THE RELATIONSHIP BETWEEN PRE-HARVEST STRESS AND CARCASS CHARACTERISTICS AND THE ABILITY TO QUALIFY FOR KOSHER ON BEEF STEERS AND HEIFERS

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ABSTRACT

The objective of this study was to determine if there is a difference in pre-harvest stress and carcass characteristics between kosher and not-qualified-as kosher cattle. Cattle that had a shorter time from gate to exsanguination and a lower vocalization score were more likely to qualify for kosher. Kosher carcasses had a larger REA, a higher WBSF value, tended to have a heavier HCW. At each individual day, kosher steaks had lower L*, a*, and b* values. These data suggest that body composition and stress level may play a factor in the likelihood of a beef animal to qualify for kosher, and there is a defined quality difference between kosher and non-kosher steaks.

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DEDICATION

To: My parents

Thank you for your never ending support in all I do.

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LIST OF ABBREVIATIONS

ADG .... average daily gain

BF .... back fat

EP .... electrical prod

EtU .... exsanguination to unconsciousness

FYG .... final yield grade

GtE .... gate to exsanguination

HCW .... hot carcass weight

KPH .... kidney pelvic and heart fat

mmol .... millimolar

REA .... ribeye area

SAS .... Statistical Analytical Software

USDA .... United States Department of Agriculture

WBSF .... Warner-Bratzler Shear Force

CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW

Introduction

People of the Jewish faith follow a special dietary regiment called “kosher”. Kosher has been around for centuries and has special rules and regulations that must be followed in order for food to be deemed acceptable to eat. However, very little research has been conducted comparing kosher beef quality with conventional beef quality. Kosher slaughter has become a concern for some consumers and retailers as animal welfare has become a prominent topic in animal agriculture. Our goal is to explore these issues by evaluating pre-harvest stress, carcasses characteristics, and tenderness measurements of cattle that qualified for kosher and those that did not.

Jewish Dietary Law

“And you shall separate between the animal that is pure and one that is impure, and between the bird that is pure and the one that is impure, and you shall not make your soul abominable by (eating) an animal or a bird or anything that creeps on the ground, that I have separated for you to be (considered) impure. And you shall be holy unto Me for I, the Lord, am holy; and I have separated you from the nations to be Mine” (Leviticus 20:25-26). Since Moses received the command on Mount Sinai, people of the Jewish faith have followed a stringent set of dietary laws known as kosher (kashrut) (Regenstein et al., 2003). Kosher dietary laws originate from the books of Genesis, Exodus, Leviticus, Numbers and Deuteronomy (Torah) as well as oral law (Talmud). Kosher dietary laws promote spiritual health rather than physical health as a reason for their existence (Katz, 1976). Rabbis have since interpreted kosher dietary laws and adapted them to fit the ever changing food market and to address new technologies in the agricultural world (Regenstein et al., 2003).

There are three major issues that kosher dietary law addresses; they are allowable species of animals, the prohibition of blood, and the prohibition of mixing milk and meat (Regenstein et al., 2003).

Allowable Animals

There are specific set criteria animals must meet in order to be deemed acceptable for kosher consumption. Ruminants need to have split hoofs and chew their cud (Regenstein et al., 2003). Cattle, sheep and deer all meet this requirement, however camels do not (no split hoof) or pigs (do not chew their cud). Traditional domesticated birds, such as chickens, turkeys, ducks, and geese are also acceptable, but wild fowl are not (Regenstein et al. 2003). It is important to note that ostrich is forbidden, as it is clearly noted in the book of Leviticus (Regenstein et al. 2003). Lastly, fish with fins and removable scales are acceptable, as long as the scales can be removed without tearing the skin of the fish and the scales are large enough to see with the human eye (Regenstein et al., 2003).

Prohibition of Blood

"And ye shall be men of holy calling unto Me, and ye shall not eat any meat that is torn in the field" (Exodus 22:30). The book of Exodus states that people should not mutilate, or process any animal until it is dead. In the Jewish faith blood is known as the life fluid and therefore must be completely removed before an animal can be eaten (Regenstein and Regenstein, 2012). The removal of blood begins at exsanguination. The animal may not be mutilated before the slaughter process and therefore no stunning is permitted prior to exsanguination (Regenstein and Regenstein, 2012). Exsanguination is performed by cutting both the carotid artery and the jugular vein in one motion to allow for maximum bloodletting (Regenstein et al., 2003). Furthermore, once the animal is deceased, the meat must be salted and

soaked within three days of slaughter. This process (melicha) involves soaking the meat for 30 minutes in cool water, and then removed and every external surface is salted (Regenstein and Regenstein, 2012). After the meat has been salted, it is rinsed for up to one hour, removing the remaining blood and salt (Regenstein and Regenstein, 2012). The salt particles must be large enough so they do not completely dissolve in the one hour soak (Regenstein and Regenstein, 2012). This process may be repeated up to 3 times to insure the removal of all blood from the meat (Regenstein and Regenstein, 2012).

Prohibition of Muscle and Milk

Lastly, kosher dietary law prohibits the mixing of milk and meat. The passage *"Thou shalt not seeth the kid in its mother's milk"* (Exodus 23:19, Exodus 34:26, Deuteronomy 14:21) appears three times in the Torah and is taken very seriously in the Jewish faith (Regenstein and Regenstein, 2012). In order to prevent the mixing of dairy and meat products, two steps are taken. First, most kosher households have separate cookware and utensils for meat products and dairy products. Next, is that there is a required amount of time to wait between consuming meat and then consuming dairy. This wait time is usually 3 to 6 hours depending on local traditions (Regenstein and Regenstein, 2012). Eggs, fish, and all plant products are considered neutral (pareve) and may be consumed with either meat or milk (Regenstein and Regenstein, 2012).

Slaughter Method

Slaughter is the first act in converting living animal tissue to an edible meat product. Welfare at the time of slaughter has become increasingly important (Grandin, 1997b), and has driven the industry to evaluate several different slaughter techniques. The primary distinguishing feature between slaughter methods is associated with stunning method. Stunning method affects bleeding efficiency (Vimini et al., 1983) The two archetypes of stunning method are stunning prior to slaughter or no stunning prior to slaughter (also known as ritual slaughter). We will discuss both types and variations of each type in this section.

The purpose of stunning prior to exsanguination is to place cattle in an unconscious state (Gregory, 2009) where they lose the ability to experience physical pain (Rosmini, 2006). Stunning also immobilizes the cattle, creating a safer work environment for workers (Guerroero-Legarreta, 2012), and allows for glycogenolysis to drive the conversion of muscle to meat (Onenc, 2004). Stunning method must follow several guidelines noted by Rosmini (2006); it must not effect meat quality, must allow for rapid bloodletting, must be easy to apply to the animal, provide no risks to the operator, and stun the animal without causing death. Gregory (1998) states that improperly stunning an animal will spike short term stress resulting in lower meat quality for that carcass. Therefore, extreme care must be taken when stunning live animals.

Contusion Stunning

Contusion stunning is a stunning method that is completed by a blow to the head to obtain unconsciousness. Compression guns, also known as captive bolt guns, can be used on cattle by projecting a metallic rod against the skull of the animal (Romans et al. 2001). It is important to note that the placement of the captive bolt is important to insure a proper stun. *Bos taurus* cattle should be stunned from the front of the skull below the poll, while *Bos Indicus* cattle should be stunned from the back of the head because of the thick skull mass in the front of their head (Guerroero-Legarreta, 2012). Gregory and Shaw (2000) confirm that when captive bolt stunning is properly applied, it can result in immediate unconsciousness. Unconsciousness is determined by an absence of a corneal reflex (Lambooy et al., 1981). The drawback of the contusion stunning method is the fact that cattle may regain consciousness if the stun has not produced enough tissue damage (Wotton, 2000). Gregory (1993) states that 6.6% of cattle are not stunned after the first attempt, even when the captive bolt gun is properly applied.

Electrical Stunning

Another possible stunning method prior to exsanguination is electrical stunning. Epileptic shock is the cause of unconsciousness, via a massive wave of neurotransmitters to the brain (Guerrero-Legarreta, 2012). The major benefit for using electrical stunning is the high rate of unconsciousness when properly used (Guerrero-Legarreta, 2012). Gregory (1994) further indicates that electrical stunning has animal welfare advantages as well; it takes the accuracy of a slaughterman out of the equation, as well as the fear of the animal regaining consciousness. Although more common in swine and sheep, electrical stunning is approved for cattle. Kicking and other physical activity after stunning poses a problem for electrical stunning. While the current is being applied, the animal is in a rigid (tonic) state with extreme muscle contraction. When the current is removed the tonic state is continue for a small period of time, followed by convulsions and kicking (clonic state) (Gregory, 1998).

Wotton (1995) notes that when pigs are electrically stunned they may become more difficult to shackle, in turn impairing worker safety. Ecchymosis, also known as blood splash, a quality defect can occur in carcasses that were harvested by electrical stunning (Gregory, 1985). Blood splash occurs when blood vessels rupture at death releasing blood into the muscle. Aalhus et al. (1991) mentions that this may be a result from vascular damage caused from the intense muscle contraction that occurs with electrical stunning. Channon et al. (2002) found that pigs that were electrically stunned had a faster muscle pH decline than pigs that were stunned with other methods, which may be due to the greater amount of muscle contraction during stunning.

Kosher Slaughter

In 1958, the U.S. Congress stated that religious slaughter, such as kosher and halal, are to be considered humane even with no prior stunning before slaughter (Regenstein et al. 2003). Jewish law forbids the mutilation of any animal before it is dead, and therefore no stunning prior to slaughter is permitted in the Jewish faith (Regenstein and Regenstein, 2012). Trained religious slaughtermen (Shochets) are responsible for slaughtering animals according to Jewish dietary law (Kashrus). It is this process of following these laws that determine if an animal is kosher, not a prayer or a blessing. One blessing is said before the beginning of the slaughtering process, not before each animal. This blessing is said by the shochet to ask for forgiveness of taking life.

Since there is no stunning prior to slaughter, restraint is extremely important for kosher slaughter. The Weinberg holding pen and the American Society for the Prevention of Cruelty to Animals (ASPCA) Pen are the two most common restraint boxes used in today's slaughter houses. The Weinberg holding pen rotates 180 degrees to invert the animal, using gravity to expose the neck. The ASPCA pen allows the animal to remain upright and uses a hydraulic ram to lift a chin strap, stretching the head of the animal upward, exposing the neck. Dunn (1990) found that cattle in the Weinberg pen struggled for significantly longer, had higher occurrences of labored breathing, frothing at the mouth, and a higher incidence of vocalization than those in ASPCA pens. Cattle also had higher blood cortisol concentrations in the Weinberg pen as compared to conventionally killed cattle or cattle killed in an ASPCA pen (Dunn, 1990). Dunn also stated that the time for exsanguination was longer for the Weinberg pen.

The shochet uses a special knife called a chalef. The chalef is a rectangular blade that is extremely sharp to insure a swift, clean cut. The blade must be twice the width of the animal's neck. After each cut, the knife is inspected for nicks or signs of improper cutting. The shochet also inspects the neck and the cut to insure that it was properly done. If an imperfection is found the animal is consider to be “triefe” or unfit for kosher consumption. The animal’s neck is inspected prior to exsanguination for any debris or dirt that may harm the chalef. If any is found the animals neck must then be washed, slowing the slaughtering procedure. The cut is made in one swift motion across the neck of the animal severing the jugular vein, carotid artery, trachea, and esophagus. Regenstein and Regenstein (2012) states that there are 5 laws that must be observed during exsanguination:

1. No pausing (Shehiyyah): The cut can be multiple continuous strokes.
2. No pressure (Derasah): Concern that the head falls back on the knife
3. No burrowing (Haladah): The knife has to be doing its job by cutting
4. No deviating (Hagrama): There is a correct area for cutting
5. No tearing (Ikkur): If the neck is stretched too tight, tearing may occur before the cutting.

After exsanguination, the animal loses consciousness from massive blood loss. Gregory, (2010) states that there is a no clear agreement among scientists on when a cattle loses consciousness during slaughter with no stunning although lack of cornea reflex is the most popular indication. Although an animal may be killed using kosher methods, further inspection must be performed to determine if the carcass can qualify as kosher. Trained rabbis inspect the carcass for defects such as lesions, lacerations, broken limbs, missing and punctured organs, all indicating an attack on the animal by another larger animal. These could result in the animal not qualifying for kosher (Regenstein et al., 2003).

The greatest cause of an animal to be rejected is lung adhesions. The lungs are inspected twice, once while sitting in the thoracic cavity, and again after they are removed. Lungs are also inspected for adhesions to the body wall and for their ability to hold air. An animal is deemed acceptable based on the rabbi's personal judgment. There are several grades within kosher that follow certain guidelines. "Glatt", meaning smooth, has less than 2 adhesions to the body wall while "Beit Yosef" must be free of any lung adhesions. Both of these designations are still considered kosher, and different groups within the Jewish faith may prefer one or the other based on their specific beliefs.

Halal Slaughter

Halal meat is consumed by members of the Muslim faith and has similarities to the kosher slaughter procedure. Like kosher, halal follows a strict set of guidelines found in the Quran. The consumption of blood is not allowed, and therefore any pre-harvest stunning is forbidden. Anil et al. (2006) reported that Halal slaughter did not have any positive effect of exsanguination in sheep. Likewise, they found that captive-bolt and electrical stunning did not have any negative effect. Anil et al. (2006) are quick to note however that this may not be the same results for cattle as they have additional extravascular branches in the neck. Levels of hemoglobin were reported to not be statistically significantly different between sheep that were Halal slaughtered versus captive bolt slaughtered (Anil et al. 2006). Thus, echoing Anil's work that blood loss is not improved or hindered by stunning method (Kalweit et al. 1989).

Muslims are also forbidden to eat any member of the porcine family as they are considered a transport for pathogenic worms to enter the body. The slaughter procedure may be performed by either a man or woman who is a sane adult follower of Allah. Animals are treated in high regard in the Muslim faith and extra steps are taken to insure humane treatment. Animals are given water and rest before slaughter, the blade of a knife may not be sharpened in front of the animal, and the blade must be razor sharp to invoke a quick death. Unlike kosher slaughter, a prayer must be said at the time of each slaughter, pronouncing the name of Allah. Like the kosher tradition, halal slaughter forbids any stunning prior to exsanguination, although some Muslim authorities have approved a low level electrical stunning procedure. The procedure involves stunning the animal with electricity, as long as the animal would be able to regain consciousness within a minute and be able to eat within five minutes (Grandin and Regenstein, 1994). The trained slaughterman makes 3 quick cuts, severing at least 3 of the following; carotid artery, jugular vein, trachea, and esophagus. After this point, halal meat is treated like conventional product, it does not need to be salted and soaked like its kosher counterpart.

Pre-Harvest Stress

Animal welfare has become a front runner in hot button agricultural issues in recent years. Programs like **The Masters of Beef Advocacy** and **Beef Check-off** have promoted positive animal welfare to a growing consumer base that is beginning to care where their food comes from and how it was treated. Webster (1983) defines animal welfare as the animal's environment being capable to meet the behavioral and health needs of that animal. At any time that these needs are not being met, the animal may be subjected to a level of stress. Grandin (1997a) describes two types of stress; psychological and physical. Restraining the animal, poor animal handling, and transport are examples of psychological stress, while hunger, thirst, temperature, and pain are examples of physical stress. It is inevitable that all animals will experience some stress in their life, but chronic, long term stress results in economic loss to the producer and must be avoided. Also short term stress prior to slaughter and chronic long term stress both can affect meat quality and cause economic loss to the packer as well as the producer. It is therefore extremely important to hold animal welfare in high regard not only for the demands of the consumer, but for high economic return as well.

Measuring Stress

Quantifying stress is a difficult task for researchers and scientists. Many methods are subjective, allowing for the results to vary upon the individual scientist, possible bias, and may be difficult to repeat. There is no one widely accepted method to measure the different amounts of stress to which an animal may be subjected. Curley et al. (2006) suggests that a good method for evaluating stress must be reliable, repeatable, and linked to the individual animal's response. Genetic markers are now being used to help detect temperament in beef cattle, however at this point in time, would not be a viable research tool for evaluating a stress response among cattle.

Pen score, chute score, and vocalization score are examples of current subjective measurements of stress. Curley et al. (2006) found that a pen scoring system of 1-5 (1 = completely calm animal, 5 = extremely excited) could be used to determine correlations with blood cortisol levels in pens containing small groups of beef cattle (n = 5). Grandin (1993b) developed a chute scoring system that has become widely accepted among animal scientist studying beef temperament. With the animal in a working chute, but not head restrained, cattle activity is observed and recorded on a 1 through 5 scale (1 = calm, 2 = slightly restless, 3 = squirming occasionally shaking the chute, 4 = continuous vigorous movement and shaking of the chute, and 5 = rearing and twisting of the body and struggling violently). Watts and Stookey (2000) stated that vocal behavior is a useful means by which to investigate the physical and psychological functioning of that animal. Vocalization can be viewed as the commentary of the individual animal in response to a situation and therefore may be valuable measurement in determining the well-being of that animal in a certain situation. Warriss et al. (1994) found that vocalization is directly correlated to blood lactate levels at time of slaughter in pigs, indicating that it may be a useful measurement of stress.

Meat Quality

Beef is generally sold at a higher price per pound than other protein sources, such as chicken or pork. Therefore consumers expect a higher palatability and eating satisfaction when purchasing beef (Issanchou, 1996). Tenderness, juiciness, and flavor are the three factors that determine palatability. Improvements have been made for these three factors in low cost beef cuts (Molina et. al, 2005). In turn, quality has become one of the most important factors on which producers and consumers focus.

Color

Color is one of the most important factors in relation to beef quality. With the exception of price, color is the largest determining factor that consumers use to select meat in a retail case (Faustman et al. 1991). Carpenter et al.(2001) found that consumers were more likely to purchase and be satisfied with bright red colored steaks and ground beef compared to purple or brown colored product, although there was no difference in tenderness or flavor. Color is determined primarily by postmortem chemical activity of the protein Myoglobin. There are 3 different chemical states of postmortem myoglobin; deoxymyoglobin, oxymyoglobin, and metmyoglobin that have different colors, dark red-purple, bright cherry red, and brown respectively. Mancini and Hunt (2005) state that there are several pre-harvest factors that affect meat color such as genetics, breed type, diet, short term pre-harvest stress , age, sex and muscle type. Typical color measurements are done by using a colorimeter on the L*, a*, and b* scale. L* is a measurement of black to white, a* is the measurement of green to red, and lastly b* is the measurement of blue to yellow. Wulf and Wise (1999) states that these measurements were helpful predictors of lean maturity and overall muscle pH. Wulf et al. (1997) also found that color was a better predictor of tenderness than marbling and suggested that using color as a critical control point in the select process for tender beef.

Tenderness

Tenderness is considered the most important palatability factor (Savell et al. 1987) compared to juiciness and flavor. Extensive research has been conducted to examine the mechanics of tenderness in beef cattle. Smith (1992) stated that tenderness was in the top ten concerns of restaurateurs and retailers. Miller et al. (2001) stated that 15 to 20 percent of steaks sold to consumers are "tough" even though they may have a premium USDA quality grade (USDA Choice or higher). This inconsistency in tenderness has become an important issue in the meat industry (Koohmaraie, 1996).Tenderness may be evaluated in 2 different ways; subjective and objective. Trained taste panels can be used as a subjective way to measure tenderness and provides a basis for consumer acceptability. Warner-Bratzler shear force is a widely accepted measurement of objective tenderness that involves cooking samples to an internal temperature of 71 °C, allowing them to cool, and coring and shearing samples resulting in an objective measurement of tenderness. Huffman et al. (1996) found that consumers were an accurate predictor of tenderness and found that 98% of steaks below 4.1 kg Warner-Braztler shear force value were acceptable tenderness. Consumers were also willing to pay a higher amount of money for a more tender steak within the same quality grade (Miller et al., 2001).

Juiciness

Juiciness is the feeling of moisture in the mouth during chewing. Juiciness allows for the flavor of the meat to come in contact with the taste buds as well as help facilitate the chewing process. There are several factors that influence juiciness. The first major factor is internal temperature of the meat. Meat cooked at higher temperatures or for longer periods of time have higher cook loss. A high cook loss is directly related to a drier steak (Aaslyng et al., 2003). Ultimate muscle pH also plays a factor in juiciness. As ultimate pH increases, the water holding capacity of muscle rises as well, resulting in muscle cells retaining large amounts of water. If pH drops at a fast rate at the time of death, muscle with become exudative and have a lower water holding capacity. Also known as PSE (pale soft and exudative), this is considered a quality defect and is undesirable (Warriss et al. 1994).

Flavor

Flavor is the final component of determining palatability, and perhaps the most complex. Flavor is determined by hundreds of volatile compounds found in the muscle tissue. Hydrocarbons, aldehydes, ketones, alcohols, esters, and furans are some examples of these compounds (Calkins et al., 2007). Flavor can also be affected by a large variety of factors such as age, nutrition, environment and sex.

Beef Carcass Quality

Unlike pork or chicken, the price of beef is based on carcass quality, therefore, there was a need to develop a carcass quality grading system to standardize carcass quality across the nation. The United States Department of Agriculture created USDA Quality Grade as a pricing tool used by packers (USDA, 1997). Beef carcass quality grade is based primarily on two factors; maturity and marbling score. Maturity is broken down into 2 major sub categories, skeletal and lean color. Overall maturity is on an A through E scale with each letter having a subset of a 100 point scale. As animals increase in age, lean color trends to darker and redder tones as myoglobin concentrations increase. This allows for lean color to be a useful tool for measuring maturity. The amount of cartilage is the indicator used in beef grading for the measurement of skeletal maturity. In young animals cartilage along the chine (vertical processes of thoracic vertebrae) is abundant; however as the animal ages the cartilage ossifies and turns to bone. The average of skeletal and lean maturity is determined to find an overall maturity for each individual carcass, however if a carcass displays a skeletal maturity later than C the overall maturity will still be considered “C.” Animals that are overall A maturity are consider young cattle and can qualify for USDA Prime, Choice, Select and Standard quality grades. Overall B maturity carcasses are also considered young; however only qualify for USDA Prime, high and average Choice, and Standard. Cattle with overall maturity for C through E are considered old cattle and are severely discounted in value, only being able to qualify for USDA Commercial, Utility, and Canner Cutter quality grades.

Marbling is the amount of intramuscular fat within a muscle. For USDA grading, marbling score is determined by the amount of fat that is in the longissimus muscle between the 12th and 13th rib of each carcass. A higher marbling score is an indicator that a cut from that particular carcass has a higher chance of being juicy and flavorful, while a lower marbling score may indicate a dry tough steak with a lower palatability. Young cattle (under 30 months of age) may grade Prime (Marbling Score = Abundant, Moderately Abundant, Slightly Abundant), High Choice (Moderate), Average Choice (Modest), Low Choice (Small), Select (Slight), or Standard (Traces, Practically Devoid). Consumers are willing to pay more for a higher quality grade to insure a positive eating experience.

Beef Carcass Defects

Blood splash is a defect that results when capillaries in the muscle rupture allowing blotches of blood to appear on the meat. The cause of this is not yet proven, however, Gregory (1998) states that this is most likely due to high blood pressure and extreme muscle contraction. He states that as an animal dies, all muscles go through a period of intense contraction. This results in muscles working against one another and can result in tearing of muscle tissues. Blood splash is undesirable and heavily discounted in packing plants.

Dark cutting beef is another carcass defect. If an animal is subject to periods of long term stress prior to slaughter it can be more susceptible to dark cutting. Long term antemortem stress drains the animal of glycogen in the muscle. That glycogen is used at the time of death in anaerobic glycolysis and is turned in to lactic acid. This lactic acid drives pH decline in the conversion of muscle to meat. If there are low glycogen levels, there is a slow or limited pH decline, resulting in a dark colored lean tissue (Scanga et al. 1998).

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CHAPTER 2. THE RELATIONSHIP BETWEEN PRE-HARVEST STRESS AND CARCASS CHARACTERISTICS AND THE ABILITY TO QUALIFY FOR KOSHER ON BEEF STEERS AND HEIFERS

Abstract

The objective of this study was to determine if there is a difference in pre-harvest stress and carcass characteristics between kosher and not-qualified-as kosher cattle. Finished steers and heifers (n = 162) were slaughtered according to kosher law by a trained religious slaughter man. Number in pen, chute score, vocalization score, electrical prod use, time from gate to exsanguination, time from exsanguination to unconsciousness, and blood lactate were measured. Carcass data was collected after a 24-h chill by trained personnel and 3.75-cm thick steak samples were taken from the 13^{th} rib. Steaks (2.5-cm thick) were fabricated from each sample, vacuum packaged, aged for 14 d, and then frozen until analysis of Warner-Bratzler shear force (WBSF). Steaks (1.25-cm thick) were also fabricated from the original sample, vacuum packaged, aged for 7 d then placed in a foam tray, overwrapped, and placed under fluorescent light in a 4 °C cooler. Minolta color scores were taken every day for 10 d. Data were analyzed using the GLM procedure of SAS using kosher as the source of variation in the model. Cattle that had a shorter time from gate to exsanguination ($P = 0.01$) and a lower vocalization score ($P = 0.01$) were more likely to qualify for kosher. Kosher carcasses had a larger REA ($P = 0.02$), a higher ($P < 0.0001$) WBSF value, and tended to have a heavier HCW ($P = 0.10$). At each individual day, kosher steaks had lower L*, a*, and b* values. These data suggest that body composition and stress level may play a factor in the likelihood of a beef animal to qualify for kosher, and there is a defined quality difference between kosher and non-kosher steaks.

Introduction

Kosher food founded from biblical origins grew into a $200 billion food industry in 2009 (Regenstein and Regenstein, 2012). The kosher slaughter process is performed by a trained religious slaughter man with no stunning of the animal prior to exsanguination. However this procedure does not solely make an animal acceptable for kosher consumption. Internal organs, specifically the lungs, must be inspected for any defects. In the lungs, lung adhesions are the primary concern; these lung adhesions are not desirable and may result in an animal failing to qualify as kosher. Lungs have been inspected since biblical times as a guard against disease, particularly tuberculosis. It is likely pneumonia and other respiratory illnesses are among the most common causes of lung adhesions. We hypothesize that pre-slaughter stress may have an effect on carcass and beef quality of steers and heifers kosher slaughtered and will affect the ability for an animal to qualify as Kosher. The objective of this study was to determine if there is are differences in pre-slaughter stress and carcass characteristics between kosher and non-kosher beef cattle

Materials and Methods

Data Collection

Trained university personnel at a commercial abattoir in New Rockford, ND, observed kosher beef slaughter of steers and heifers (n = 162). Pre-slaughter measurements recorded include; number of animals in lairage pens, chute score, vocalization score, number of electrical prods used, and time from entering the v-belt to exsanguination (GtE). Chute score (1 = calm, no movement; 2 = slightly restless; 3 = squirming, occasionally shaking the chute; 4 = continuous, very vigorous movement and shaking of the chute; 5 = rearing, twisting of the body and struggling violently) was adapted from Grandin (1993) and recorded in the holding chute prior to entering the v-belt restrainer. Vocalization scores (0 = no vocalization, 1 = low intensity, singular vocalization;

2 = mild intensity, one to two vocalization; 3 = high intensity, two or more vocalizations) were observed in the v-belt restrainer. Time was recorded from exsanguination to unconsciousness (EtU). Unconsciousness was defined by lack of corneal reflex. Approximately 30 s after exsanguination, a 2-mL blood sample was collected in order to obtain a blood lactate concentration (Lactate Pro Meter, Arkray, USA Inc., Edina, MN). After chilling for ~24 h carcass measurements were obtained at North Dakota Natural Beef processing facility in Fargo, ND. Measurements included hot carcass weight (HCW), 12th rib fat (BF), rib eye area (REA), kidney pelvic and heart fat percentage (KPH), final yield grade (FYG), marbling score (Marb), as well as the presence of beef quality defects. A sample, approximately 3.8-cm thick, was obtained from the loin at the 13th rib, placed in a labeled bag inside a cooler, and transported to North Dakota State University's meats laboratory. Upon arrival 2.54-cm and 1.25-cm steaks were cut from each sample, and vacuum packaged using a Cryovac® vacuum packager (Duncan, SC).

Warner-Bratzler Shear Force (WBSF)

After aging for 14 d in darkness at 4°C, steaks were immediately frozen at -20°C until analysis. To measure tenderness, the 2.54-cm steaks were allowed to warm to 4 °C in the cooler, were weighed, and a thermocouple was inserted (Omega Engineering Inc., Stamford, CT.) in the geometric center of the steak. Steaks were cooked to an internal temperature of 71° C using a George Foreman grill (Model No. GRP99 Columbia, MO), removed, allowed to cool, and reweighed for cook loss. Six 1-cm cores were taken from each steak with the grain of the muscle fiber and sheared once across the grain for measurement of tenderness via the procedure from AMSA (1995).

Display Life

After aging for 7 d in darkness, the 1.25-cm steaks were removed from their packages, placed in a foam tray and overwrapped with clear cellophane. Steaks were then placed in a 4° C cooler under continuous fluorescent light. L*, a*, and b* values were taken every 24 h for 10 d using a Minolta colorimeter (Konica Minolta, Toyko, Japan), on each individual steak. After measurements were taken each day, steaks were randomly sorted to mimic movement found in a retail case.

Sarcomere Length

Frozen muscle tissue from the strip loin (1.5 g) was frozen 24 h post-mortem. Samples were then removed from the freezer, minced and homogenized using a Polytron with a PT-10s probe (Brinkmann, Westbury, NY) in rigor buffer [75 m*M* KCl, 10 m*M* imidazole, 2 m*M* $MgCl_2$, 2 m*M* ethylenediaminetetraacetic acid (EDTA), 1 m*M* NaN_3; pH 7.2]. Just before homogenizing, 200 m*M* Phenylethyl sulfonyl fluoride (PMSF) was added to Rigor Buffer to a final concentration of 0.1 m*M*. Myofibrils were prepared by method modified from Weaver (2009). Sarcomere length estimation was determined using modified method from Weaver (2008). Images were captured using the Zeiss Axio Imager Z2 upright microscope equipped with high resolution AxioCamMRc3 camera and the A-Plan100x 1.25 oil Ph3 objective (Carl Zeiss Microscopy, LLC; 1 Zeiss Dr., Thornwood, NY, 10594, USA)

Statistical Analysis

The kosher data were obtained from North Dakota Natural Beef. Carcasses were assigned either as glatt kosher or Non-kosher designation. Data was analyzed using PROC GLM procedures of SAS (SAS Institute Inc., Cary, NC) with kosher as the source of variation in the model

Results and Discussion

Pre-Harvest Stress Measurement

Least square means and standard errors calculated for pre-harvest stress measurements of beef steers and heifers are presented in Table 2.1. Number of animals in pen, chute score, EtU, and number of times of electrical prods were used did not have an effect on kosher qualification ($P > 0.10$). Grandin and Regenstein (1994) found that most cattle lose consciousness 5 to 60 seconds after kosher exsanguination, however our findings are consistent with Blackmore (1984) and Daly (1988) who state that it may be over a minute. Grandin (1980) found that short term acute stress resulted in a buildup of lactic acid. In the present study, blood lactate was measured with the aim of objectively measuring stress during slaughter conditions. The animal's blood lactate level was not related ($P > .05$) to kosher qualification. Cattle that qualified for kosher, were less vocal ($P < 0.01$) and took less time from entering the gate to exsanguination ($P = 0.01$). Grandin (1997) observed 112 cattle through six different plants and found that cattle vocalize after an adverse event such as electrical prodding, slipping, or excessive pressure in a powered restraining device. Dunn (1990) found that animals that were inverted prior to exsanguination have higher cortisol levels in the blood as well as a great vocalization score, suggesting that vocalization may be an indicator for an animal's stress level.

Carcass Measurements

Least square means and standard errors were calculated for carcass measurements of beef steers and heifers and are presented in Table 2.3. 12th rib fat, KPH, and USDA yield grade were not significantly different ($P > .05$) between kosher and non-kosher cattle. Although there was no difference between 12th rib

Table 2.1. Least-squares means and standard errors for pre-harvest characteristics of beef steers and heifers.

Trait	Non-Kosher	SEM	Kosher	SEM	*P*-value
	n = 85		n = 77		
# in Pen	10.59	0.35	10.26	0.37	0.53
Chute score	2.97	0.15	2.85	0.16	0.60
Blood lactate, L/mmol	7.48	0.60	7.78	0.63	0.73
GtE, s	53.67	1.92	46.49	1.99	0.01
EtU, s	78.05	2.75	83.19	2.88	0.20
Vocal Score	1.09	0.15	0.47	0.16	< 0.01
# of EP	1.03	0.16	0.92	0.17	0.64

Table 2.2. Carcass traits and shear force values of beef steers and heifers.

Variable	n	Mean	Standard Deviation	Minimum	Maximum
Final USDA Yield Grade	162	2.62	0.84	1.00	5.40
Hot carcass weight, kg	162	356.52	46.27	221.81	444.08
12th Rib Fat Thickness, cm^2	162	1.22	0.53	0.25	2.79
Ribeye Area, cm^2	162	83.87	10.97	54.20	129.03
Kidney Pelvic and Heart Fat, %	162	2.00	0.01	1.00	3.50
Marbling Score[1]	162	425.40	101.90	280.00	760.00
Warner-Bratzler Shear Force, kg	160	3.50	1.13	1.70	7.42

[1]Marbling Score 200 = practically devoid, 300 = slight; 400 = small; 500 = modest; 600 = moderate, 700 = slightly abundant.

fat and KPH in our study, there was a trend ($P = 0.09$) that non-kosher cattle displayed higher marbling scores. Daniel et al. (2006) found that lambs with severe lung lesions had lower ADG and higher average marbling scores than those with normal lungs. This suggests that ruminants with lung health issues may spend a larger amount of time in the finishing phase, allowing for an increase in intramuscular fat. Kosher cattle possessed larger REA ($P = 0.02$) and heavier hot carcass weights ($P = 0.10$). Reinhart et al. (2009) found that more excitable cattle had a lower HCW ($P > 0.01$) which corresponds to our current findings. Schneider et al. (2009) and Reinhart et al. (2009) also found that cattle with increased number of lung lesions also had decreased

HCW, and REA suggesting that cattle with health concerns in the feedlot may not reach full carcass potential. These data suggest that there may be a phenotypical difference in kosher vs. non-kosher cattle with kosher cattle being larger, more muscular, with less marbling in the longissimus at the 12th rib.

Table 2.3. Least-squares means and standard errors for carcass characteristics of beef steers and heifers.

Trait	Non-Kosher	SEM	Kosher	SEM	*P*-value
	n = 85		n = 77		
HCW, kg	336.78	8.15	354.84	6.96	0.10
BF, cm	1.17	0.10	1.14	0.08	0.82
REA, cm^2	78.77	1.87	84.71	1.61	0.02
KPH, %	2.00	0.01	2.00	0.01	0.18
FYG	2.55	0.13	2.38	0.12	0.33
Marb[1]	453.95	17.84	413.27	15.25	0.09

[1]Marbling Score 300 = slight; 400 = small; 500 = modest; 600 = moderate.

Beef Tenderness Measurements

Least squares means and standard errors for tenderness measurements of beef steers and heifers were presented in Table 2.4. Kosher grade carcasses displayed a larger WBSF value ($P < 0.0001$). Longissimus samples from Kosher qualified cattle tended to have shorter sarcomere length ($P = 0.09$) than non-kosher. Short sarcomere length has a direct relationship with meat tenderness (Aberle et al., 2001). King et al. (2006) state that cattle with calmer temperaments possessed longer sarcomeres than those with excitable temperaments.

Table 2.4. Least-squares means and standard errors for tenderness measurements of beef steers and heifers.

Trait	Non-Kosher	SEM	Kosher	SEM	*P*-value
	n = 83		n = 77		
WBSF, kg	3.37	0.17	4.28	0.15	< 0.0001
Sarcomere Length, µm	1.92	0.03	1.84	0.03	0.09

Display Life Color Score Measurements

L*, a*, and b* values are represented on Figures 2.1., 2.2., and 2.3. respectively. On each individual day kosher steaks were significantly different lower ($P < 0.05$) in L*, a* and b* values. Also each day was significantly different ($P < 0.05$) in L*, a*, and b* values than the previous day. However the interaction of kosher grade and time were not significant. Wulf et al. (1997) found that steaks displaying a higher L*,a* and b* value (lighter, redder, more yellow value) to be more tender and have lower shear force value, which is contradictory to the findings of our study. Breidenstein et al. (1968) has found that steaks with a higher marbling score also have a higher color score, which is consistent with our findings in this study.

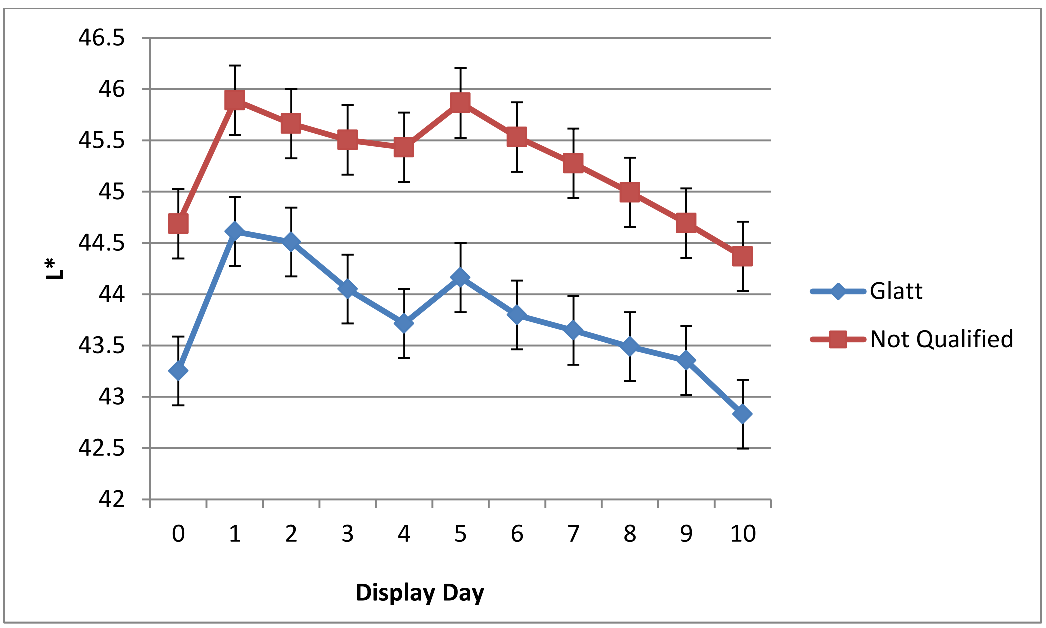

Figure 2.1. Minolta L* color score values of beef loin steaks from cattle that either qualified or did not qualify as glatt kosher.

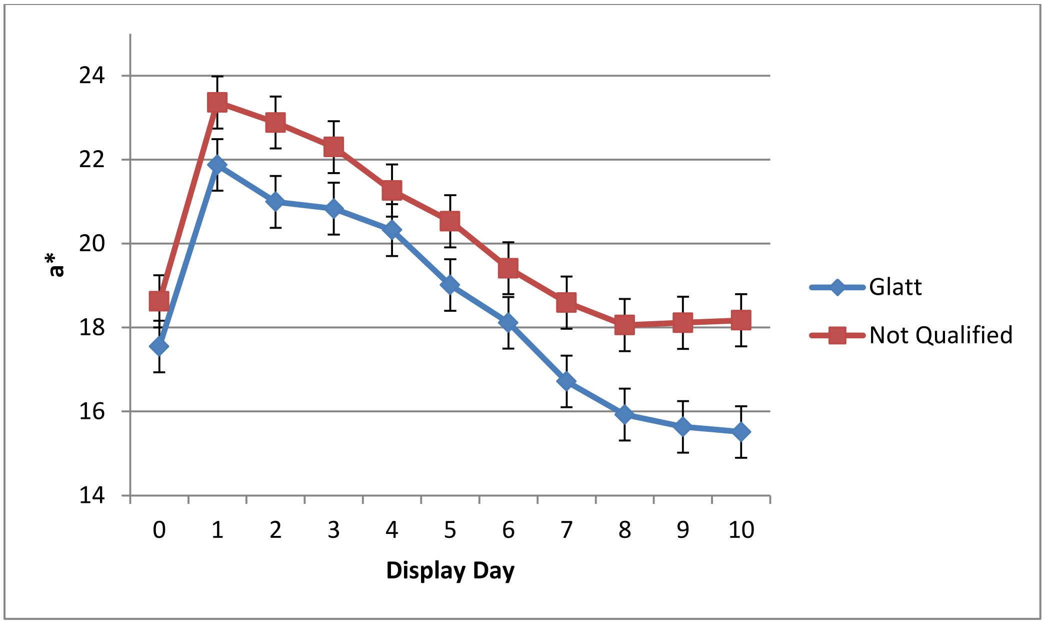

Figure 2.2. Minolta a* color score values of beef loin steaks from cattle that either qualified or did not qualify as glatt kosher.

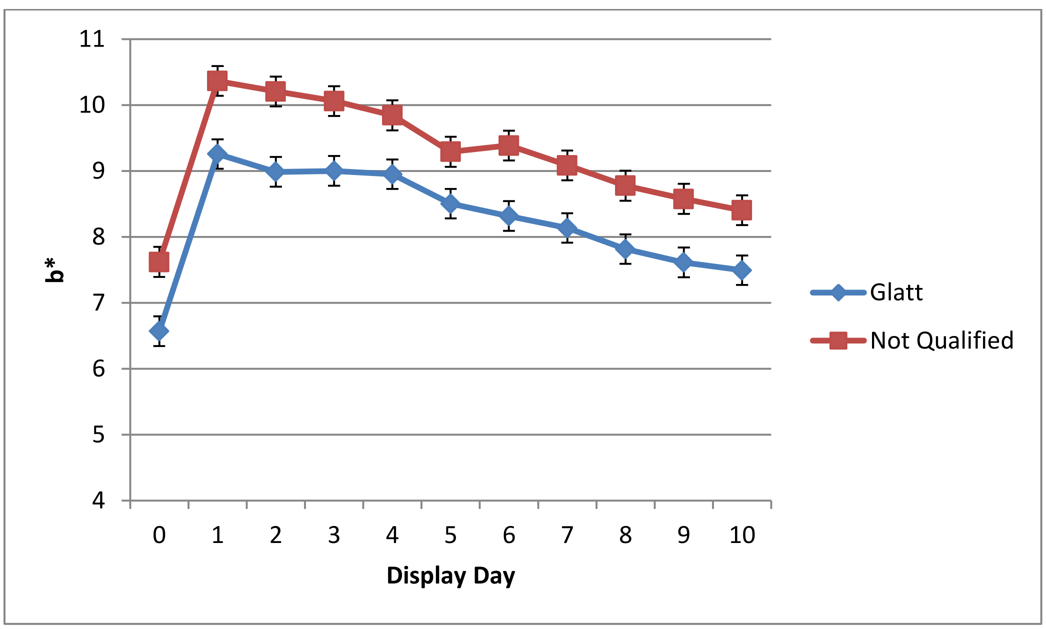

Figure 2.3. Minolta b* color score values of beef loin steaks from cattle that either qualified or did not qualify as glatt kosher.

Conclusion

In summary, we determined that cattle that graded kosher were heavier muscled and larger, as evident by the larger rib eye area and hot carcass weight. Cattle that graded kosher also had a calmer temperament and were able to move through the abattoir more quickly. Factors of carcass type and temperament could be useful selection tools to cattle buyers looking to purchase cattle for the kosher market. It may also help reduce the percentage of cattle purchased by kosher buyers that do not qualify for kosher.

Lastly we also found a significant difference in tenderness between kosher and non-kosher steaks. Further research is needed to understand the relationship between kosher grade and tenderness, and the possibility of producing a more tender kosher product.

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