F ranked fifth (4.54 lb./f) as far as overall tenderness and ranked fifth out of the seven loins in cooking loss. Cooking loss for the HeartBrand F was 3.75 pounds or 26.6% of total loin weight. WBSF values of the six roasts of loin HeartBrand F and the cores taken from each of the roasts are shown in Table 7, Figure 31 and Figure 32.

Table 7.  Warner-Bratzler values for Cores in the six roasts in the HeartBrand F loin

| ID | 1 | 2 | 3 | 4 | 5 | 6 | Mean | STD |
|---|---|---|---|---|---|---|---|---|
| | | | **Roasts[1]** | | | | | |
| Core A | 3.72 | 6.32 | 5.54 | 4.86 | 4.66 | 5.90 | 5.17 | 0.861 |
| Core B | 5.56 | 5.10 | 4.58 | 4.64 | 5.78 | 4.18 | 4.97 | 0.564 |
| Core C | 3.38 | 4.48 | 3.66 | 5.22 | 4.02 | 4.50 | 4.21 | 0.606 |
| Core D | 5.12 | 4.26 | 3.80 | 4.54 | 3.04 | 4.58 | 4.22 | 0.660 |
| Core E | 4.86 | 3.24 | 5.26 | 3.62 | 3.66 | 3.86 | 4.08 | 0.724 |
| Core F | 4.22 | 4.88 | 4.28 | 4.30 | 4.56 | 5.22 | 4.58 | 0.365 |
| | | | | | | | | |
| Mean | 4.48 | 4.71 | 4.52 | 4.53 | 4.29 | 4.71 | | |
| STD | 0.772 | 0.930 | 0.696 | 0.496 | 0.862 | 0.676 | | |

| | |
|---|---|
| **Loin Total Mean** | 4.54 |
| **Loin Total STD** | 0.766 |

[1] Units lb./f
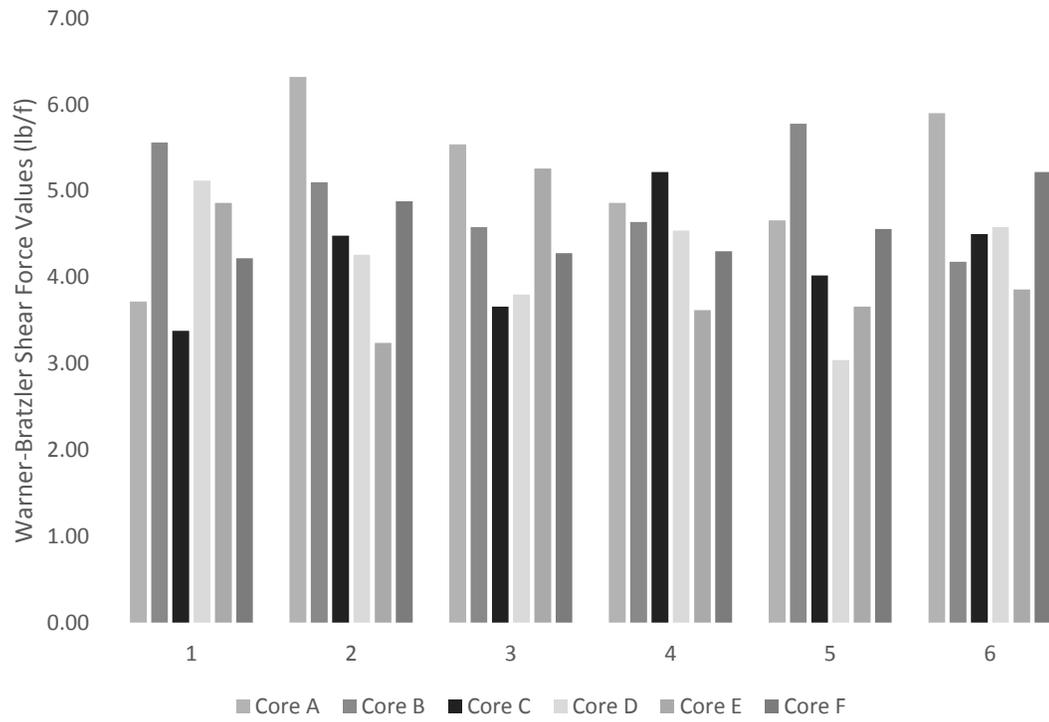
*Figure 31.* Six roasts and the 6 cores from each roast of HeartBrand F loin
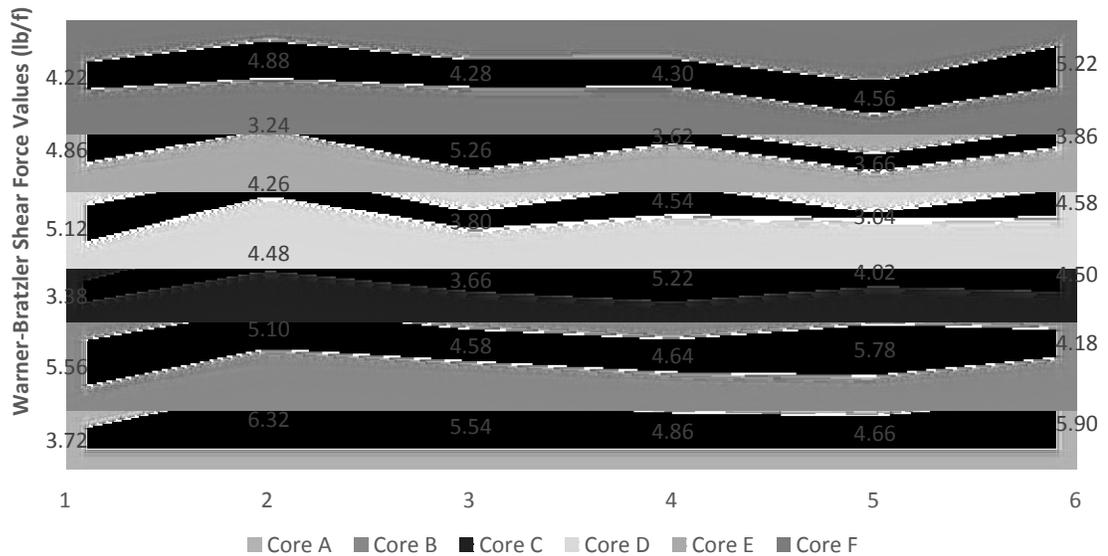
*Figure 32.* Six roasts and an accumulative display of the 6 cores from each roast of HeartBrand F loin

## Comprehensive Loin Experiment Results

Tenderness did not show any significances or trends.  As a summary, the most tender loin was HeartBrand B.  Toughest loin was HeartBrand D. Tenderness of the loins as ranked from most tender to least tender is HeartBrand B, E, Control, HeartBrand A, F, C and D.  This finding was interesting.  All loins and roasts are shown in Table 8 and Figure 33.

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## Warner-Bratzler Loin Values

Table 8.  Effects of Loin Source on Warner-Bratzler Shear Force Values (WBSF)[1,2]

| | Roasts | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | Mean | STD |
|---|---|---|---|---|---|---|---|---|
| **Control** | 4.55 | 4.10 | 3.60 | 4.18 | 4.64 | 4.06 | 4.19 | 0.343 |
| **HeartBrand A** | 4.46 | 4.56 | 4.72 | 4.17 | 4.46 | 4.48 | 4.48 | 0.164 |
| **HeartBrand B** | 3.51 | 3.74 | 3.73 | 3.60 | 4.09 | 3.66 | 3.72 | 0.182 |
| **HeartBrand C** | 5.11 | 5.31 | 4.28 | 4.21 | 4.92 | 4.61 | 4.74 | 0.409 |
| **HeartBrand D** | 5.13 | 4.67 | 4.44 | 5.12 | 5.07 | 4.96 | 4.90 | 0.258 |
| **HeartBrand E** | 4.05 | 3.65 | 4.54 | 3.87 | 5.02 | 3.60 | 4.12 | 0.507 |
| **HeartBrand F** | 4.48 | 4.71 | 4.52 | 4.53 | 4.29 | 4.71 | 4.54 | 0.144 |
| | | | | | | | | |
| **Mean** | 4.47 | 4.39 | 4.26 | 4.24 | 4.64 | 4.30 | | |
| **STD** | 0.528 | 0.549 | 0.398 | 0.450 | 0.352 | 0.491 | | |

[1] 6 cores per roast

[2] Units lb./f
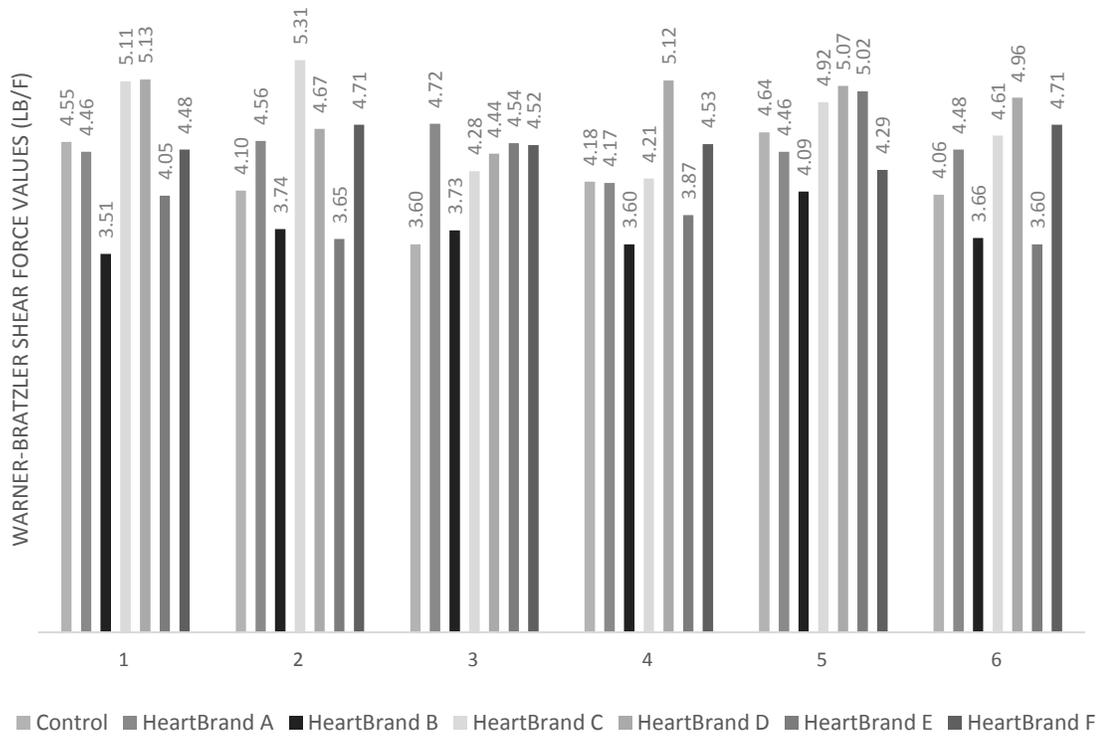
*Figure 33.* Comparison of individual roasts in each loin

**Loin Tenderness Comparison Results**

The comparison of the overall tenderness of each loin along with standard deviations are shown in Figure 34.
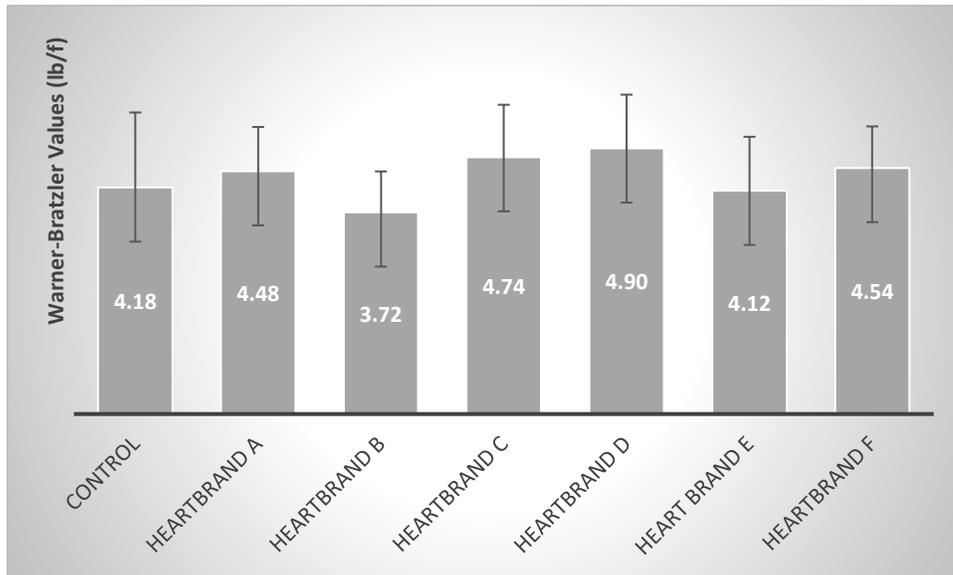


*Figure 34.* Overall tenderness of loins with SD bars

Overall tenderness of each loin along with standard deviations in order of tenderness are shown in Figure 35.
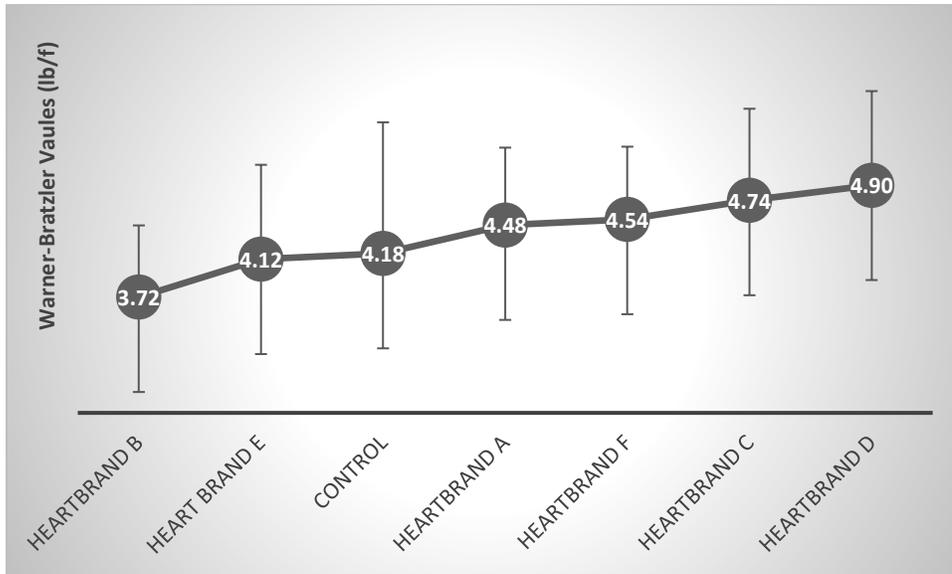


*Figure 35.* Overall tenderness of loins with SD bars in order of tenderness

**Range of Warner-Bratzler Values**

Although there was no significance in overall tenderness when comparing the HeartBrand loins to the control loin, there was a significant difference in the consistency of the loins. Control loin had the greatest range in Warner-Bratzler values. Control loin had a standard deviation of 1.38. HeartBrand loins had standard deviations ranging from 0.756 - .995. Table 9 and Figure 36 shows the average core values and Figure 37 shows low and high individual core values on the loins.

Table 9. Range of Warner-Bratzler Shear Force Values on Roasts in Loins [a,b]

| | Control | | Heart Brand A | | Heart Brand B | | Heart Brand C | | Heart Brand D | | Heart Brand E | | Heart Brand F | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| Roast1 | 2.24 | 8.38 | 2.30 | 5.94 | 2.48 | 4.18 | 2.78 | 6.50 | 2.94 | 6.98 | 2.56 | 5.32 | 3.38 | 5.56 |
| Roast2 | 2.94 | 6.64 | 3.56 | 5.22 | 2.52 | 4.58 | 4.38 | 6.10 | 3.38 | 6.02 | 2.44 | 5.00 | 3.24 | 6.32 |
| Roast 3 | 2.86 | 4.64 | 3.89 | 5.54 | 3.24 | 3.96 | 2.18 | 4.76 | 3.86 | 5.26 | 3.34 | 5.58 | 3.66 | 5.54 |
| Roast 4 | 3.50 | 6.72 | 3.48 | 5.14 | 2.64 | 4.72 | 3.06 | 5.42 | 4.22 | 6.72 | 2.50 | 4.98 | 3.62 | 5.22 |
| Roast 5 | 2.64 | 6.48 | 3.20 | 5.66 | 2.70 | 5.18 | 4.12 | 6.08 | 4.18 | 5.90 | 4.02 | 6.02 | 3.04 | 5.78 |
| Roast 6 | 2.94 | 6.80 | 3.20 | 5.68 | 2.20 | 4.60 | 3.32 | 5.74 | 3.36 | 6.98 | 2.34 | 4.62 | 3.86 | 5.90 |
| | | | | | | | | | | | | | | |
| Mean | 2.85 | 6.61 | 3.27 | 5.53 | 2.63 | 4.54 | 3.31 | 5.77 | 3.66 | 6.31 | 2.87 | 5.25 | 3.47 | 5.72 |
| STD | 0.377 | 1.086 | 0.494 | 0.276 | 0.315 | 0.390 | 0.755 | 0.560 | 0.467 | 0.635 | 0.611 | 0.454 | 0.276 | 0.343 |

[a] = 6 cores/ roast

[b] = Unit lb/f

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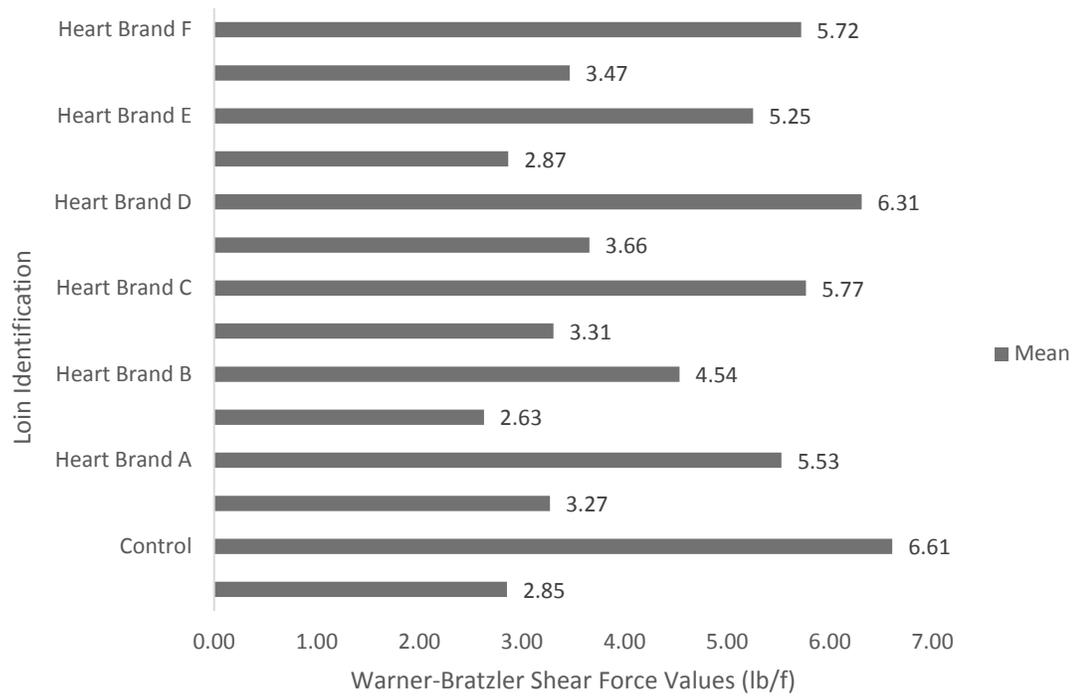
*Figure 36.* Averages of low and high Warner-Bratzler (WBSF) values for each loin
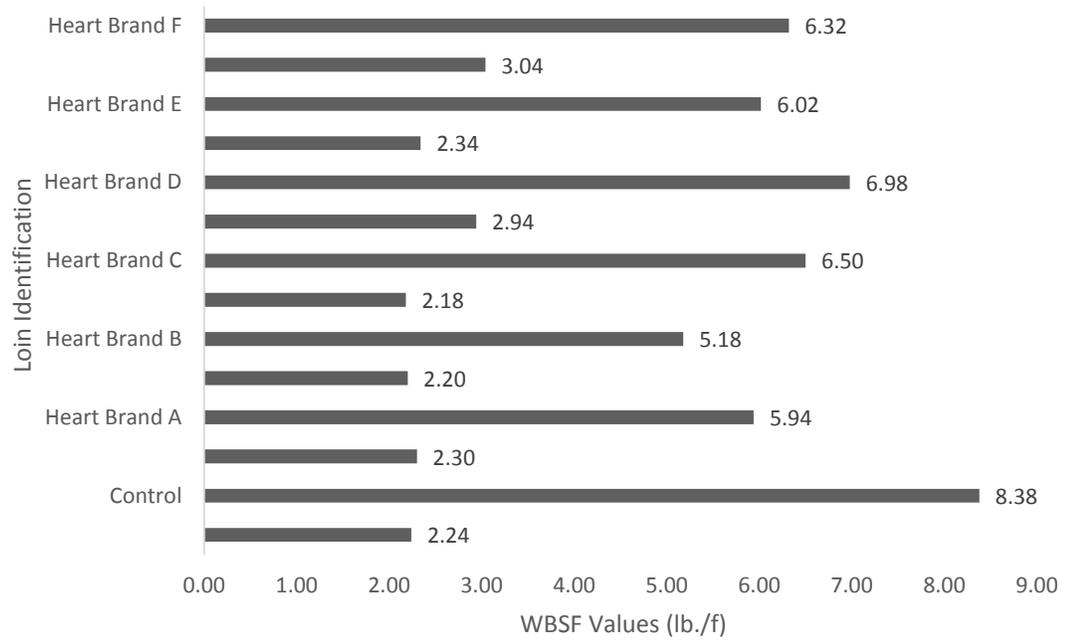
*Figure 37.* Individual low and high WBSF tenderness values on each loin

## Frequency of Distribution of Warner-Bratzler Values

Frequency of WBSF values in the individual cores of all the loins are shown in Table 10. Location of cores in the individual roasts are shown in Figure 38.

Table 10. Frequency of Distribution of WBSF Values by Core Location[1,2]

|  | Core A | Core B | Core C | Core D | Core E | Core F |
|---|---|---|---|---|---|---|
| Mean | 4.64 | 4.67 | 4.09 | 4.23 | 4.38 | 4.29 |
| Median | 4.62 | 4.62 | 4.08 | 4.21 | 4.24 | 4.37 |
| STD | 1.17 | 0.89 | 1.13 | 1.07 | 0.94 | 0.97 |
| Range | 4.68 | 4.46 | 4.52 | 5.94 | 3.84 | 4.48 |
| Minimum | 2.30 | 2.34 | 2.20 | 2.44 | 2.64 | 2.50 |
| Maximum | 6.98 | 6.80 | 6.72 | 6.48 | 6.48 | 6.98 |

[1] lb/f

[2] 42 cores for each value
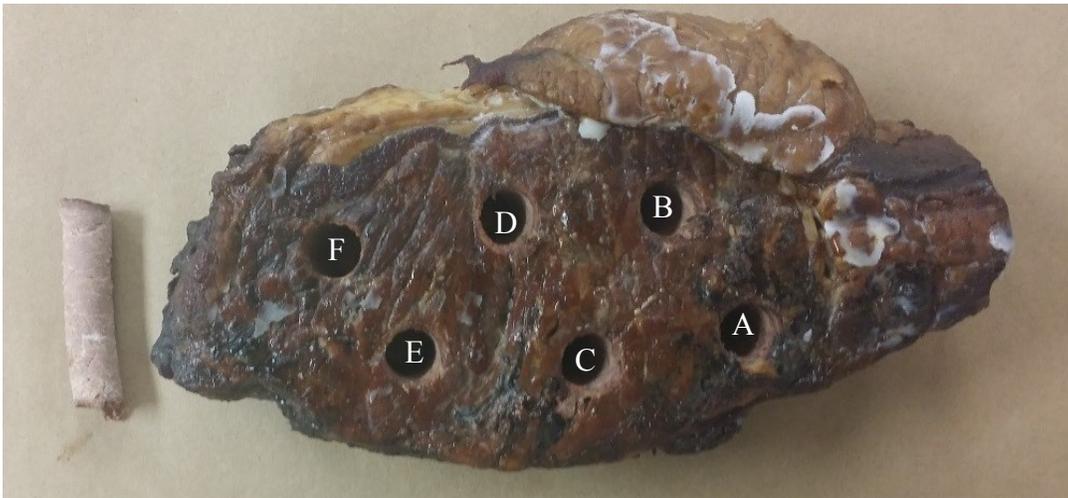


*Figure 38.* Core locations in roasts of loins

HeartBrand B (most tender loin) had the lowest Warner-Bratzler values for both the low and high range values. When comparing the core values from each loin, HeartBrand B had the most tender core score for Core A-E and the second most tender F core.

Tenderness measurements were taken throughout the loins. Care was taken to be consistent in dividing of the loins into roasts and also in the location of the core samples in each roast. HeartBrand B was the most tender loin of the study and had a significant difference (p<.05) in tenderness when compared to either HeartBrand A, HeartBrand C, HeartBrand D or HeartBrand F loins. HeartBrand D was the toughest of the loins in the study and had a significant difference (p<.05) in tenderness when compared to the Control, HeartBrand B, and HeartBrand E loins.

HeartBrand B also had the smallest standard deviation (0.76) of the seven loin indicating tenderness consistency. Control loin had the largest standard deviation (1.38) of the seven loins indicating inconsistency in tenderness. HeartBrand B loin had the most tender core A-E of all the loins and with Core F HeartBrand B loin was second in tenderness. Core F was the only core with any significant measurement difference between the seven loins. Control, HeartBrand B, and HeartBrand C loin were the loins that demonstrated a significantly more tender Core F than the rest of the loins. Core F is located on the exterior portion of the loin closest to the *Spinalis dorsi* muscle and often a line of dense connective tissue was seen close to the area of Core F measurements.

Each loin was cut into six roasts starting at the distal or caudal end of the loin and six measurements were taken from each on the roasts. Loins were cut in same manner looking for trends on which roast location in the loin was most tender. No significant differences were found between the six roasts. An overall average of the all the roasts in the 7 loins showed that Roast 4 was the most tender, but the difference was not significant. When observing the roasts individually in the loins, four of the seven loins showed Roasts 3 and 4 as most tender roast of the loin. Roasts 3 and 4 locations would

be in the middle of the length of the loin.  More numbers are needed to see if this finding is a trend or if there is a significant difference of tenderness in the middle of the loin.

During the measurements of tenderness, the hope was to be able to distinguish which area of the loin was most tender in both roast location and core location.  Trends were seen in both areas with Core C being the most tender core overall in the seven loins and roasts 3 and 4 being the more common tender roast in the loins, but these findings are only trends with no significant differences.

### Loin Cooking Weight Loss

Degree of cooking loss between the loins was also a significant finding in the loin study.  Cooking weight loss in the loin study is shown in Table 11 and Figure 39.

Table 11.  Cooking Weight Loss of Loins

| | Roasts[1] | | | | | | | | Total Loin Weight | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | Mean | STD | Fresh | Loss |
| **Control** | 0.45 | 0.42 | 0.40 | 0.36 | 0.40 | 0.37 | 0.40 | 0.03 | 11.75 | 2.40 |
| **HeartBrand A** | 0.58 | 0.56 | 0.50 | 0.51 | 0.47 | 0.52 | 0.52 | 0.04 | 13.11 | 3.14 |
| **HeartBrand B** | 0.55 | 0.57 | 0.52 | 0.52 | 0.52 | 0.56 | 0.54 | 0.02 | 12.02 | 3.24 |
| **HeartBrand C** | 0.68 | 0.64 | 0.58 | 0.57 | 0.50 | 0.51 | 0.58 | 0.06 | 13.37 | 3.48 |
| **HeartBrand D** | 0.66 | 0.62 | 0.62 | 0.60 | 0.61 | 0.56 | 0.61 | 0.03 | 13.36 | 3.67 |
| **HeartBrand E** | 0.61 | 0.63 | 0.60 | 0.62 | 0.58 | 0.68 | 0.62 | 0.03 | 15.08 | 3.72 |
| **HeartBrand F** | 0.70 | 0.68 | 0.61 | 0.60 | 0.60 | 0.57 | 0.63 | 0.05 | 14.13 | 3.76 |
| | | | | | | | | | | |
| **Mean** | 0.60 | 0.59 | 0.55 | 0.54 | 0.53 | 0.54 | | | | |
| **STD** | 0.08 | 0.08 | 0.07 | 0.08 | 0.07 | 0.09 | | | | |

[1] Units -pounds
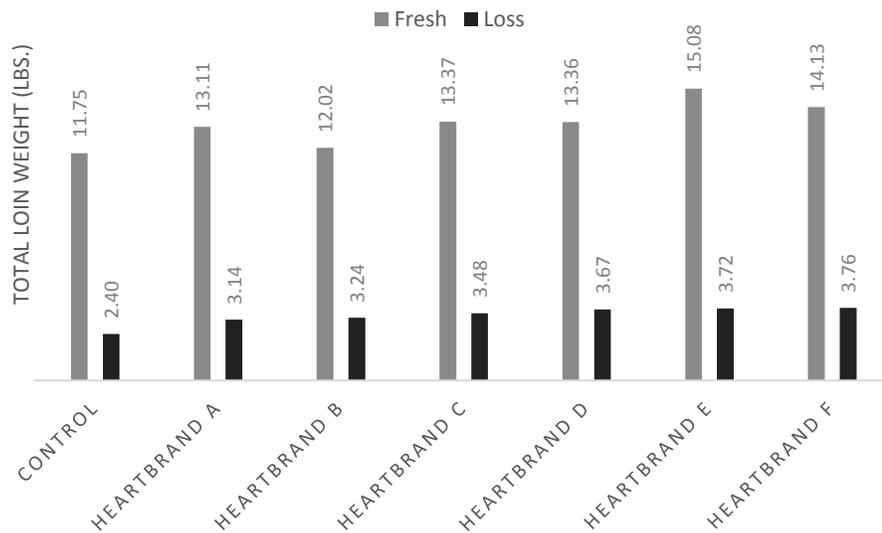
*Figure 39*.  Total loin weight and total loin weight of cooking loss

Cooking loss in the control loin (20.4%) was significantly lower when compared with the HeartBrand loins (24- 27.5%).  Marbling content difference may explain the greater cooking loss in the HeartBrand loins.  It has been reported that Japanese cattle breeds have a higher content of monounsaturated fatty acids which causes there to be a lower melting point in the intramuscular fat (Scollan et al., 2014).  No measurements or further observations were made on the loin cooking loss other than the change in weight of the roasts from fresh to cooked.

During the measurements of tenderness, finding the most tender roast in a loin or observing the most tender core position in the roast was the desire, but there were no significant findings or trends observed.  Dividing the loins into more "steak" representative portions (1 – 1.5 thick slices) may provide the additional information needed for that determination.

**Ground Beef Experiment Results**

**Cooking Weight Loss**

Ground beef experiment did not show significant differences between Control and

HeartBrand ground beef in cooking weight losses as shown in Table 12 and Figure 40.

Table 12.  Ground Beef Mean Cooking Weight Loss

| ID | Fresh(g) | STD | Cooked(g) | STD | Differences(g) | STD |
|---|---|---|---|---|---|---|
| **Control** | 117.70 | 3.99 | 72.28 | 4.83 | 45.33 | 3.74 |
| **HeartBrand** | 116.38 | 2.09 | 71.38 | 3.13 | 44.98 | 2.68 |
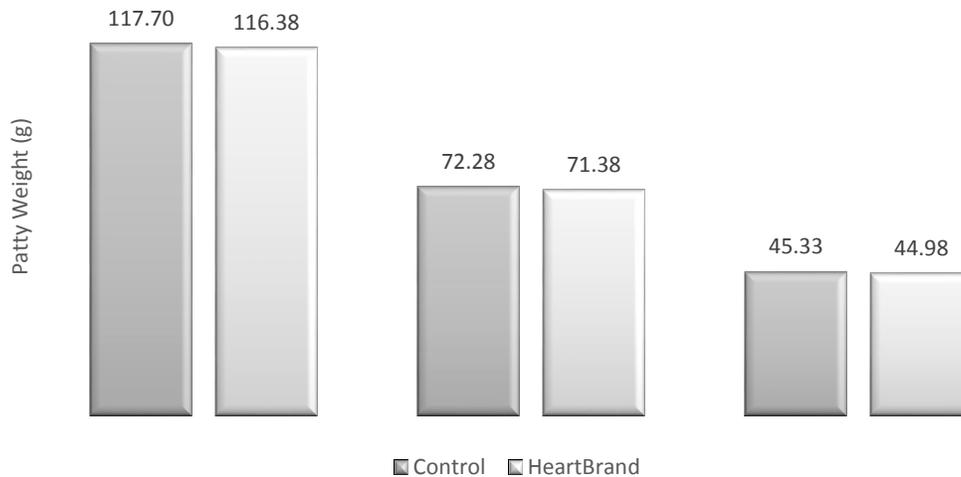


*Figure 40*.  Ground beef mean cooking weight loss

**Circumference Measurements**

Areas of significant differences were found in the measurements of the patties.

Both circumference measurements and thickness measurements showed that HeartBrand

ground beef did not shrink as much as the Control ground beef.  Circumference

measurements for the Control ground beef averaged 25.20 cm ± 1.79 fresh, 21.30 cm

±0.53 cooked with a difference of 4.00cm ± 0.59 while HeartBrand Ground beef

averaged 25.15 cm ± 0.31 fresh, 21.91cm ± 0.53 cooked with a difference of 3.21cm

±0.47 with p<.05.  These values are shown in Table 13 and figure 41.

Table 13.  Average Circumference Measurements of Ground Beef Patties

| ID | Fresh(cm) | STD | Cooked(cm) | STD | Differences(cm)* | STD |
|---|---|---|---|---|---|---|
| Control | 25.20 | 1.79 | 21.30 | 0.63 | 4.00 | 0.59 |
| HeartBrand | 25.15 | 0.31 | 21.91 | 0.53 | 3.21 | 0.47 |

*p<.05
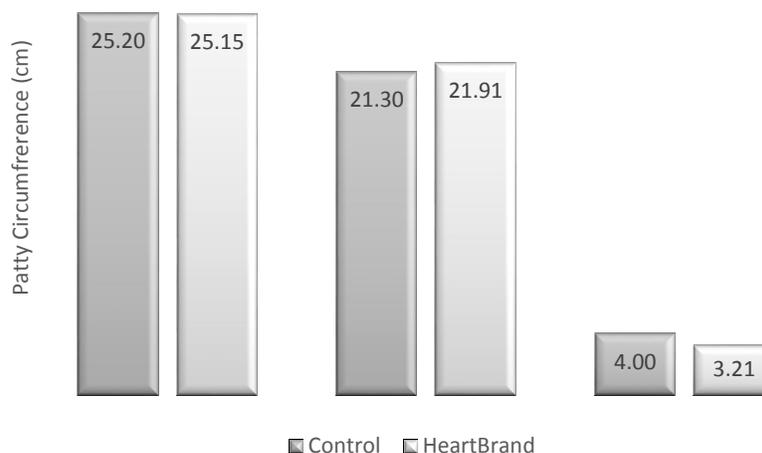


*Figure 41.*  Average circumference measurements of ground beef patties

**Thickness Measurements**

Thickness measurements of the Control ground beef patties were 2.36 cm ± 0.17

fresh, 2.14 ± 0.18 cooked with a difference of 0.22cm ± .019 and HeartBrand ground beef

patties were 2.45 cm ± 0.10 fresh, 2.31 cm ± 0.10 cooked with a difference of 0.151 cm ±

0.11 with p<.05 as shown in Table 14 and Figure 42.

Table 14.  Thickness Measurements of Ground Beef Patties

| ID | Fresh (cm) | STD | Cooked (cm) | STD | Difference (cm)* | STD |
|---|---|---|---|---|---|---|
| Control | 2.36 | 0.17 | 2.14 | 0.18 | 0.22 | 0.19 |
| HeartBrand | 2.45 | 0.10 | 2.31 | 0.10 | 0.15 | 0.11 |

*p<.05
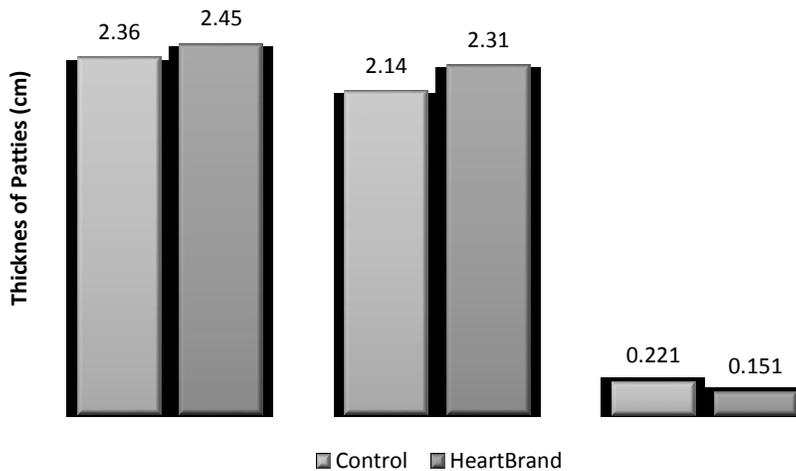


*Figure 42.* Thickness measurements of ground beef patties

**Dripping Collection Measurements**

Another area of observation on the cooking of ground beef patties that was significantly different between Control and HeartBrand was the drippings collected. Each pound of ground beef (4 patties) was cooked on the grill and drippings collected. No significant difference was noted in the total drippings collected - Control 62.4g ± 4.66 and HeartBrand 64.3g ± 5.1, but significant differences were found in the components of the drippings.  Drippings from the Control ground beef was 12.3g ± 2.72 of solids and 50.00g ± 0.61 liquid with the liquids being 79.97% of the total drippings.  HeartBrand

ground beef drippings were 18.2g ± 3.11 of solids and 46.10g ± 0.32 of liquid with the

liquids being 72.3% of the total drippings as shown in Table 15 and Figure 43.

Table 15. Evaluations of Ground Beef Drippings[1]

| ID | Total (g) | STD | Solids (g)* | STD | Liquid (g)* | STD | Liquid %* | STD |
|---|---|---|---|---|---|---|---|---|
| **Control** | 62.40 | 4.66 | 12.30 | 2.72 | 50.00 | 0.61 | 79.97 | 4.54 |
| **HeartBrand** | 64.30 | 5.10 | 18.20 | 3.11 | 46.10 | 0.32 | 72.30 | 3.58 |

[1] n=20
*p<.05
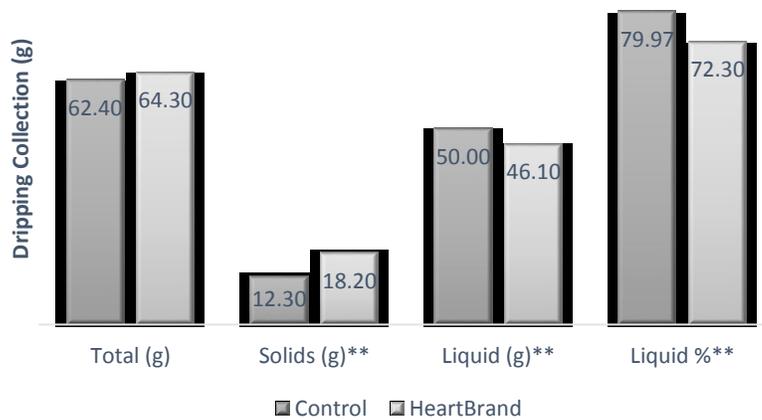


**p<.05

*Figure 43.* Evaluation of ground beef drippings with composition of drippings

No further testing has been done on the liquids or the solids from the drippings of

the ground beef after separation.  Proteins would be the main component of the solids

present in the drippings.  Increase in protein content in the HeartBrand ground beef

drippings is likely due to the high marbling (intramuscular adipose tissue) and the overall

composition and architectural arrangement of the proteins in the development of muscle tissue.

**Cooking Length Measurements**

Additional data collected on the ground beef experiment includes cooking time and cooking temperatures. No significant difference was found in the amount of time needed for patties to reached the desired temperature of $165^0$ F as shown in Table 16 and Figure 44.

Table 16. Length of Cooking Time for Ground Beef Patties

| ID | Cooking Time(min) | STD | Start Temp($F^0$) | STD | End Temp($F^0$) | STD |
|---|---|---|---|---|---|---|
| **Control** | 7.86 | 0.75 | 40.25 | 3.34 | 170.90 | 7.67 |
| **HeartBrand** | 7.84 | 0.50 | 37.19 | 4.70 | 168.87 | 4.71 |
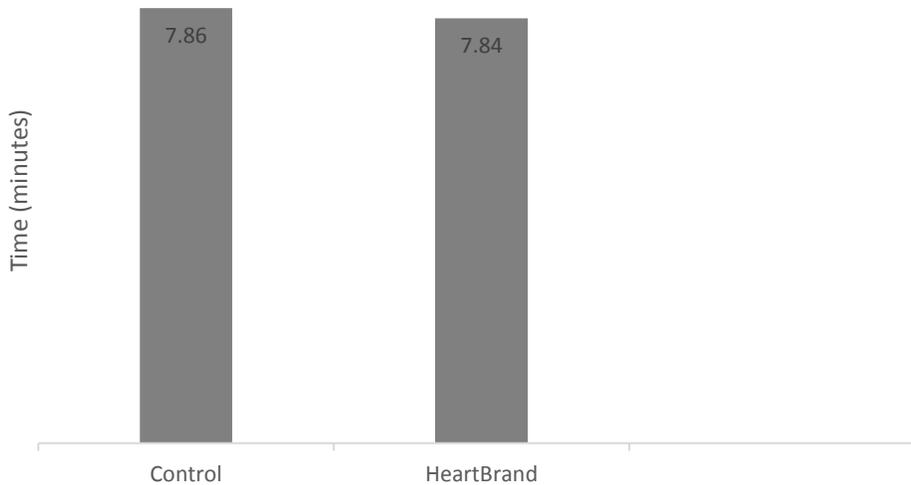


*Figure 44.* Length of cooking time for ground beef patties

**Starting and Ending Cooking Temperatures**

Temperatures of patty # 1 (back left grill position) and patty #4 (right front grill position) were monitored using Taylor digital thermometers. Significant differences were found in the start temperature between the 2 study groups. Two pounds (replication #28 and#29) of the HeartBrand ground beef packages had some ice when patties were being formed. When these two pounds were eliminated from total pounds of ground beef, there was no longer a significance. Some experimental error had been introduced in to the study when using the ground beef that was not totally thawed. Starting and ending temperatures are shown in Table 17 and Figure 45.

Table 17. Starting and Ending Cooking Temperatures

| ID | Start Temp($F^0$) * | STD | End Temp($F^0$) | STD |
|---|---|---|---|---|
| **Control** | 40.25 | 3.34 | 170.90 | 7.67 |
| **HeartBrand** | 37.19 | 4.69 | 168.87 | 4.71 |

*$p<.05$

Start Temp**     End Temp

Control     HeartBrand
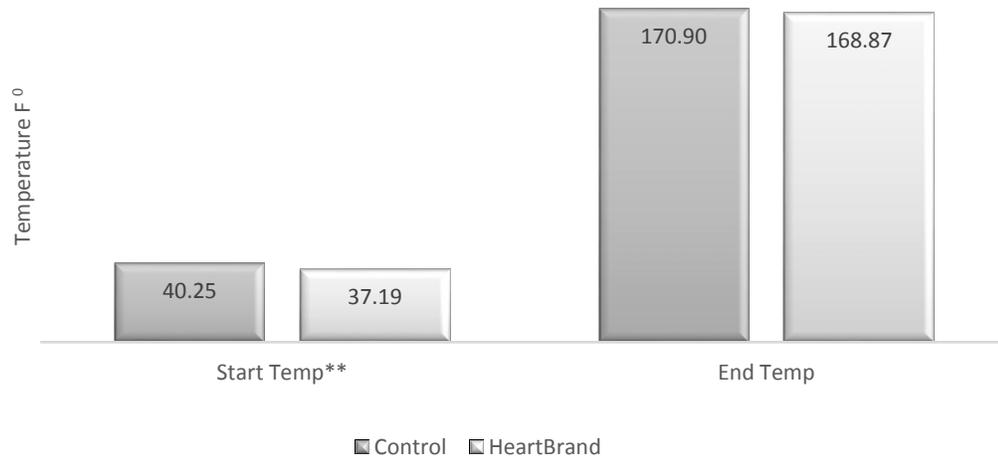
Temperature F $^0$

*p<.05

*Figure 45*.  Average starting and ending temperature of patty #1 and #4

## V.  SUMMARY

Since quality is a key demand driver for consumers consuming beef, the quality of beef needs to be consistent. Producing a consistent, high quality meat is the beef industry's challenge and is difficult to achieve due to the influence of genetics, nutrition, environmental stresses, age, and health of the cattle.  Additionally, the effects of cooking influence the value and quality of meat including tenderness and weight loss.  Two spectrums of beef quality were observed in this study:  Beef loins representing a more expensive, premium cut of meat, and ground beef representing the less expensive and more commonly consumed cut of beef.

 Experiments were designed to determine if:

1)  there is a difference in tenderness and cooking loss between commercial grocery store beef loins and HeartBrand beef loins;

2)  there is a difference in cooking loss (weight and size) between commercial grocery store ground beef and HeartBrand ground beef; and

3)  there are quality and consistency of quality differences between commercial grocery store beef and HeartBrand beef.

Data collected in this study showed differences in quality of meat due to source. Overall tenderness in premium loins was not always the lowest in tenderness scores, but the premium loins all had smaller standard deviations in tenderness measurements which shows more consistency in tenderness.  Ground beef from premium sources showed less shrinkage in circumference and thickness.  Drippings of the premium ground beef were also different in content.   HeartBrand ground beef left more solid contents on the grill which were added to the liquid drippings when cleaning drippings off the grill.  Solid

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contents are mainly protein. Akaushi beef (HeartBrand) are known for high intramuscular marbling and the adipose deposits would affect the arrangement of the proteins in the muscle tissue. This change in muscle protein architecture may be part of the explanation of why there was a significant difference ($p<.05$) in solid content of drippings collected.

Tenderness of meat is affected by factors related to the conversion of muscle to meat, components of fresh meat, and to the cooking of the meat. Harvesting conditions (animal level of excitement, glycogen levels and temperature) have a direct influence on the pH of the meat. Both pH and temperature will affect the timing and degree of pH drop in the carcass which has an impact on the tenderness of the meat. Although quality grades of meats indicate meat quality, there are other influences that will impact the consumer's satisfaction especially when tenderness is the attribute. Quality in beef production has made various advancements, but continual improvement is needed to satisfy the consumers demand for consistency in quality and value.

**Research Recommendations**

Further research recommendations for the loin experiment would be to increase the number of control loins and to adjust the orientation of the cores to match the direction of muscle fibers. Roasts were thicker than a steak and hard to distinguish the muscle fiber direction and consistency of the direction of the muscle fibers across the full thickness of the roast. Cutting loins into steak size portions (1-inch-thick) would provide more research sample numbers per loin and might prove to make some of the trends observed into significant differences. Additionally, testing the pH of the fresh meat, and after cooking may have shown a correlation with the tenderness of the roasts. Another revision to the study would be to adjust or change the cooking temperature and/ or the

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desired internal temperature of the meat.  Fatty acid analysis was not performed on the samples, but might provide additional information on consistency of quality of the meat.

Further research recommendations on the ground beef experiment would be to take circumference and thickness measurements in millimeters.  Determining protein analysis of the solids and drippings would also provide valuable information.

**APPENDIX A: LOIN DATA COLLECTION FORM**

**Steak #**_____                    **Loin #** _____
                                                  **Steak #** _____

# <u>Meat Cooking Smoker Protocol</u>

Record the following data:

Date _____    Start prepping time _____

Description of meat

_____

Weight of the meat:

Total package weight: _____        **Notes**:

Scale weight: _____

Picture of fresh meat _____

Smoker temperatures:

Chamber                    $220^0$ F _____

Internal probe temperature:   $165^0$ F _____

Smoker rinse time: _____

Temperature of chamber before rinse: _____

Temperature of chamber after rinse: _____

Smoker hopper start time: _____

Meat placed in smoker: _____

Time smoker started: _____

Time smoker reached temperature: _____

Time humidity turned on: _____

Cook time start: _____

Meat "rest" time: _____

Internal meat probe: _____

Smoke chamber temperature: _____

End of smoke "rest" time: _____

Smoke chamber temperature: _____

Time smoker re-started: _____

Slightly open the damper of smoker: _____

End time for smoker: _____

End chamber temperature: _____

Cooked weight: _____
Photograph of smoked meat: _____

Temperature of meat: small end_____        middle face_____      large end_____

"Rest and cool" @ rm temp for 30 minutes:  room temp_____

start_____    end _____

Temperature of meat: small end_____    middle face_____        large end_____

Bag meat record time, date & meat info on meat package:   _____

# Warner Bratzler Protocol

Date: _____     Date smoked_____

Meat ID     _____ Meat

Description_____

Time meat pulled from the cooler: _____

Temperature of cooler:     _____

Picture of meat with ID     _____

Meat temperature (taken on "face" of meat)

       Pre Time: _____    Post Time: _____

Small end     _____                    _____

Middle     _____                    _____

Large end     _____                    _____

### Warner-Bratzler Values

| Core # | kgf | lb/f | N | Notes |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |

Take picture of meat and core #6

| 6 | | | | |

Take picture of meat and all cores     _____

Take post temperature_____

Bag meat and cores     _____

Time back in the cooler or freezer     _____

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**Hamburger #**_____ **Replication #** _____

# <u>Ground Beef Cooking Protocol</u>

Record the following data:

Date _____ Start Prepping Time _____

Description of Meat

_____

Weight of the Meat:

Total Package Weight: _____

Scale Weight: _____(lbs) _____(grams)

| Form ¼ lb patties | Weight (lbs) | Weight (g) | Circumference | Thickness |
|---|---|---|---|---|
| Patty # _____ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ |
| Patty # _____ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ |
| Patty # _____ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ |
| Patty # _____ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ |
| Totals | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ |

Picture of fresh meat _____

Preheat time of grill: _____

Time of preheat end: _____

(Green light turns on = 3 minutes)

Time meat placed on grill: _____

Temperature: patty #1 (back left)      patty #4 (front right)

| | patty #1 (back left) | patty #4 (front right) |
|---|---|---|
| Beginning | _____ | _____ |
| Minute 1 | _____ | _____ |
| Minute 2 | _____ | _____ |
| Minute 3 | _____ | _____ |
| Minute 4 | _____ | _____ |
| Minute 5 | _____ | _____ |

Minute 6      _____      _____

Minute 7      _____      _____

Minute 8      _____      _____

Minute 9      _____      _____

Minute 10      _____      _____

Immediately remove patties from grill and remove liquid loss with a spatula

Collect drippings – leave tray on grill (5 minutes)

Start: _____      End: _____

| Cooked Weight | Weight (lbs) | Weight (g) | Circumference | Thickness |
|---|---|---|---|---|
| Patty #_____ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ |
| Patty #_____ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ |
| Patty #_____ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ |
| Patty #_____ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ |
| Totals | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ | \_\_\_\_\_ |

Photograph meat: _____

Measure drippings:

Weight of drippings and pan: _____ lb      _____grams

Pan weight: _____

Weight of drippings: _____

Put dripping in bottle: _____

Bag meat record time, date & meat info on meat package: _____

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