MEAT QUALITY AND DISPOSITION OF F_2 NELLORE X ANGUS CROSS CATTLE

A Dissertation

by

KRISTIN LEIGH NICHOLSON

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2008

Major Subject: Animal Science

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Approved by:

Chair of Committee:	Jeffrey W. Savell
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ABSTRACT

Meat Quality and Disposition of F_2 Nellore × Angus Cross Cattle.

(August 2008)

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Chair of Advisory Committee: Dr. Jeffrey W. Savell

Correlations between cattle disposition and meat quality were expected to be found, as well as differences in meat quality traits among contemporary groups, sires, and families nested within sires. Temperament effects on meat quality were evaluated in Nellore × Angus F_2 cross cattle (n = 238) over a 3-yr period, with harvests twice a year. Five aspects of temperament -- aggressiveness, nervousness, flightiness, gregariousness, and overall temperament -- were evaluated at weaning and yearling ages, as well as an overall temperament score at slaughter. USDA quality grade, fat thickness, adjusted fat thickness, hot carcass weight, USDA yield grade, and chemical fat were correlated negatively ($P < 0.05$) with weaning temperament scores, aggressiveness, nervousness, flightiness, gregariousness, and overall temperament. No significant correlation was found between Warner-Bratzler shear and weaning temperament traits. USDA quality grade and live weight were correlated negatively ($P < 0.05$) with yearling temperament scores, nervousness, flightiness, gregariousness, overall temperament score as well as the temperament score observed at slaughter. Fat thickness and adjusted fat thickness also were correlated negatively ($P < 0.05$) with yearling gregariousness, yearling overall, and slaughter overall temperament. Yearling gregariousness was correlated positively ($P < 0.05$) with Warner-Bratzler shear from both ES and NON carcasses. Least squares mean differences were evaluated among contemporary groups, sires, and families nested within sires for overall temperament traits and meat quality traits. Contemporary group differences found were thought to be explained by environmental factors, as seen in contemporary group 5, which had the smallest ribeye possibly caused by the shortest feeding period. Steers sired by 297J had the lowest (calmest) temperament scores, most 12th rib fat, highest numerical yield grade, and the heaviest weights. Sire 437J had steers with the highest (wildest) temperament scores, the least fat and lowest numerical yield grade. This population was designed to identify QTL for economically important traits and appears to be useful for this purpose because of the differences found both between and within families.

DEDICATION

This dissertation is dedicated to John David, the love of my life. He is not only my husband, but also my best friend and my soul mate.

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I would like to begin by thanking God, for through Him all things are possible. Grad school has shown me numerous times that what He brings you to, He will bring you through, and I truly appreciate all the opportunities I have been given and blessings I have.

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CHAPTER I

INTRODUCTION

Disposition, or temperament, plays a key role in livestock production and is vital to the success of the beef industry. Morris, Cullen, Kilgour, and Bremner (1994) defined temperament as a term used to illustrate the ease of approaching, driving, weighing, treating for injury or routine health, handling, milking, or training an animal. Some describe temperament as a fear response to human interaction. Buchenauer (1999) stated that the genetic background, environment, and the interaction of heredity and the environment results in the phenotypic expression of behavior.

Not only can temperament be the determining factor in producers' safety and management practices, it also has been shown to have an effect on carcass or meat quality, as well as feed efficiency. Fordyce, Wythes, Shorthose, Underwood, and Shepherd (1988b) reported that many producers believed cattle with poor temperaments were more prone to increased bruising and darker, tougher meat. Adverse effects on carcass quality can potentially cost the beef industry money that could be returned to the producer (NCBA, 2006). Grandin (2006) stated that she believed animal handling would improve when there was a financial reward available. McDonald's corporation began auditing their suppliers of beef and pork in 1999 and consequently, the number of plants improving animal welfare, counted by the number passing audits, has increased since that time (Grandin, 2006).

This dissertation follows the style of *Meat Science.*

Grandin (1994) also stated that excitable livestock not only affect the quality of the end product, but also can have an effect on handling welfare. Excitable animals tend to be harder to handle and often refuse to cooperate, causing a reaction from the handler that may result in pain or damage to the animal. According to Lanier, Grandin, Green, Avery, and McGee (2000), a survey was conducted by R. D. Green (unpublished data) that found that commercial cow/calf producers ranked disposition second, after birth weight, as their most important trait in bulls. In addition to the economic benefit of calmer cattle, animal welfare could be improved by reducing the number of injuries to animals (Voisinet, Grandin, Tatum, O'Connor, & Struthers, 1997a).

Giving beef producers an opportunity to distinguish between excitable and non-excitable animals will allow them to increase profits and have a more productive business by decreasing discounts they may receive due to quality defects and increasing the daily gain of cattle. Fell, Colditz, Walker, and Watson (1999) stated that not all cattle are suited for commercial feedlots and differences were found in performance between cattle of differing temperaments. For example, this research found that five out of twelve nervous cattle were taken to the hospital pen resulting in a loss of profit for those that were sick. During this study, no animals designated as calm were taken to the hospital. Classification of calves by temperament upon entrance to the feedlot could prove to be a useful tool to sort cattle into productive outcome groups that differ in performance and carcass traits (Brown et al., 2004).

To help beef producers make more profit, research has begun in the area of temperament to discover what causes differences in disposition and whether there is a strong genetic basis. Also, research to determine whether disposition affects meat quality traits or other production traits is proving to be valuable. Therefore, this research determined the correlation between meat quality traits and overall disposition of *Bos indicus* × *Bos taurus* steers. In addition, this study determined the correlation between meat quality traits and four component traits of behavior: aggressiveness, nervousness, flightiness, and gregariousness. We expect to find correlations between temperament and meat quality characteristics and by gaining knowledge of this correlation; we are better able to assess the quality of the carcass using live animal characteristics. Finally, this research will evaluate the effects of contemporary group, sire and/or family on variation in meat quality. This population also was structured to identify QTL for economically important traits and residuals from these analyses will be used in future mapping studies.

CHAPTER II

LITERATURE REVIEW

Previous research shows that many attributes contribute to the disposition of cattle. Traits such as age, heritability, breed, sex, stress, the presence or absence of horns, and whorl patterns could all be contributing factors to the temperament of an animal. Production traits such as average daily gain and meat quality are two vital areas that temperament has shown to influence. Both of these production traits are economically important to cattle producers and often are used in selection criteria for the herd.

Age

Sato (1981) found that as animals aged, the calmer they became, though individual animal variation in temperament did not change. However, another study found no significant effect of age on temperament (Fordyce, Dodt, & Wythes, 1988a). Petherick, Holroyd, Doogan, and Venus (2002) found that animals with poor temperaments maintained poor temperaments throughout their lives, whereas those with good temperaments continued to be good. However, they hypothesized that it was possible for changes in temperament to occur in younger animals learning from others over a long period of time. Supporting this, Hearnshaw and Morris (1984) found that cows had lower mean temperament scores than calves, which they believed meant that cows had become more accustomed to management with age.

Heritability

It has been said “a crazy cow always has a crazy calf,” and there may be some scientific truth to that homily. Temperament has been shown to be a moderately heritable trait (Burrow & Corbet, 2000; Fordyce, Goodard, Tyler, Williams, & Tolleman, 1985; Gauly, Mathiak, Hoffman, Kraus, & Erhardt, 2001; Le Neindre, Trillat, Sapa, Merlissier, Bonnet, & Chupin, 1995; O’Bleness, Van Vleck, & Henderson, 1960; Shrode & Hammack, 1971; Stricklin, Heisler, & Wilson, 1980). Arave and Albright (1981) stated that inherited behavior is illustrated in aggressive dairy bulls as compared to more docile beef bulls, because the mean behavior is developed without environmental differences.

Morris et al. (1994) stated that a small positive cow-calf correlation for average temperament score (0.27) was found, supporting findings of Hearnshaw and Morris (1984) who stated that heritability was 0.03 for *Bos taurus* calves and 0.46 for *Bos indicus* sired calves. However, the population structure in this study did not lend itself to reliable calculations of heritability. Other research discovered that cow exit velocity can be used as an indicator of calf temperament but cow temperament scores were more highly correlated with calf temperament (Curley, Neuendorff, Lewis, Cleere, Welsh, & Randel, 2004). Amen (2007) suggested that temperament of recipient females may have had a small effect on the temperament of the calf. This research found that recipient dam temperament was lowly correlated with gregariousness and overall temperament, and these same correlations approached significance for aggressiveness, nervousness, and flightiness (Amen, 2007).

Breed differences

Several studies reported that Brahman (*Bos indicus*) influenced cattle have lower (poorer) temperament scores than *Bos taurus* cattle (Hearnshaw & Morris, 1984; Fordyce, Goddard, & Seifert, 1982; Fordyce et al., 1988a; Voisinet et al., 1997a; Wulf, O'Connor, Taturm, & Smith, 1997). Although *Bos indicus* cattle may be more excitable, they offer many traits that are very desirable to cattle producers. Cartwright (1980) listed differences between the two types to be heat adaptation and cold tolerance, reproduction, parturition, lactation, growth and maturation rates, and temperament. By crossbreeding these two subspecies of cattle, a large amount of breed complementarity results. Many cattle found in warmer climates, for example, the southern United States, are *Bos indicus* cross cattle.

Other breed differences in temperament have been found as well. Lanier, Grandin, Green, Avery, and McGee (2000) reported that Holsteins were more touch and sound sensitive in the auction ring compared to beef cattle. However, Lanier, Grandin, Green, Avery, and McGee (2001) stated that temperament scores showed that Holsteins were calmer than beef cattle. Gauly et al. (2001) found that Simmental cattle ran longer than Angus when in contact with humans, and when alone Angus cattle had lower temperament scores, indicating they are easier to handle compared to Simmental cattle.

Sex differences

Traditionally, heifers are smaller and less efficient in daily gain than their male counterparts. Several studies have shown this trend in temperament differences between sexes. Heifers have higher temperament scores than their male castrated contemporaries

(Stricklin et al., 1980; Voisinet et al., 1997a ; Voisinet et al., 1997b). Gauly et al. (2001) found that females were more difficult to handle than males. Lanier et al. (2000) reported that heifers were the most touch sensitive in the auction ring when compared to steers, bulls, and cows. Bulls were reported as the calmest of all groups. Sato (1981) and Tulloh (1961) found that sex difference was not significantly different but the trend was that heifers were less calm than steers. Hearnshaw and Morris (1984) also found no significant effect of sex on temperament scores at weaning.

Stress effects

Many believe that excited temperaments are a result of fear and can lead to the stressing of an animal. Stressed animals have been shown to possess meat quality defects at slaughter (Apple et al., 1995). Long-term glycogen depletion caused by stress can result in a condition known as dark cutting beef. This defect causes the pH of the meat to remain elevated, results in a darker colored lean, and produces a higher water-holding capacity compared to that found in normal, non-stressed animals (Apple et al., 1995). This condition has been known to be caused by both environmental and heritable factors (Scanga, Belk, Tatum, Grandin, & Smith, 1998).

Almost two percent of cattle sampled in the 2005 National Beef Quality Audit were labeled as “dark cutters” (NCBA, 2006). Because of adverse effects on color of this beef, significant discounts are applied to carcasses displaying this defect. Voisinet, Grandin, O’Connor, Tatum, and Deesing (1997b) found that borderline dark cutters were significantly related to temperament, contrasting the findings of King et al. (2006), who found that temperament group did not affect the presence of dark cutters. Petherick et al.

(2002) found that a greater proportion of animals from the poor temperament and mixed (both poor and good temperaments) groups experienced more stress before slaughter than those from the good temperament group. Possible explanations given by Petherick et al. (2002) were there may have been a greater proportion of slow-twitch muscle fibers and variability in residual glycogen and glucose in muscle at low pH levels.

On the contrary, Fordyce et al. (1988b) found no apparent relationship between temperament score and ultimate pH. Grouping by temperament was not shown to influence carcass traits, but evidence was found to support lower initial pH levels and indicators of "heat shortening" in steers with poor temperaments compared with those with good temperaments (Petherick et al., 2002).

Horned versus polled

Other phenotypic expressions have been linked to temperament scores found in previous research. Fordyce et al. (1988a) reported that horned cattle tended to possess better, or calmer, temperaments than polled or scurred animals. However, many believe that the presence of horns has an adverse effect on the occurrence of carcass bruising, negating any advantage of temperament between horned, polled, or scurred animals. Bruises present on animals at the time of slaughter result in discounts because the bruised tissue must be removed before the meat is sold. The 2005 National Beef Quality Audit reported that 35.2% of fed cattle sampled had at least one bruise present on the carcass (NCBA, 2006).

In another study, Fordyce et al. (1988b) demonstrated that cattle with high temperament scores (poorer temperaments) had more bruising along the back and over the hip area, even though many were polled. Although not significantly correlated, when stratified according to temperament groups, cattle in the nervous temperament group had the highest mean bruise score and the docile group had the lowest (Fordyce et al., 1985).

Whorl patterns

The presence or absence of whorl patterns on an animal's face has been another phenotypic factor that is commonly associated with temperament. Grandin, Deesing, Struthers, and Swinker (1995) stated that cattle with a round hair whorl located above their eyes became more agitated while restrained in a squeeze chute than those with a whorl located between or below the eyes. They found a positive linear relationship between cattle temperament and the location of facial hair whorls. Lanier et al. (2001) also found strong correlations between whorl placement and disposition. Those animals with no whorl became more agitated than those with whorls. Also, lower whorl placement on face tended to be associated with slower moving, calmer animals. Supporting these findings, Randle (1998) reported that cattle with mid-placed whorls exhibited greater flight distances than those with low whorls.

Average daily gain

Many sectors of the beef industry use weight gain as an indicator of productivity and thus revenue. In the feedlot industry, average daily gain is directly correlated to profit. The more weight cattle gain while in the feed yard, the more profit the operation will recover. Many have reported that animals with calmer temperament scores have higher daily gains (Brown et al., 2004; Burrow & Dillon, 1997; Petherick et al., 2002;

Tulloh, 1961; and Voisinet et al., 1997a). Gauly et al. (2001) reported that negative correlations between daily weight gain and temperament scores suggest that less docile animals are also less productive. Supporting this, Fell et al. (1999) stated that average daily gain was found to be lower in the nervous group versus the calm group, when animals were separated according to disposition. Wulf et al. (1997) found that calmer *Bos taurus* cattle had higher average daily gains and higher slaughter weights. Fordyce et al. (1985) and Fordyce et al. (1988a) also found a trend for heavier animals to have lower (calmer) temperament scores. In contrast, Sato (1981) found that temperament and weight gain were not significantly related.

Supporting research by Brown et al. (2004) and Frisch and Vercoe (1969), researchers at Texas A&M University hypothesized that voluntary intake can be affected by disposition (Gill, Herring, & Sanders, 2007; Herring & Gill, 2006), possibly explaining the reason for lower feed intake of Brahman-influenced cattle. Frisch and Vercoe (1969) demonstrated that eating rate is highly correlated with voluntary feed intake and live weight gain thus supporting the Gill et al. (2007) hypothesis. However, Petherick et al. (2002) found that disposition grouping had no effect on feed intake. Johnston, Reverter, Burrow, Oddy, and Robinson (2003) found that tropically adapted breeds tended to be more nervous in disposition, eat more times per day, but spend less total time eating. Frisch and Vercoe (1969) reported that Brahman-influenced cattle had higher feed efficiency, although they also had lower feed intake.

Seasonal differences also affect average daily gain and feed intake of animals (Ray and Roubicek, 1971). Cattle tend to eat more, and more frequently, in the cooler months of the year. In warmer months, cattle eat more during the cooler parts of the day, including morning and evening (Ray and Roubicek, 1971). Despite the earlier research, few attempts have been made to explain the mechanism of the relationship between temperament and production.

Meat quality traits

Dark cutting is not the only meat quality defect that has been found to be affected by temperament. Voisinet et al. (1997b) found that tenderness was significantly affected by temperament as well. Wulf, O'Connor, Tatum, and Smith (1997) reported moderate correlations between chute scores and tenderness, both Warner-Bratzler shear force and sensory panel tenderness values. King et al. (2006) found an interaction between temperament category and contemporary group affecting sarcomere length. One contemporary group that was considered to have calm temperaments had longer sarcomere lengths, thus resulting in a more tender product (King et al., 2006). Falkenberg, Miller, Holloway, Rouquette, Randel, and Carstens (2005) found that exit velocity at weaning was correlated with Warner-Bratzler shear force values but exit velocity at time of feedlot entrance was not correlated with the previous trait. Voisinet et al. (1997b) reported that temperament score had a significant effect on Warner-Bratzler shear tenderness. Fordyce et al. (1988b) reported that cattle with high temperament scores tended to have higher mean shear force values, indicating their meat was less tender. They also found neither ultimate pH nor sarcomere length to be related to temperament score.

Other meat quality traits have been evaluated and differing results have been presented. Burrow and Dillon (1997) found no relationship between flight speed, as a measure of temperament, and fat thickness or bruising. On the contrary, Petherick et al. (2002) stated that cattle with poor temperaments had poorer body conditions and lower dressing percentages compared to cattle with good temperaments. This research also reported that temperament grouping had no effect on muscle color, marbling scores, fat depth, and total carcass weights (Petherick et al., 2002). Supporting this, King et al. (2006) reported that classification of temperament did not affect muscle proximate composition, muscle color values, or 72-h calpastatin activity.

Brown et al. (2004) found that exit velocity was positively correlated with ribeye area, but not with marbling or backfat. In another study, backfat and quality grade were correlated with exit velocity when cattle entered the feedlot and that yield grade was correlated with exit velocity at weaning (Faulkenberg et al., 2005). Wulf et al. (1997) found that higher (more excitable) temperament was correlated with lower weight gains, lower live and carcass weights, higher calpastatin activities, higher muscle pH values, lower L* and b* values, and decreased tenderness. Relationships of behavior traits with carcass traits were found to generally reflect relationships among growth rate, feed intake, and body composition (Nkrumah et al., 2007). Eating time tended to be correlated with fatness; the more an animal ate, the fatter it became (Nkrumah et al., 2007). Presently the effects of temperament on carcass traits is weakly characterized, but it has been hypothesized that differences in behavior may affect overall energy metabolism and therefore, product quality (Nkrumah et al., 2007).

Temperament tests

Measures of temperament can vary greatly depending on the type of test used. Useful tools for identifying cattle temperament must be reliable, repeatable, and linked to the individual animal's stress responsiveness (Curley, Paschal, Welsh, & Randel, 2006). Various testing procedures have been used to assess temperament; however, many are of a subjective nature, thus allowing for human error or bias to affect the temperament assessment made. Some tests that have been used include docility tests, crush tests, exit velocity, subjective behavior scores (including pen score and chute score), and cortisol assays. Within these tests various factors are observed and rated. For example, Fordyce et al. (1985) measured vigor of movement and degree of audible respiration when the cattle were in a crush test and a total temperament score was calculated using all measurements.

Docility tests are performed by a human leading an animal and for them to maintain the animal in the corner of a pen for a considerable amount of time (i.e., 30 s). Scores then are generated based on the animal's behavioral reaction to the test. A crush test is conducted using social isolation of the animal in a crush with the head maintained in a head gate. Blood is drawn for and cortisol levels are determined when using a cortisol assay to test the temperament of an animal. Exit velocity is measured by the speed an animal exits the holding chute. Fordyce et al. (1985) found that the crush test proved to be more successful in identifying cattle with poor temperaments.

Fordyce et al. (1985) also stated that the behavior of cattle when handled is not only due to their temperament, but also to the manner in which they are handled.

This study demonstrated a correlation between cattle temperaments and meat quality traits does exist and further research is needed to examine the relationship more closely. Variation was also found among contemporary groups, sires, and families nested within sires indicating that this population will prove to be useful for QTL mapping.

CHAPTER III

MATERIALS AND METHODS

This study utilized disposition, carcass and meat quality data collected from six contemporary groups of F_2 Nellore-Angus steers (n = 181) produced by embryo transfer from 13 F_1 Nellore-Angus donor females and 4 Nellore-Angus F_1 sires (Families 70-84) and natural service paternal half-sibs (n = 58) out of Brahman-Angus or Brahman-Hereford cows (Families 95-98), as part of the Texas A&M University McGregor Genomics Project. All F_1 parents were Nellore-sired. Steers born in the same year and season were managed together in the same contemporary group (Tables 1-3). All procedures involving animals were approved by the Texas A&M University Institutional Animal Care and Use Committee; AUP # 2002-116 and 2005-147.

Table 1
Contemporary group designation and frequency

Birth Year/Season	Slaughter Year/Season	Contemporary Group	n
Spring 2003	Fall 2004	1	32
Fall 2003	Spring 2005	2	26
Spring 2004	Fall 2005	3	56
Fall 2004	Spring 2006	4	32
Spring 2005	Fall 2006	5	62
Fall 2005	Spring 2007	6	30

Table 2
Frequency table by contemporary group and sire

	Contemporary Group						
Sire	1	2	3	4	5	6	Total
297J	3	7	16	7	11	5	49
432H	13	3	11	0	10	13	50
437J	10	1	21	7	23	7	69
551G	6	15	8	18	18	5	70
Total	32	26	56	32	62	30	238

Table 3
Frequency table by contemporary group and family

Family	Contemporary Group						
	1	2	3	4	5	6	Total
70	1	5	4	2	1	4	17
71	2	2	5	5	2	1	17
72	5	0	5	0	2	7	19
73	2	3	0	0	0	0	5
74	4	0	0	0	0	0	4
75	5	0	0	2	4	0	11
76	2	3	0	0	0	0	5
77	1	5	1	1	11	0	19
79	1	0	0	0	0	0	1
80	0	7	3	16	0	1	27
81	0	1	13	3	5	5	27
82	0	0	0	0	0	6	6
83	0	0	3	2	4	2	11
84	0	0	0	1	7	4	12
95	0	0	7	0	8	0	15
96	6	0	6	0	8	0	20
97	1	0	5	0	10	0	16
98	3	0	4	0	0	0	7
Total	33	26	56	32	62	30	239

Temperament scoring

Steers were scored for disposition 1 mo after weaning by a panel of four evaluators. Calves were grouped into pens of approximately 15 steers and released into a 20-m alleyway in pairs; two evaluators were stationed at the end of the alley. The animals were left in the alley for 2 to 3 min, and one animal then was directed back into the pen with the others. The animal remaining in the alley was scored. Animals were scored for four component traits of behavior at weaning — aggressiveness (WAGRES), nervousness (WNERV), flightiness (WFLIGHT), gregariousness (WGREG) — in addition to overall disposition (WOVERALL). Once scored, the animal was driven from the alley into a large pen with the animals that had already been scored. Individual animals were scored on 9-point scales. Aggressiveness referred to the animal's desire to hit evaluators, where 1 was non-aggressive, and 9 was extremely aggressive. Nervousness referred to the animal's behavior in regard to walking and running, vocalization, and physically shaking, where 1 was totally calm and 9 was extremely nervous. Flightiness referred to an animals' desire to keep away or get away from evaluators, where 1 was totally quiet and 9 extremely flighty. Gregariousness referred to an animal's desire to get back to the group of individuals from which it came and how it acted in a pair as compared to being separated, where 1 was totally willing to be separated from the group and 9 was unwilling to be separated. Overall disposition was scored as a separate trait (as opposed to being an average of the others), where 1 was completely docile and 9 was wild. For analysis, disposition scores for each animal were averaged across the four evaluators for each component trait.

Steers were scored in the feeding pens for the same traits (YAGRES, YNERV, YFLIGHT, YGREG, and YOVERALL), but by a single evaluator. Recipient females also were scored for temperament shortly after calving on a scale of 1 to 5, where 1 represented a docile disposition and 5 was a wild and/or aggressive disposition.

Harvest

Steers were harvested in six groups over a 3-yr period at the Texas A&M University Rosenthal Meat Science and Technology Center. Disposition was observed once again in the holding pens before harvest. Overall disposition was the only trait scored at this time (1 was completely docile and 9 was wild). Steers were harvested following typical industry procedures following the facility's HACCP plan, including antemortem inspection, immobilization, exsanguination, hide removal, evisceration, splitting, postmortem inspection, zero tolerance inspection, carcass wash, and application of a lactic acid spray (Savell and Smith, 2000). After carcass splitting, only the right side of the animal was electrically stimulated (ES) and the left side was not stimulated (NON). Stimulation (Koch Britton Stimulator 350, Kansas City, MO) was applied through a probe inserted into the neck muscles at 550 V for 3 sec repeated 20 times with a 1 sec rest period between. Before carcasses were placed in the cooler (approximately 45 min postmortem) carcass weights were recorded.

Carcass data collection

After a 48-h chill, carcasses were ribbed and trained personnel collected USDA (1997) Quality and Yield Grade data including maturity, marbling, fat thickness at the 12^{th} rib, adjusted fat thickness, ribeye area (REA), kidney, pelvic, and heart fat (KPH), and hot carcass weight (HCW). A Hunter Miniscan XE (Hunter Labs, Inc., Reston VA; Illuminant A, 10° observer) then was used to collect CIE L*, a*, and b* values from both sides of the animal.

Carcass composition

Carcass composition was estimated using the $9\text{-}10\text{-}11^{th}$ rib section separation procedure (Hankins and Howe, 1946). The rib section was removed from each left side at 48 h postmortem. Rib sections were weighed and separated into the *M. longissimus thoracis*, lean, bone, and subcutaneous, intermuscular, and channel fat. After each dissection, technicians recorded weights of all components, lean trimmings, fat trim, and bone ensuring at least 99% recovery of rib weight. The soft tissue was coarse-ground once through a 0.64-cm diameter plate and then ground twice through a 0.32-cm diameter plate. Subsamples were put in Whirlpac bags and frozen immediately in a -10°C freezer. Samples were used for chemical analysis, which included moisture, fat, protein, and ash by difference.

Steak cutting

Steaks (2.54 cm-thick) were removed from the 12th rib section from non-electrically stimulated carcasses and were designated for chemical fat analysis, sarcomere length, and myofibrillar fragmentation index (MFI). The loin was removed from both sides of the carcass and cut into steaks. The most anterior steak from both loins was cut 2.54 cm-thick and used for Warner-Bratzler shear (WBS) force determination. The next two steaks were cut 2.54 cm thick and were designated for sensory evaluation. The next two steaks from the electrically stimulated loin were used for sarcomere length determination and MFI, respectively. Steaks assigned to sarcomere length and chemical fat analysis were vacuum-packaged and frozen immediately in a -10°C freezer. Other steaks, including sensory, WBS, and MFI steaks, also were vacuum-packaged and held in a cooler (2° C) until 14 d postmortem and then frozen in a -10°C freezer.

Laboratory analyses

Fat and moisture analysis, for both the ground composition sample and the steak designated for chemical fat analysis, was conducted by snap-freezing the sample in liquid nitrogen and pulverizing in a Waring blender. Approximately 3 g of sample then was weighed into a pre-dried filter-paper thimble and used to determine the fat and moisture content of the muscle by the oven drying and ether extraction procedures (AOAC, 1990) in duplicate. Composition samples were analyzed for N by combustion (AOAC, 1990) using a Leco protein/nitrogen determinator (Model FP2000, St. Joseph, MI) and then converted to protein by multiplying N by 6.25. These samples were conducted in triplicate and an average was taken for the protein value of the sample.

Sarcomere length was determined on three samples from each steak representing the lateral, center, and medial portions of the steak. Ten fibers from each sample were measured for sarcomere length, and the mean value obtained from the three samples was reported as the sarcomere length for the muscle. Approximately 5 g of minced muscle tissue was removed from each sample designated for sarcomere length determination. The sample was homogenized in buffer (25 mM sucrose, 0.2 mM KCl; pH 7.0). Drops of homogenate were placed on glass microscope slides and covered with a cover slip. Sarcomere length was measured with a He-Ne laser (γ = 0.6328 nm) according to the procedure described by Cross, West, and Dutson (1981).

Myofibrillar fragmentation index was used as an indicator of postmortem proteolysis (Culler, Parris, Smith, & Cross, 1978). A 4-g muscle sample was homogenized with 35 ml MFI buffer (100 mM KCl, 20 mM K_2PO_4, 1 mM EGTA, 1 mM $MgCl_2$, and 1 mM NaN_3; pH 7.0) and centrifuged at 1000xg for 15 min to extract myofibrils. The myofibrils were re-suspended in 35 ml MFI buffer and centrifuged for

15 min at 1000xg. The pellet was re-suspended in 10 mL MFI buffer and adjusted to 0.5 mg protein/ml solution. The absorbance at 540 nm was measured using a Spectronic 20 spectrophotometer (Bausch & Lomb, Rochester, NY) and was used to calculate MFI.

Warner-Bratzler shear determination

Steaks were thawed in a 4°C cooler for 48 h before cooking. Grated, non-stick electric grills (Hamilton Beach™ Indoor/Outdoor Grill) were used to cook the retail cuts. The grills were preheated for 15 min to an approximate temperature of 177°C. Internal temperature was monitored with a thermometer (Omega™ HH501BT, Stamford, CT) using a 0.02 cm diameter, iron-constantan Type-T thermocouple wire. All steaks were turned after reaching an internal temperature of 35°C, removed at a final internal temperature of 70°C, and cooled approximately 4 h or until reaching room temperature.

After cooling, steaks were trimmed free of visible connective tissue to expose the muscle fiber orientation. At least six 1.27 cm diameter cores were removed from the *M. longissimus lumborum*. Cores were removed parallel to the muscle fiber orientation and sheared once, perpendicular to the muscle fibers, on a United Testing machine (United 5STM-500, Huntington Beach, CA) using an 11.3 kg load cell, and a V-notch Warner-Bratzler shear force attachment. The peak force (N) needed to shear each core was recorded, and the mean for each steak was used in the statistical analyses.

Statistical analysis

All meat quality measurements were correlated to the disposition scores of the crossbred steers. Correlations were determined among meat quality traits and overall disposition, aggressiveness, nervousness, flightiness, and gregariousness by the CORR procedure of SAS (SAS, Cary, NC). The MIXED procedure of SAS also was used to evaluate carcass and meat traits using fixed effects of contemporary group, sire, and family nested within sire, slaughter day within contemporary group, and the regression of age within contemporary group.

CHAPTER IV

RESULTS AND DISCUSSION

Simple statistics for all variables analyzed are reported in Table 4. Temperament scores varied greatly, from 1.00 to 8.00. Marbling ranged from 280 to 780, Traces 80 to Slightly Abundant 80, and USDA Quality Grades ranged from Standard 90 to Prime 27. Adjusted fat thickness averaged 1.40 cm and ranged from 0.38 to 2.54 cm. Ribeye area averaged 73.36 cm^2 and ranged from 54.83 to 96.75 cm^2. Considerable variation was seen in hot carcass weight as well, 195.91 kg to 389.09 kg. Yield grades averaged 3.21 and varied from 1.00 to 5.40.

USDA quality grade, fat thickness, adjusted fat thickness, USDA yield grade, and chemical fat were correlated negatively ($P < 0.05$) with weaning temperament scores, aggressiveness, nervousness, flightiness, gregariousness, and overall temperament (Table 5). Thus as temperament score increased (poor temperament), these meat quality traits decreased. Supporting these data, Faulkenberg et al. (2005) reported that exit velocity at weaning was correlated negatively with yield grade. Live weight and hot carcass weight were correlated negatively ($P < 0.05$) with weaning temperament traits, nervousness, flightiness, gregariousness, and overall temperament score. Sarcomere length from the non-stimulated side was correlated positively ($P < 0.05$) with weaning flightiness and weaning gregariousness. This suggests that as the weaning temperament scores increased, the sarcomere length did also, indicating an increase in tenderness; however, no significant correlation was found between WBS and weaning temperament traits from either side. Previously, Faulkenberg et al. (2005) found that Warner-Bratzler shear force was correlated positively with exit velocity. Recipient disposition negatively was correlated with the CIE L* value for both the electrically stimulated and non-stimulated sides, but was not significantly correlated with any other traits.

Pearson correlation coefficients between recipient disposition, weaning temperament scores, dissection percentages, and proximate analysis values are reported in Table 6. Total dissected fat and extracted fat negatively were correlated ($P < 0.05$) and total lean, moisture, and protein were correlated positively ($P < 0.05$) with weaning temperament scores, aggressiveness, nervousness, flightiness, gregariousness, and overall temperament.

Table 4
Simple statistics

Variable[a]	n	Mean	Standard Deviation	Minimum	Maximum
Recipient disposition	180	2.41	0.99	1.00	5.00
WAGRES	239	2.63	1.63	1.00	7.50
WNERV	239	4.08	1.88	1.00	7.75
WFLIGHT	239	3.83	1.97	1.00	8.00
WGREG	239	3.74	1.85	1.00	7.50
WOVRALL	239	3.70	1.94	1.00	8.00
YAGRES	239	1.12	0.63	1.00	6.00
YNERV	239	3.39	1.42	1.00	8.00
YFLIGHT	239	3.37	1.43	1.00	8.00
YGREG	239	2.29	1.40	1.00	7.00
YOVRALL	239	3.22	1.21	1.00	8.00
SLOVRALL	238	2.43	1.03	1.00	8.00
Skeletal maturity	239	47.87	11.00	30.00	70.00
Lean maturity[b]	239	58.91	16.31	30.00	120.00
Overall maturity[b]	239	53.37	10.66	30.00	90.00
Marbling[b]	239	413.89	86.35	280.00	780.00
USDA quality grade[b]	239	288.14	46.90	190.00	427.00
Fat thickness (cm)	239	1.25	0.45	0.25	2.41
Adjusted fat (cm)	239	1.40	0.45	0.38	2.54
REA (cm^2)	239	73.36	7.40	54.83	96.75
KPH (%)	239	2.32	0.60	1.00	4.50
HCW (kg)	239	302.35	34.00	195.91	389.09
USDA yield grade	239	3.21	0.67	1.00	5.40
Sarcomere length ES	229	1.74	0.07	1.56	1.97
Sarcomere length NON	233	1.75	0.08	1.46	2.11
L* ES	201	44.60	5.23	26.19	54.38
a* ES	201	30.88	4.60	18.37	41.65
b* ES	201	24.25	4.68	12.39	37.52
L* NON	209	39.32	5.04	23.79	50.22
a* NON	209	28.62	4.75	15.37	40.34
b* NON	209	22.17	4.74	10.50	36.42
Chemical fat (%)	239	4.20	1.71	1.26	12.91
Live weight (kg)	239	459.82	49.36	316.36	585.91
Dressing percent (%)	239	65.72	1.78	60.75	71.98

[a] WAGRES = Weaning aggressiveness. 1 = non-aggressive, 9 = extremely aggressive; WNERV = weaning nervousness. 1 = totally calm, 9 = extremely nervous; WFLIGHT = weaning flightiness. 1 = totally quiet, 9 = extremely flighty; WGREG = weaning gregariousness. 1 = totally willing to be separated from the group, 9 = unwilling to be separated; WOVRALL = weaning overall. 1= completely docile, 9 = crazy; YAGRES = Yearling aggressiveness. 1 = non-aggressive, 9 = extremely aggressive; YNERV = yearling nervousness. 1 = totally calm, 9 = extremely nervous; YFLIGHT = yearling flightiness. 1 = totally quiet, 9 = extremely flighty; YGREG = yearling gregariousness. 1 = totally willing to be separated from the group, 9 = unwilling to be separated; YOVRALL = yearling overall. 1= completely docile, 9 = crazy; SLOVRALL = slaughter overall. 1 = completely docile, 9 = crazy; REA = ribeye area; KPH = kidney, pelvic, and heart fat; HCW = hot carcass weight; ES = electrically stimulated; NON = non-electrically stimulated; LD = *M. longissimus dorsi*; MFI = myofibrillar fragmentation index; WBS = Warner-Bratzler shear force.
[b] Measurement taken from left (non-stimulated) side of the carcass

Table 4 Continued

Variable	n	Mean	Standard Deviation	Minimum	Maximum
LD (%)	238	18.88	2.58	12.57	25.70
External fat (%)	238	11.64	3.28	4.23	24.16
Seam fat (%)	238	19.04	4.28	6.43	31.37
Channel fat (%)	238	4.04	1.63	1.24	13.67
Total fat (%)	238	34.72	6.02	19.12	50.56
Total lean (%)	238	28.72	3.67	19.00	41.06
Bone (%)	238	17.06	2.40	11.57	26.85
MFI ES	172	122.23	23.51	66.00	188.50
MFI NON	179	122.83	30.75	61.50	199.50
WBS ES (N)	231	26.92	5.80	14.43	45.48
WBS NON (N)	239	35.60	10.16	16.75	69.20

[a] WAGRES = Weaning aggressiveness. 1 = non-aggressive, 9 = extremely aggressive; WNERV = weaning nervousness. 1 = totally calm, 9 = extremely nervous; WFLIGHT = weaning flightiness. 1 = totally quiet, 9 = extremely flighty; WGREG = weaning gregariousness. 1 = totally willing to be separated from the group, 9 = unwilling to be separated; WOVRALL = weaning overall. 1= completely docile, 9 = crazy; YAGRES = Yearling aggressiveness. 1 = non-aggressive, 9 = extremely aggressive; YNERV = yearling nervousness. 1 = totally calm, 9 = extremely nervous; YFLIGHT = yearling flightiness. 1 = totally quiet, 9 = extremely flighty; YGREG = yearling gregariousness. 1 = totally willing to be separated from the group, 9 = unwilling to be separated; YOVRALL = yearling overall. 1= completely docile, 9 = crazy; SLOVRALL = slaughter overall. 1 = completely docile, 9 = crazy; REA = ribeye area; KPH = kidney, pelvic, and heart fat; HCW = hot carcass weight; ES = electrically stimulated; NON = non-electrically stimulated; LD = *M. longissimus dorsi*; MFI = myofibrillar fragmentation index; WBS = Warner-Bratzler shear force.

Table 5
Pearson correlation coefficients between recipient disposition[a], weaning temperament scores[a], and meat quality traits[b]

	RECIPDISP	WAGRES	WNERV	WFLIGHT	WGREG	WOVERALL
Skeletal maturity	-0.10	-0.03	-0.12	-0.10	-0.05	-0.09
Lean maturity[c]	0.07	-0.01	-0.03	-0.01	0.00	-0.02
Overall maturity[c]	-0.04	-0.05	-0.05	-0.04	-0.06	-0.05
Marbling[c]	-0.09	-0.14*	-0.13	-0.13*	-0.12	-0.14*
USDA quality grade[c]	-0.05	-0.18**	-0.18**	-0.18**	-0.17**	-0.20**
Fat thickness	-0.02	-0.15*	-0.19**	-0.20**	-0.15*	-0.18**
Adjusted fat	-0.07	-0.15*	-0.18**	-0.19**	-0.14*	-0.17**
REA	0.03	0.09	0.08	0.09	0.10	0.09
KPH	0.00	0.15*	0.09	0.09	0.09	0.10
HCW	0.02	-0.12	-0.19**	-0.19**	-0.18**	-0.18**
USDA yield grade	-0.05	-0.15*	-0.21**	-0.21***	-0.19**	-0.20**
Chemical fat	-0.08	-0.20**	-0.23***	-0.23***	-0.21**	-0.24***
Live weight	0.01	-0.12	-0.20**	-0.20**	-0.18**	-0.18**
Dressing percent	0.01	0.02	-0.00	-0.01	-0.01	-0.01
Sarcomere length ES	-0.02	-0.09	-0.09	-0.07	-0.07	-0.09
Sarcomere length NON	-0.09	0.09	0.11	0.13*	0.13*	0.12

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$
[a] RECIPDISP = Recipient disposition. 1 = docile disposition, 5 = wild and/or aggressive disposition; WAGRES = weaning aggressiveness. 1 = non-aggressive, 9 = extremely aggressive; WNERV = weaning nervousness. 1 = totally calm, 9 = extremely nervous; WFLIGHT = weaning flightiness. 1 = totally quiet, 9 = extremely flighty; WGREG = weaning gregariousness. 1 = totally willing to be separated from the group, 9 = unwilling to be separated; WOVRALL = weaning overall. 1= completely docile, 9 = crazy.
[b] REA = ribeye area; KPH = kidney, pelvic, and heart fat; HCW = hot carcass weight; ES = electrically stimulated; NON = non-electrically stimulated; MFI = myofibrillar fragmentation index; WBS = Warner-Bratzler shear force.
[c] Measurement taken from left (non-stimulated) side of the carcass

Table 5 Continued

	RECIPDISP	WAGRES	WNERV	WFLIGHT	WGREG	WOVERALL
L* ES	-0.31***	-0.16*	-0.14*	-0.14*	-0.14*	-0.17*
a* ES	-0.04	0.11	0.04	0.07	-0.07	0.04
b* ES	0.08	0.19**	0.10	0.13	0.01	0.12
L* NON	-0.25**	-0.11	-0.09	-0.10	-0.08	-0.11
a* NON	-0.01	0.12	0.07	0.10	-0.03	0.07
b* NON	0.09	0.18**	0.12	0.15*	0.04	0.14
MFI ES	-0.06	0.06	0.09	0.11	0.07	0.09
MFI NON	-0.05	0.06	0.06	0.08	0.07	0.08
WBS ES	0.03	0.08	0.10	0.07	0.07	0.10
WBS NON	-0.01	-0.02	-0.02	-0.01	-0.03	-0.03

* $P < 0.05$

** $P < 0.01$

*** $P < 0.001$

[a] RECIPDISP = Recipient disposition. 1 = docile disposition, 5 = wild and/or aggressive disposition; WAGRES = weaning aggressiveness. 1 = non-aggressive, 9 = extremely aggressive; WNERV = weaning nervousness. 1 = totally calm, 9 = extremely nervous; WFLIGHT = weaning flightiness. 1 = totally quiet, 9 = extremely flighty; WGREG = weaning gregariousness. 1 = totally willing to be separated from the group, 9 = unwilling to be separated; WOVRALL = weaning overall. 1= completely docile, 9 = crazy.

[b] ES = electrically stimulated; NON = non-electrically stimulated; MFI = myofibrillar fragmentation index; WBS = Warner-Bratzler shear force.

[c] Measurement taken from left (non-stimulated) side of the carcass

Table 6
Pearson correlation coefficients between recipient disposition[a], weaning temperament scores[a], dissection percentages, and proximate analysis values

	RECIPDISP	WAGRES	WNERV	WFLIGHT	WGREG	WOVERALL
Dissection (%)						
LD[b]	0.00	0.12	0.18**	0.17**	0.13	0.16*
External	-0.01	-0.10	-0.09	-0.09	-0.09	-0.11
Seam	-0.06	-0.16*	-0.20**	-0.20**	-0.17**	-0.19**
Channel	0.01	-0.11	-0.13*	-0.14*	-0.15*	-0.15*
Total fat	-0.04	-0.20**	-0.23***	-0.23***	-0.21**	-0.23***
Lean trim	0.04	0.20**	0.22**	0.22***	0.22***	0.23***
Bone	0.07	0.06	0.03	0.05	0.04	0.05
Proximate (%)						
Moisture	0.05	0.17**	0.18**	0.18**	0.15*	0.19**
Fat	-0.05	-0.19**	-0.18**	-0.19**	-0.17**	-0.20**
Protein	0.01	0.21**	0.17**	0.17**	0.16*	0.18**
Ash	0.04	0.05	0.06	0.09	0.10	0.08

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$
[a] RECIPDISP = Recipient disposition. 1 = docile disposition, 5 = wild and/or aggressive disposition; WAGRES = weaning aggressiveness. 1 = non-aggressive, 9 = extremely aggressive; WNERV = weaning nervousness. 1 = totally calm, 9 = extremely nervous; WFLIGHT = weaning flightiness. 1 = totally quiet, 9 = extremely flighty; WGREG = weaning gregariousness. 1 = totally willing to be separated from the group, 9 = unwilling to be separated; WOVRALL = weaning overall. 1= completely docile, 9 = crazy.
[b] LD = *M. longissimus dorsi*.

USDA quality grade, live weight, and CIE L* ES values were correlated negatively ($P < 0.05$) with yearling temperament scores, nervousness, flightiness, gregariousness, overall temperament, and the temperament score observed at slaughter (Table 7). Contrary to these data, Petherick et al. (2002) found that temperament group had no significant effect on muscle color or marbling score. Hot carcass weight was correlated negatively ($P < 0.05$) with yearling nervousness and overall temperament score was correlated ($P < 0.001$) to slaughter overall temperament score. Fat thickness and adjusted fat thickness were correlated negatively ($P < 0.05$) with yearling gregariousness, yearling overall, and slaughter overall temperament. Other research supports these findings, as a previous study found that Bonsmara x Beefmaster cattle's exit velocity upon entering the feedlot was correlated with back fat and USDA quality grade; however, the relationship was different, as the cattle with fast exit velocities also had more back fat (Faulkenberg et al., 2005). King et al. (2006) conversely reported that categories of temperament did not affect USDA yield or quality grade factors. Brown et al. (2004) stated that back fat and marbling were not correlated with exit velocity; but ribeye area negatively was correlated. Nkrumah et al. (2007) also found that flight speed was not correlated to ultrasound back fat or marbling, but did find a positive correlation to ultrasound ribeye area. Petherick et al. (2002) found that temperament group had no effect on fat depth, carcass weight, or dressing percentage; however, they did notice a trend in the "good" having heavier carcass weights than the "poor" group. Wulf et al. (1997) reported that as temperament ratings increased, live and hot carcass weights decreased, L* and b* values decreased, as did tenderness values. No differences were found in dressing percentage in the present study; however, Burrow and Dillon (1997) previously found a negative correlation between flight speed and dressing percentage. They also found that cattle with slower flight speeds (calmer temperament) had heavier slaughter and carcass weights, but no correlation was found between flight speed and fat thickness. Amen (2007) reported that for cattle from the same population as in the current study, aggressiveness, nervousness, flightiness, and overall temperament were correlated with fat thickness; and nervousness, flightiness, gregariousness, and overall temperament were correlated with USDA yield grade.

Sarcomere length from electrically stimulated carcasses was correlated ($P < 0.05$) with slaughter overall temperament scores, but no other correlations were found for sarcomere length among the yearling disposition traits. King et al. (2006) found that temperament category and contemporary group interacted to affect sarcomere length. Others have found no differences in sarcomere length between temperament groups (Fordyce et al., 1988b). CIE a* values were correlated negatively ($P < 0.05$) to most of the yearling disposition traits, but surprisingly not to the slaughter temperament measure. Yearling gregariousness was correlated positively ($P < 0.05$) with WBS from both the electrically stimulated and non-stimulated side, demonstrating that as temperament score increased so did the WBS value indicating an increase in toughness. These findings support the research of Voisinet et al. (1997b), who showed that tenderness is affected by temperament ranking.

In Table 8, Pearson correlation coefficients are shown for yearling temperament scores, dissection percentages, and proximate analysis values. External fat, total fat, and lean trim were correlated (*P* < 0.05) with yearling gregariousness, the fat traits negatively correlated and lean positively correlated. Total fat negatively was correlated (*P* < 0.05) with slaughter overall temperament rating, while protein and bone positively were correlated (*P* < 0.05).

Live weight was correlated positively (*P* < 0.05) with MFI ES, MFI NON, and WBS ES, but was correlated negatively (*P* < 0.05) with WBS NON (Table 9). Hot carcass weight was positively correlated (*P* < 0.05) with MFI ES, WBS ES, and negatively correlated with WBS NON. Sarcomere length from ES sides was correlated (*P* < 0.01) with WBS values from both ES and NON sides, but sarcomere length from the non-stimulated sides only was correlated with shear values from the same side. CIE L* values also were correlated negatively with WBS values from both the stimulated and non-stimulated sides. Surprisingly, no correlation was found between the CIE b* values and WBS values, as shown in previous research (Wulf et al., 1997). MFI and WBS values were correlated (*P* < 0.001) to each other.

Table 10 contains the Pearson correlation coefficients between MFI values, WBS values, dissection percentages, and proximate analysis values. Channel fat was correlated negatively (*P* < 0.05) with MFI ES.

Table 7
Pearson correlation coefficients between yearling temperament scores [a] and meat quality traits[b]

	YAGRES	YNERV	YFLIGHT	YGREG	YOVERALL	SLOVERALL
Skeletal maturity	-0.01	-0.00	-0.03	-0.11	-0.06	-0.11
Lean maturity[c]	0.17*	0.15*	0.14*	0.08	0.18**	0.03
Overall maturity[c]	0.05	0.07	0.07	0.04	0.09	-0.04
Marbling[c]	-0.07	-0.11	-0.11	-0.13*	-0.17*	-0.10
Quality grade[c]	-0.06	-0.16*	-0.16*	-0.18**	-0.22***	-0.14*
Fat thickness	-0.02	-0.14*	-0.12	-0.20**	-0.15*	-0.18**
Adjusted fat	-0.02	-0.12	-0.11	-0.19**	-0.13*	-0.20**
REA	-0.09	-0.06	-0.06	-0.01	-0.09	-0.19**
KPH	0.09	0.14*	0.12	-0.05	0.10	-0.03
HCW	-0.02	-0.15*	-0.12	-0.14	-0.17**	-0.27***
Yield grade	-0.01	-0.10	-0.09	-0.23**	-0.12	-0.16*
Chemical fat	0.10	0.00	0.01	-0.18**	-0.04	-0.05
Live weight	-0.01	-0.18**	-0.15*	-0.16*	-0.18**	-0.28***
Dressing percent	-0.03	0.12	0.10	0.05	0.06	-0.03
Sarcomere length ES	-0.02	-0.08	-0.10	-0.12	-0.09	-0.16*
Sarcomere length NON	0.09	0.02	0.02	-0.07	0.09	-0.01

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$
[a] YAGRES = Yearling aggressiveness. 1 = non-aggressive, 9 = extremely aggressive; YNERV = yearling nervousness. 1 = totally calm, 9 = extremely nervous; YFLIGHT = yearling flightiness. 1 = totally quiet, 9 = extremely flighty; YGREG = yearling gregariousness. 1 = totally willing to be separated from the group, 9 = unwilling to be separated; YOVRALL = yearling overall. 1= completely docile, 9 = crazy; SLOVRALL = slaughter overall. 1 = completely docile, 9 = crazy.
[b] REA = ribeye area; KPH = kidney, pelvic, and heart fat; HCW = hot carcass weight; ES = electrically stimulated; NON = non-electrically stimulated; MFI = myofibrillar fragmentation index; WBS = Warner-Bratzler shear force.
[c] Measurement taken from left (non-stimulated) side of the carcass.

Table 7 Continued

	YAGRES	YNERV	YFLIGHT	YGREG	YOVERALL	SLOVERALL
L* ES	0.04	-0.17*	-0.16*	-0.30***	-0.17*	-0.20**
a* ES	-0.10	-0.22**	-0.20**	-0.27***	-0.20**	-0.01
b* ES	-0.14*	-0.13	-0.11	-0.12	-0.13	0.06
L* NON	0.06	-0.15*	-0.13	-0.17*	-0.13	-0.14*
a* NON	-0.17*	-0.23***	-0.28**	-0.21**	-0.23***	-0.01
b* NON	-0.20**	-0.13	-0.13	-0.11	0.16*	0.05
MFI ES	0.13	0.07	-0.01	0.13	0.04	-0.03
MFI NON	-0.03	-0.01	0.00	-0.07	0.02	-0.17*
WBS ES	-0.03	0.16*	0.16*	0.24***	0.14*	0.14*
WBS NON	-0.06	0.06	0.05	0.13*	-0.00	0.12

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$
[a] YAGRES = Yearling aggressiveness. 1 = non-aggressive, 9 = extremely aggressive; YNERV = yearling nervousness. 1 = totally calm, 9 = extremely nervous; YFLIGHT = yearling flightiness. 1 = totally quiet, 9 = extremely flighty; YGREG = yearling gregariousness. 1 = totally willing to be separated from the group, 9 = unwilling to be separated; YOVRALL = yearling overall. 1= completely docile, 9 = crazy; SLOVRALL = slaughter overall. 1 = completely docile, 9 = crazy.
[b] REA = ribeye area; KPH = kidney, pelvic, and heart fat; HCW = hot carcass weight; ES = electrically stimulated; NON = non-electrically stimulated; MFI = myofibrillar fragmentation index; WBS = Warner-Bratzler shear force.
[c] Measurement taken from left (non-stimulated) side of the carcass.

Table 8
Pearson correlation coefficients between yearling temperament scores [a], dissection percentages, and proximate analysis values

	YAGRES	YNERV	YFLIGHT	YGREG	YOVRALL	SLOVERALL
Dissection (%)						
LD[b]	-0.09	0.06	0.07	0.12	0.09	0.07
External	0.08	-0.05	-0.07	-0.14*	-0.07	-0.10
Seam	0.03	0.01	0.01	-0.09	-0.02	-0.06
Channel	-0.01	0.03	0.05	-0.04	0.02	-0.11
Total fat	0.06	-0.01	-0.02	-0.15*	-0.05	-0.13*
Lean trim	-0.06	0.01	0.01	0.15*	0.00	0.07
Bone	0.05	-0.07	-0.05	0.03	0.01	0.16*
Proximate (%)						
Moisture	-0.04	-0.05	-0.05	0.04	-0.01	0.09
Fat	0.02	0.03	0.03	-0.05	-0.02	-0.10
Protein	-0.02	0.02	0.01	0.02	0.04	0.14*
Ash	0.09	0.03	0.03	0.02	0.09	0.01

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$
[a] YAGRES = Yearling aggressiveness. 1 = non-aggressive, 9 = extremely aggressive; YNERV = yearling nervousness. 1 = totally calm, 9 = extremely nervous; YFLIGHT = yearling flightiness. 1 = totally quiet, 9 = extremely flighty; YGREG = yearling gregariousness. 1 = totally willing to be separated from the group, 9 = unwilling to be separated; YOVRALL = yearling overall. 1= completely docile, 9 = crazy; SLOVRALL = slaughter overall. 1 = completely docile, 9 = crazy.
[b] LD = *M. longissimus dorsi*.

Table 9
Pearson correlation coefficients between MFI[a] values, WBS[b] values, and meat quality traits[c]

	MFI ES	MFI NON	WBS ES	WBS NON
Skeletal maturity	-0.05	-0.05	-0.05	0.02
Lean maturity[d]	-0.14	0.09	0.07	0.25***
Overall maturity[d]	-0.01	0.02	-0.04	0.09
Marbling[d]	-0.01	-0.10	-0.12	-0.08
USDA quality grade[d]	0.01	-0.04	-0.13*	-0.10
Fat thickness	0.02	0.14	-0.01	-0.09
Adjusted fat	0.10	0.15	0.01	-0.10
REA	0.20**	0.10	-0.04	-0.15*
KPH	0.09	-0.01	0.05	-0.12
HCW	0.22**	0.14	0.14*	-0.15*
USDA yield grade	0.03	0.11	0.07	-0.11
Chemical fat	-0.07	0.00	-0.11	-0.02
Live weight	0.21**	0.17*	0.15*	-0.14*
Dressing percent	0.06	-0.07	0.01	-0.04
Sarcomere length ES	0.03	0.03	-0.21**	-0.24***
Sarcomere length NON	0.14	0.14	-0.09	-0.30***
L* ES	-0.06	-0.06	-0.28***	-0.18*
a* ES	0.12	0.24**	-0.19**	0.00
b* ES	0.12	0.25**	-0.07	0.04
L* NON	-0.14	-0.13	-0.13	-0.20**
a* NON	0.21*	0.09	-0.16*	-0.07
b* NON	0.24**	0.13	-0.05	-0.05
MFI[a] ES		0.29***	-0.06	-0.10
MFI[a] NON			-0.21**	-0.21**
WBS[b] ES				0.23***

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$
[a] MFI = Myofibrillar fragmentation index.
[b] WBS = Warner Bratzler Shear force.
[c] REA = ribeye area; KPH = kidney, pelvic, and heart fat; HCW = hot carcass weight; ES = electrically stimulated; NON = non-electrically stimulated.
[d] Measurement taken from left (non-stimulated) side of the carcass.

Table 10
Pearson correlation coefficients between MFI[a] values, WBS[b] values, dissection percentages, and proximate analysis values

	MFI ES	MFI NON	WBS ES	WBS NON
Dissection (%)				
LD[c]	-0.01	-0.05	-0.03	0.02
External	0.04	0.11	-0.03	0.01
Seam	0.09	-0.02	0.03	-0.06
Channel	-0.17*	0.02	-0.01	0.00
Total fat	0.05	0.05	-0.00	-0.04
Lean trim	0.04	-0.01	-0.01	-0.04
Bone	-0.15	-0.07	0.05	0.12
Proximate (%)				
Moisture	-0.10	-0.01	-0.04	0.07
Fat	0.10	0.03	0.03	-0.05
Protein	-0.14	-0.09	0.01	0.01
Ash	0.11	0.04	-0.04	-0.04

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$
[a] MFI = Myofibrillar fragmentation index.
[b] WBS = Warner Bratzler Shear force.
[c] LD = *M. longissimus dorsi*.

CIE L* values for both stimulated and non-stimulated carcasses were correlated positively ($P < 0.01$) with lean maturity, overall maturity, marbling, and USDA quality grade (Table 11). Chemical fat was correlated ($P < 0.05$) with CIE L* ES, b* ES, L*, a*, and b* NON values. Dressing percentage and sarcomere ES values were correlated ($P < 0.05$) with CIE L* ES and NON measures. L*, a*, b* values were correlated strongly ($P < 0.05$) to each other, with the exception of L* ES and NON and a* ES values.

Table 11

Pearson correlation coefficients between CIE values and meat quality traits[a]

	L* ES	a* ES	b* ES	L* NON	a* NON	b* NON
Skeletal maturity	0.10	-0.10	-0.13	0.06	-0.08	-0.10
Lean maturity[b]	-0.27***	-0.14*	-0.14	-0.30***	-0.20**	-0.19**
Overall maturity[b]	-0.17**	-0.08	-0.00	-0.28***	0.02	0.04
Marbling[b]	0.27***	0.04	-0.00	0.23***	0.05	0.00
USDA quality grade[b]	0.27***	0.08	0.02	0.23***	0.06	0.01
Fat thickness	0.15*	0.03	-0.00	0.09	0.09	0.10
Adjusted fat	0.17*	0.03	-0.00	0.11	0.11	0.11
REA	-0.01	-0.05	0.03	0.11	-0.07	-0.04
KPH	0.11	0.03	0.00	0.07	0.07	0.09
HCW	0.10	-0.00	0.02	0.09	-0.02	0.01
USDA yield grade	0.18**	0.04	-0.01	0.06	0.12	0.13
Chemical fat	0.25***	-0.14	-0.14*	0.15*	-0.18**	-0.15*
Live weight	0.08	0.02	0.03	0.05	0.00	0.03
Dressing percent	0.17*	-0.04	-0.01	0.20**	-0.06	-0.05
Sarcomere length ES	0.27***	0.01	-0.07	0.25***	-0.02	-0.10
Sarcomere length NON	0.12	0.11	0.10	0.17*	0.10	0.07
L* ES		-0.04	-0.36***	0.76***	0.02	-0.24***
a* ES			0.88***	-0.13	0.82***	0.68***
b* ES				-0.37***	0.71***	0.73***
L* NON					-0.21**	-0.46***
a* NON						0.90***

* $P < 0.05$

** $P < 0.01$

*** $P < 0.001$

[a] REA = ribeye area; KPH = kidney, pelvic, and heart fat; HCW = hot carcass weight; ES = electrically stimulated; NON = non-electrically stimulated; MFI = myofibrillar fragmentation index; WBS = Warner-Bratzler shear force.

[b] Measurement taken from left (non-stimulated) side of the carcass.

Pearson correlation coefficients of CIE values, dissection percentages, and proximate analysis values are presented in Table 12. CIE L* values from ES carcasses were correlated positively ($P < 0.05$) with seam fat, channel fat, total fat, and extracted fat percentages.

Lean maturity and sarcomere length NON were correlated negatively ($P < 0.05$) (Table 13). Marbling, USDA quality grade, fat thickness, adjusted fat thickness, ribeye area, hot carcass weight, USDA yield grade, chemical fat, and live weight were correlated positively ($P < 0.05$) with sarcomere lengths from ES carcasses. Fat thickness, adjusted fat thickness, ribeye area, hot carcass weight, and live weight also were correlated positively ($P < 0.05$) with sarcomere values from non-stimulated carcasses.

Table 14 contains Pearson correlation coefficients between sarcomere lengths, dissection percentages, and proximate analysis values. Total fat and bone were correlated ($P < 0.05$) with sarcomere values from electrically stimulated carcasses.

Skeletal maturity was correlated ($P < 0.05$) with the LD, external fat, seam fat, total fat, and bone percentage (Table 15). Marbling, USDA quality grade, fat thickness, adjusted fat thickness, kidney, pelvic, and heart fat, hot carcass weight, USDA yield grade, chemical fat, live weight, and dressing percentage were correlated ($P < 0.05$) with dissection components: LD, external fat, seam fat, total fat, lean trim, and bone percentage. Dissection components were moderately correlated to themselves with the exception of channel fat. Dissection components were correlated ($P < 0.001$) with proximate values: moisture, fat, and protein.

Table 12

Pearson correlation coefficients between CIE values[a], dissection percentages, and proximate analysis values

	L* ES	a* ES	b* ES	L* NON	a* NON	b* NON
Dissection (%)						
LD[b]	-0.14*	0.08	0.13	-0.11	0.04	0.06
External	0.04	0.16*	0.14	-0.02	0.17*	0.19**
Seam	0.19**	0.03	0.04	0.13	0.05	0.06
Channel	0.17*	-0.07	-0.11	0.07	-0.16	-0.16*
Total fat	0.19**	0.09	0.07	0.10	0.08	0.10
Lean trim	-0.12	-0.14*	-0.15*	-0.01	-0.11	-0.14*
Bone	-0.16	-0.06	-0.06	-0.16*	-0.05	-0.06
Proximate (%)						
Moisture	-0.14	-0.01	0.00	-0.11	-0.01	-0.03
Fat	0.15*	0.05	0.03	0.10	0.07	0.08
Protein	-0.08	-0.09	-0.10	-0.05	-0.16*	-0.19**
Ash	-0.15*	-0.05	0.02	-0.06	-0.02	0.05

* $P < 0.05$

** $P < 0.01$

*** $P < 0.001$

[a] ES = electrically stimulated; NON = non-electrically stimulated.

[b] LD = *M. longissimus dorsi*.

Table 13
Pearson correlation coefficients between sarcomere lengths[a] and meat quality traits[b]

	Sarcomere length ES	Sarcomere length NON
Skeletal maturity	0.13	-0.01
Lean maturity[c]	-0.03	-0.16*
Overall maturity[c]	0.01	-0.05
Marbling[c]	0.14*	0.01
USDA quality grade[c]	0.18**	0.01
Fat thickness	0.21**	0.16*
Adjusted fat	0.24***	0.18**
REA	0.22**	0.25***
KPH	0.09	0.10
HCW	0.18**	0.16*
USDA yield grade	0.15*	0.06
Chemical fat	0.16*	-0.04
Live weight	0.17*	0.18**
Dressing percent	0.07	-0.04
Sarcomere length ES		0.30***

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$
[a] ES = electrically stimulated; NON = non-electrically stimulated.
[b] REA = ribeye area; KPH = kidney, pelvic, and heart fat; HCW = hot carcass weight; MFI = myofibrillar fragmentation index; WBS = Warner-Bratzler shear force.
[c] Measurement taken from left (non-stimulated) side of the carcass.

Table 14
Pearson correlation coefficients between sarcomere lengths[a], dissection percentages, and proximate analysis values

	Sarcomere length ES	Sarcomere length NON
Dissection (%)		
LD[b]	-0.11	0.00
External	0.09	0.03
Seam	0.11	0.09
Channel	0.03	-0.123
Total fat	0.14*	0.04
Lean trim	0.01	-0.01
Bone	-0.26***	-0.08
Proximate (%)		
Moisture	-0.12	0.05
Fat	0.10	-0.04
Protein	-0.08	-0.06
Ash	0.03	0.10

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$
[a] ES = electrically stimulated; NON = non-electrically stimulated.
[b] LD = *M. longissimus dorsi*.

Table 15
Pearson correlation coefficients between dissection percentages, meat quality traits[a], and proximate analysis values

	LD[b]	External	Seam	Channel	Total fat	Lean trim	Bone
Skeletal maturity	-0.34***	0.19**	0.17**	0.01	0.23**	0.00	-0.24**
Lean maturity[c]	-0.15*	0.04	-0.06	0.02	-0.01	0.08	0.05
Overall maturity[c]	-0.09	0.06	0.31	-0.07	0.04	0.05	-0.08
Marbling[c]	-0.30***	0.19**	0.43**	0.13*	0.44***	-0.27***	-0.39***
Quality grade[c]	-0.32***	0.24***	0.45***	0.14*	0.49***	-0.29***	-0.44***
Fat thickness	-0.60***	0.53***	0.47***	-0.03	0.62***	-0.30***	-0.47***
Adjusted fat	-0.60***	0.60***	0.47***	-0.03	0.66***	-0.33***	-0.51***
REA	0.18**	-0.06	-0.07	-0.07	-0.10	0.17**	-0.20**
KPH	-0.15*	0.19**	0.23***	0.11	0.30***	-0.17*	0.31***
HCW	-0.23***	0.23***	0.30***	0.06	0.36***	-0.21**	-0.34***
Yield grade	-0.62***	0.56***	0.52***	0.08	0.69***	-0.44***	-0.42***
Chemical fat	-0.38***	0.17**	0.43***	0.16*	0.45***	-0.25**	-0.35***
Live weight	-0.18**	0.20**	0.22***	0.05	0.27***	-0.16*	-0.25***
Dressing percent	-0.23**	0.21**	0.42***	0.07	0.43***	-0.28***	-0.41***
LD		-0.38***	-0.51***	-0.11	-0.60***	0.09	0.32***
External			0.18**	-0.05	0.66***	-0.51***	-0.46***
Seam				0.00	0.81***	-0.59***	-0.59***
Channel					0.25***	-0.25***	-0.14*
Total Fat						-0.77***	-0.70***
Lean trim							-0.21**
Proximate (%)							
Moisture	0.55***	-0.50***	-0.71***	-0.23***	-0.84***	0.58***	0.65***
Fat	-0.55***	0.58***	0.73***	0.19**	0.86***	-0.61***	-0.65***
Protein	0.50***	-0.57***	-0.65***	-0.11	-0.78***	0.56***	0.55***
Ash	0.06	-0.09	-0.12	0.03	-0.14*	0.11	0.10

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$
[a] REA = ribeye area; KPH = kidney, pelvic, and heart fat; HCW = hot carcass weight; MFI = myofibrillar fragmentation index; WBS = Warner-Bratzler shear force.
[b] LD = *M. longissimus dorsi*.
[c] Measurement taken from left (non-stimulated) side of the carcass.

Pearson correlation coefficients for meat quality traits and proximate analysis values are reported in Table 16. Marbling, USDA quality grade, fat thickness, adjusted fat thickness, kidney, pelvic, and heart fat, hot carcass weight, USDA yield grade, chemical fat, live weight, and dressing percentage all were correlated moderately ($P < 0.01$) with proximate values moisture, fat, and protein.

Fat thickness and adjusted fat thickness were correlated positively ($P < 0.001$) with skeletal maturity, marbling, USDA quality grade, chemical fat, live weight, and dressing percentage (Table 17). Ribeye area was correlated positively ($P < 0.001$) with live weight and dressing percentage, while kidney, pelvic, and heart fat was correlated ($P < 0.05$) with live weight, dressing percentage, and chemical fat. Hot carcass weight and USDA yield grade were correlated positively ($P < 0.05$) with skeletal maturity, USDA quality grade, chemical fat, live weight, and dressing percentage. USDA yield grade also was correlated ($P < 0.001$) with marbling. USDA yield grade factors all were correlated ($P < 0.01$) with themselves except ribeye area and kidney, pelvic, and heart fat.

Skeletal maturity was correlated ($P < 0.05$) with lean maturity, overall maturity, and quality grade (Table 18). Lean maturity also was correlated ($P < 0.001$) with overall maturity, and marbling was correlated ($P < 0.001$) with USDA quality grade.

Pearson correlation coefficients between live weight, dressing percentage, and chemical fat are presented in Table 19. Chemical fat was correlated ($P < 0.05$) with live weight and dressing percentage.

Table 16
Pearson correlation coefficients between meat quality traits[a], and proximate analysis values (%)

	Moisture	Fat	Protein	Ash
Skeletal maturity	-0.22***	0.17**	-0.06	0.01
Lean maturity[b]	0.20**	-0.01	0.08	-0.04
Overall maturity[b]	-0.02	0.02	0.02	-0.06
Marbling[b]	-0.51***	0.51***	-0.38***	-0.14*
USDA quality grade[b]	-0.54***	0.55***	-0.41***	-0.12
Fat thickness	-0.50***	0.52***	-0.50***	-0.08
Adjusted fat	-0.52***	0.55***	-0.53***	-0.05
REA	0.10	-0.11	0.03	0.15*
KPH	-0.32***	0.29***	-0.21**	0.02
HCW	-0.28***	0.29***	-0.30***	0.01
USDA yield grade	-0.58***	0.60***	-0.52***	-0.12
Chemical fat	-0.49***	0.48***	-0.31***	-0.15*
Live weight	-0.21**	0.22***	-0.24***	0.01
Dressing percent	-0.38***	0.38***	-0.34***	-0.02
Moisture		-0.98***	0.72***	0.18**
Fat			-0.81***	-0.26***
Protein				-0.09

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$
[a] REA = ribeye area; KPH = kidney, pelvic, and heart fat; HCW = hot carcass weight.
[b] Measurement taken from left (non-stimulated) side of the carcass.

Table 17

Pearson correlation coefficients between USDA quality and yield grade factors[a]

	Fat thickness	Adjusted fat	REA	KPH	HCW	UDSA yield grade
Skeletal maturity	0.29***	0.30***	0.03	0.08	0.21**	0.27***
Lean maturity[b]	0.03	-0.02	-0.12	-0.05	-0.17**	-0.03
Overall maturity[b]	0.07	0.04	-0.09	0.02	-0.02	0.04
Marbling[b]	0.26***	0.24***	0.01	0.11	0.10	0.23***
USDA quality grade[b]	0.30***	0.30***	0.04	0.12	0.17*	0.27***
Chemical fat	0.33***	0.29***	-0.02	0.22***	0.19**	0.33***
Live weight	0.47***	0.49***	0.52***	0.23***	0.97***	0.49***
Dressing percent	0.25***	0.26***	0.22***	0.13*	0.32***	0.22***
Fat thickness	--	0.95***	0.17**	0.17**	0.51***	0.79***
Adjusted fat			0.17**	0.19**	0.53***	0.84***
REA				0.077	0.56***	-0.18**
KPH					0.26***	0.36***
HCW						0.51***

* $P < 0.05$

** $P < 0.01$

*** $P < 0.001$

[a] REA = ribeye area; KPH = kidney, pelvic, and heart fat; HCW = hot carcass weight; MFI = myofibrillar fragmentation index.

[b] Measurement taken from left (non-stimulated) side of the carcass.

Table 18
Pearson correlation coefficients between USDA quality grade factors

	Lean maturity[a]	Overall maturity[a]	Marbling[a]	USDA quality grade
Skeletal maturity	0.18***	0.20**	0.11	0.13*
Lean maturity[a]		0.29***	-0.06	-0.07
Overall maturity[a]			-0.05	-0.05
Marbling[a]				0.95***

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$
[a] Measurement taken from left (non-stimulated) side of the carcass.

Table 19
Pearson correlation coefficients between live weight, dressing percentage, and chemical fat

	Live weight	Dressing percent
Chemical fat	0.13*	0.26***
Live weight		0.09

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

The effects of sire and family nested within sire accounted for variation in overall weaning and yearling temperament scores (Tables 20 and 21). None of the variables that were evaluated contributed to differences in slaughter overall temperament scores (Table 22). This could be as a result of limited variation in the temperament scores at slaughter due to the steers being accustomed to handling by this point. Although the range of scores was 1 to 8, the mean was 2.43 and the standard deviation was 1.03, indicating a small amount of variation in the scores compared to the other temperament scores.

Table 20
Weaning overall temperament score fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.82	0.5390
Sire	6.38	0.0004
Family(Sire)	2.09	0.0159
Age(Contemporary group)	0.93	0.4776

Table 21
Yearling overall temperament score fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.93	0.4597
Sire	6.03	0.0006
Family(Sire)	2.72	0.0014
Age(Contemporary group)	0.84	0.5383

Table 22
Slaughter overall temperament score fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.35	0.8809
Sire	1.66	0.1771
Family(Sire)	0.89	0.5670
Slaughter day(Contemporary group)	1.29	0.2631
Age(Contemporary group)	0.61	0.7196

Least squares means and standard errors for weaning and yearling temperament scores separated by sire are presented in Table 23. Sire 437J had the highest (poorest) ($P < 0.05$) weaning and yearling temperament score and sire 297J had the lowest (calmest) ($P < 0.05$) temperament scores. Weaning and yearling temperament scores stratified by family nested within sire are shown in Table 24. Family 74, sired by 437J, produced steers with the highest ($P < 0.05$) weaning and yearling temperament scores, but the standard error was large, and the number of cattle within the family was very small (n = 4). Family 81's steers (n = 27), also sired by 437J, had the second highest weaning overall temperament score at 4.99. Family 71, sired by 297J, had the lowest (*P* < 0.05) weaning and yearling temperament scores.

Table 23
Least squares means ± standard errors for overall temperament scores[a] by sire

Sire	WOVRALL	YOVRALL
297J	$3.05^{b} \pm 0.32$	$2.73^{b} \pm 0.20$
432H	$3.93^{cd} \pm 0.35$	$3.53^{c} \pm 0.22$
437J	$4.55^{d} \pm 0.32$	$3.67^{c} \pm 0.20$
551G	$3.19^{bc} \pm 0.29$	$3.46^{c} \pm 0.19$
P-value	0.0004	0.0006

[a] WOVRALL = weaning overall. 1= completely docile, 9 = wild; YOVRALL = yearling overall. 1= completely docile, 9 = wild.
Within a column, means lacking a common letter (b-d) differ (*P* < 0.05).

Table 24
Least squares means ± standard errors for overall temperament scores[a] by family (sire)

Sire Family	WOVRALL	YOVRALL
297J		
70	3.38^{bc} ± 0.49	3.12^{cde} ± 0.31
71	2.28^{b} ± 0.46	2.31^{b} ± 0.29
95	3.49^{c} ± 0.54	2.77^{bcd} ± 0.34
432H		
72	4.04^{cd} ± 0.46	3.79^{ef} ± 0.29
73	3.91^{cd} ± 0.83	4.19^{fg} ± 0.52
82	4.38^{cde} ± 0.82	3.42^{cdef} ± 0.52
96	3.39^{bc} ± 0.45	2.74^{bc} ± 0.28
437J		
74	6.49^{e} ± 0.96	5.50^{g} ± 0.60
75	3.83^{cd} ± 0.57	3.01^{bcde} ± 0.36
81	4.99^{de} ± 0.42	3.44^{cdef} ± 0.26
83	2.94^{bc} ± 0.57	3.07^{bcde} ± 0.36
97	4.52^{cde} ± 0.50	3.35^{cdef} ± 0.32
551G		
76	2.54^{bc} ± 0.91	3.13^{cdef} ± 0.57
77	2.80^{bc} ± 0.48	3.16^{cdef} ± 0.30
80	3.45^{c} ± 0.42	3.95^{f} ± 0.26
84	4.08^{cd} ± 0.56	3.65^{def} ± 0.35
98	3.09^{bc} ± 0.71	3.40^{cdef} ± 0.45
P-value	0.0159	0.0014

[a] WOVRALL = weaning overall. 1= completely docile, 9 = wild; YOVRALL = yearling overall. 1= completely docile, 9 = wild.
Within a column, means lacking a common letter (b-g) differ ($P < 0.05$).

Sire accounted for variation in skeletal maturity (Table 25), while the effects of sire, family nested within sire, and slaughter day within contemporary group accounted for variation in carcass lean maturity (Table 26). Overall carcass maturity fixed effects are found in Table 27 and sire and slaughter day within contemporary group accounted for some of the variation in maturity. Table 28 shows the marbling fixed effects and none were significant. The effect of sire was found to be significant for USDA quality grade (Table 29).

Table 25
Carcass skeletal maturity fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.43	0.8261
Sire	3.56	0.0152
Family(Sire)	0.90	0.5501
Slaughter day(Contemporary group)	0.84	0.6416
Age(Contemporary group)	0.42	0.8645

Table 26
Carcass lean maturity fixed effects

Effect	F Value	*P*-Value
Contemporary group	1.72	0.1309
Sire	5.57	0.0011
Family(Sire)	2.06	0.0180
Slaughter day(Contemporary group)	2.72	0.0005
Age(Contemporary group)	1.92	0.0792

Table 27
Overall carcass maturity fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.45	0.8094
Sire	8.45	<0.0001
Family(Sire)	1.12	0.3476
Slaughter day(Contemporary group)	2.16	0.0065
Age(Contemporary group)	1.00	0.4247

Table 28
Marbling fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.49	0.7846
Sire	2.35	0.0738
Family(Sire)	1.27	0.2360
Slaughter day(Contemporary group)	1.03	0.4297
Age(Contemporary group)	0.39	0.8868

Table 29
USDA quality grade fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.74	0.5956
Sire	3.91	0.0097
Family(Sire)	1.56	0.1001
Slaughter day(Contemporary group)	0.94	0.5242
Age(Contemporary group)	0.56	0.7595

Least squares means and standard errors for USDA quality grade factors by sire are shown in Table 30. Sire 432H produced steers that had the most youthful ($P < 0.05$) skeletal, lean, and overall maturity, as well as the highest ($P < 0.05$) USDA quality grade at Choice 09. Steers sired by 551G had the lowest ($P < 0.05$) USDA quality grade at Select 77. Family 84, sired by 551G, produced the lowest ($P < 0.05$) USDA quality grade (Table 31). Family 72, sired by 432H, had the highest ($P < 0.05$) USDA quality grade at Choice 19 and the most youthful ($P < 0.05$) lean maturity. Family 76, sired by 551G, produced steers with the most advanced ($P < 0.05$) lean maturity at A80.

Table 30

Least squares means ± standard errors for USDA quality grade factors by sire

Sire	Skeletal maturity	Lean maturity[a]	Overall maturity[a]	USDA quality grade[a]
297J	53.07^{c} ± 1.95	61.33^{cd} ± 2.59	57.17^{d} ± 1.67	299.12^{cd} ± 8.10
432H	44.83^{b} ± 2.15	50.58^{b} ± 2.84	47.15^{b} ± 1.84	308.82^{d} ± 8.90
437J	48.03^{b} ± 2.00	56.11^{bc} ± 2.65	51.94^{c} ± 1.71	282.57^{bc} ± 8.31
551G	48.37^{bc} ± 1.90	63.46^{d} ± 2.51	56.16^{cd} ± 1.62	276.57^{b} ± 7.86
P-value	0.0152	0.0011	< 0.0001	0.0097

[a] Measurement taken from left (non-stimulated) side of the carcass.

Within a column, means lacking a common letter (b-c) differ ($P < 0.05$).

Table 31
Least squares means ± standard errors for USDA quality grade factors by family (sire)

Sire Family	Lean maturity[a]
297J	
70	64.92[efg] ± 3.94
71	60.98[def] ± 3.71
95	58.09[cdef] ± 4.39
432H	
72	48.93[bc] ± 3.62
73	56.85[bcdef] ± 6.94
82	44.78[b] ± 6.45
96	51.77[bcd] ± 3.64
437J	
74	56.13[bcdef] ± 7.80
75	62.98[defg] ± 4.72
81	55.01[bcde] ± 3.33
83	54.69[bcde] ± 4.59
97	51.71[bcd] ± 4.09
551G	
76	80.32[g] ± 8.49
77	56.08[bcde] ± 3.92
80	72.93[fg] ± 3.54
84	50.90[bcd] ± 4.42
98	57.08[bcdef] ± 5.65
P-value	0.0180

[a] Measurement taken from left (non-stimulated) side of the carcass. Within a column, means lacking a common letter (b-f) differ ($P < 0.05$).

The effects of sire and family nested within sire accounted for the variation in carcass fat thickness and adjusted fat thickness (Tables 32 and 33). Table 34 illustrates the ribeye area fixed effects and contemporary group, sire, family nested within sire, and age within contemporary group accounted for variation in ribeye area. Sire accounted for variation in kidney, pelvic, and heart fat percentage (Table 35). Fixed effects for hot carcass weight are presented in Table 36. Sire, family nested within sire, and slaughter day within contemporary group were found to be significant indicating they account for some of the variation in this trait. Sire was significant in accounting for variation in USDA yield grade (Table 37). Table 38 displays the fixed effects for live weight. Sire, family nested within sire, and slaughter day within contemporary group were shown to be significant in live weight. Sire and slaughter day within contemporary group were significant fixed effects for dressing percentage (Table 39). Variation attributed to the fixed effect of slaughter day within contemporary group could be due to the differences in slaughter personnel or conditions on a particular slaughter day. Chemical fat percentage fixed effects are shown in Table 40 and none of the variables evaluated contributed to variation in this trait.

Table 32
Carcass fat thickness fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.13	0.9849
Sire	5.73	0.0009
Family(Sire)	2.35	0.0061
Slaughter day(Contemporary group)	0.78	0.7173
Age(Contemporary group)	0.21	0.9730

Table 33
Carcass adjusted fat thickness fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.31	0.9057
Sire	6.75	0.0002
Family(Sire)	2.43	0.0046
Slaughter day(Contemporary group)	0.99	0.4703
Age(Contemporary group)	0.37	0.8969

Table 34
Ribeye area fixed effects

Effect	F Value	*P*-Value
Contemporary group	2.49	0.0326
Sire	6.44	0.0004
Family(Sire)	2.26	0.0089
Slaughter day(Contemporary group)	1.15	0.3081
Age(Contemporary group)	2.16	0.0483

Table 35
Kidney, pelvic, and heart fat percentage fixed effects

Effect	F Value	*P*-Value
Contemporary group	1.91	0.0952
Sire	4.37	0.0053
Family(Sire)	0.58	0.8653
Slaughter day(Contemporary group)	1.61	0.0652
Age(Contemporary group)	1.92	0.0797

Table 36
Hot carcass weight fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.80	0.5496
Sire	5.79	0.0008
Family(Sire)	2.20	0.0109
Slaughter day(Contemporary group)	2.50	0.0014
Age(Contemporary group)	1.06	0.3864

Table 37
USDA yield grade fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.63	0.6745
Sire	2.74	0.0448
Family(Sire)	1.67	0.0709
Slaughter day(Contemporary group)	0.83	0.6608
Age(Contemporary group)	0.67	0.6705

Table 38
Live weight fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.64	0.6722
Sire	6.18	0.0005
Family(Sire)	2.32	0.0071
Slaughter day(Contemporary group)	2.48	0.0015
Age(Contemporary group)	1.17	0.3260

Table 39
Dressing percentage fixed effects

Effect	F Value	*P*-Value
Contemporary group	1.18	0.3210
Sire	13.24	<0.0001
Family(Sire)	1.39	0.1688
Slaughter day(Contemporary group)	2.06	0.0100
Age(Contemporary group)	0.95	0.4580

Table 40
Chemical fat percentage fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.44	0.8206
Sire	1.53	0.2079
Family(Sire)	0.71	0.7519
Slaughter day(Contemporary group)	1.30	0.1988
Age(Contemporary group)	0.89	0.4997

Ribeye area least squares means by contemporary group are found in Table 41. Contemporary group 5 had the smallest ($P < 0.05$) ribeye area and group 4 had the largest ($P < 0.05$) ribeye area. This effect partially could be due to the length of time these steers were on feed. Group 5 steers were fed the shortest amount of time, 130 d, compared to 148 d of group 4. Sire 297J produced steers that possessed the most (*P* < 0.05) fat thickness at the 12th rib, the most (*P* < 0.05) adjusted fat, highest (*P* < 0.05) numerical yield grade at 3.48, and the heaviest (*P* < 0.05) hot carcass and live weight (Table 42). Steers sired by 432H had the largest (*P* < 0.05) ribeye area and the highest (*P* < 0.05) dressing percentage. Those sired by 437J had the least (*P* < 0.05) 12th rib fat thickness, adjusted fat thickness, and the lowest (*P* < 0.05) numerical yield grade. Sire 551G produced steers with the smallest (*P* < 0.05) ribeye area and the lightest (*P* < 0.05) hot carcass and live weights. Least squares means and standard errors for USDA yield grade factors and live weight are found in Table 43. Family 82, sired by 432H, produced steers with the largest (*P* < 0.05) ribeye area and the heaviest (*P* < 0.05) hot carcass weight. However, this is confounded with contemporary group because all of these calves (n = 6) were produced in contemporary group 6, that were on feed for 152 d, the second longest feeding time to group 2, which was 154 d. Family 71, sired by 297J, had steer progeny with the heaviest (*P* < 0.05) live weight. Family 74, sired by 437J, had the least (*P* < 0.05) fat thickness and adjusted fat thickness, as well as the lightest (*P* < 0.05) hot carcass and live weight. Family 76, sired by 551G, produced steers with the smallest (*P* < 0.05) ribeye area. Family 77, also sired by 551G, had steers with the most (*P* < 0.05) 12th rib fat thickness and adjusted fat thickness.

Table 41
Least squares means ± standard errors for ribeye area by contemporary group

Group	Ribeye area (cm^2)
1	72.35^{c} ± 1.62
2	70.37^{ab} ± 3.42
3	70.90^{b} ± 1.87
4	77.63^{d} ± 1.30
5	70.06^{a} ± 1.34
6	75.84^{d} ± 1.17
P-value	0.0326

Within a column, means lacking a common letter (a-d) differ ($P < 0.05$).

Table 42

Least squares means ± standard errors for USDA yield grade factors[a], live weight, and dressing percentage by sire

Sire	Fat thickness (cm)	Adjusted fat (cm)	REA (cm^2)	KPH (%)	HCW (kg)	USDA yield grade
297J	1.45^{d} ± 0.08	1.59^{d} ± 0.08	73.58^{c} ± 1.2	2.48^{b} ± 0.10	316.84^{d} ± 5.53	3.48^{c} ± 0.12
432H	1.30^{cd} ± 0.09	1.48^{cd} ± 0.09	75.86^{c} ± 1.3	2.32^{b} ± 0.12	309.65^{cd} ± 6.08	3.24^{bc} ± 0.14
437J	1.04^{b} ± 0.08	1.15^{b} ± 0.08	73.07^{c} ± 1.2	2.77^{c} ± 0.10	295.91^{bc} ± 5.67	3.05^{b} ± 0.13
551G	1.24^{bc} ± 0.08	1.39^{c} ± 0.08	68.91^{b} ± 1.1	2.38^{b} ± 0.10	291.55^{b} ± 5.38	3.35^{bc} ± 0.12
P-value	0.0009	0.0002	0.0004	0.0053	0.0008	0.0448

[a] REA = Ribeye area; KPH = kidney, pelvic, and heart fat; HCW = hot carcass weight.

Within a column, means lacking a common letter (b-d) differ ($P < 0.05$).

Table 42 Continued

Sire	Live weight (kg)	Dressing percent (%)
297J	484.02^{c} ± 7.96	65.40^{b} ± 0.28
432H	459.06^{b} ± 8.75	67.43^{c} ± 0.31
437J	450.42^{b} ± 8.16	65.77^{b} ± 0.29
551G	444.75^{b} ± 7.73	65.37^{b} ± 0.27
P-value	0.0005	< 0.0001

Within a column, means lacking a common letter (b-c) differ ($P < 0.05$).

Table 43
Least squares means ± standard errors for USDA yield grade factors[a] and live weight by family (sire)

Sire Family	Fat thickness (cm)	Adjusted fat (cm)	REA (cm^2)	HCW (kg)	Live weight (kg)
297J					
70	1.42[ef] ± 0.12	1.54[def] ± 0.12	71.56[bcd] ± 1.87	312.57[cde] ± 8.42	473.85[de] ± 12.11
71	1.46[ef] ± 0.12	1.59[def] ± 0.11	76.34[ef] ± 1.76	320.94[e] ± 7.94	491.31[e] ± 11.42
95	1.48[ef] ± 0.14	1.63[ef] ± 0.13	72.85[bcdef] ± 2.08	317.37[cde] ± 9.37	486.91[de] ± 13.49
432H					
72	1.24[cdef] ± 0.11	1.37[cdef] ± 0.11	72.17[bcde] ± 1.71	298.38[bcd] ± 7.74	442.05[bcd] ± 11.13
73	1.33[def] ± 0.22	1.51[cdef] ± 0.21	72.52[bcdef] ± 3.28	299.19[bcde] ± 14.83	439.33[bcd] ± 21.33
82	1.37[def] ± 0.20	1.63[ef] ± 0.20	80.59[f] ± 3.05	321.04[e] ± 13.78	474.96[de] ± 19.83
96	1.24[cdef] ± 0.11	1.42[cdef] ± 0.11	78.13[f] ± 1.73	320.00[de] ± 7.79	479.89[de] ± 11.21
437J					
74	0.55[b] ± 0.24	0.68[b] ± 0.24	73.68[bcdef] ± 3.69	269.62[b] ± 16.67	416.99[bc] ± 23.99
75	1.17[cde] ± 0.15	1.24[cd] ± 0.14	69.31[bc] ± 2.23	292.01[bcd] ± 10.09	440.33[bcd] ± 14.51
81	1.12[cd] ± 0.10	1.26[cd] ± 0.10	74.06[cdef] ± 1.58	306.98[cde] ± 7.11	467.64[cde] ± 10.23
83	1.05[bcd] ± 0.14	1.16[bc] ± 0.14	72.08[bcde] ± 2.17	304.67[bcde] ± 9.82	464.33[cde] ± 14.13
97	1.30[def] ± 0.13	1.43[cdef] ± 0.13	76.23[def] ± 1.94	306.27[cde] ± 8.75	462.79[cde] ± 12.58
551G					
76	1.19[cdef] ± 0.26	1.28[cdef] ± 0.26	65.19[b] ± 4.02	277.97[bc] ± 18.16	428.08[bcd] ± 26.13
77	1.67[f] ± 0.12	1.85[f] ± 0.12	71.39[bc] ± 1.86	317.44[cde] ± 8.39	478.16[de] ± 12.07
80	1.30[def] ± 0.11	1.41[def] ± 0.11	72.11[bcde] ± 1.69	288.98[bc] ± 7.61	440.19[bcd] ± 10.89
84	0.90[bc] ± 0.14	1.12[bc] ± 0.14	66.55[b] ± 2.09	271.89[b] ± 9.45	415.97[b] ± 13.60
98	1.12[cde] ± 0.18	1.27[cde] ± 0.17	69.34[bc] ± 2.67	301.47[bcde] ± 12.07	461.34[cde] ± 17.37
P-value	0.0061	0.0046	0.0089	0.0109	0.0071

[a] REA = Ribeye area; KPH = kidney, pelvic, and heart fat; HCW = hot carcass weight.
Within a column, means lacking a common letter (b-g) differ ($P < 0.05$).

Sarcomere length fixed effects for electrically stimulated carcasses are presented in Table 44. Slaughter day within contemporary group was the only effect that accounted for variation in sarcomere length. This could be due to slaughter personnel or variable conditions on the day of slaughter. None of the variables evaluated accounted for variation in sarcomere length from non-stimulated carcasses (Table 45).

Contemporary group and sire accounted for variation in myofibrillar fragmentation index from electrically-stimulated carcasses (Table 46). Sire, family nested within sire, and slaughter day within contemporary group were significant effects for myofibrillar fragmentation index from non-electrically stimulated carcasses (Table 47). Warner-Bratzler shear force fixed effects from electrically-stimulated and non-electrically stimulated carcasses are shown in Tables 48 and 49, respectively. Family nested within sire was shown to account for variation in both.

Table 44
Sarcomere length (from electrically stimulated carcasses) fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.61	0.6907
Sire	1.24	0.2977
Family(Sire)	1.27	0.2334
Slaughter day(Contemporary group)	1.98	0.0144
Age(Contemporary group)	0.59	0.7418

Table 45
Sarcomere length (from non-electrically stimulated carcasses) fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.85	0.5192
Sire	0.98	0.4051
Family(Sire)	0.63	0.8231
Slaughter day(Contemporary group)	0.58	0.9037
Age(Contemporary group)	1.04	0.3985

Table 46
Myofibrillar fragmentation index (from electrically stimulated carcasses) fixed effects

Effect	F Value	*P*-Value
Contemporary group	2.73	0.0460
Sire	4.37	0.0057
Family(Sire)	1.66	0.0972
Slaughter day(Contemporary group)	1.50	0.1294
Age(Contemporary group)	2.24	0.0676

Table 47
Myofibrillar fragmentation index (from non-electrically stimulated carcasses) fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.68	0.5651
Sire	3.44	0.0184
Family(Sire)	3.26	0.0008
Slaughter day(Contemporary group)	3.96	<0.0001
Age(Contemporary group)	0.50	0.7330

Table 48
Warner-Bratzler shear force (from electrically stimulated carcasses) fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.44	0.8199
Sire	1.24	0.2983
Family(Sire)	1.82	0.0426
Slaughter day(Contemporary group)	1.30	0.1935
Age(Contemporary group)	0.48	0.8209

Table 49
Warner-Bratzler shear force (from non-electrically stimulated carcasses) fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.84	0.5226
Sire	2.41	0.0681
Family(Sire)	1.77	0.0494
Slaughter day(Contemporary group)	1.54	0.0839
Age(Contemporary group)	0.72	0.6343

Table 50 displays the least squares means for MFI by contemporary group (Table 50). Contemporary group 3 had the lowest ($P < 0.05$) MFI value and group 5 had the highest ($P < 0.05$) value. Myofibrillar fragmentation index values stratified by sire are shown in Table 51 and steers sired by 551G had the lowest ($P < 0.05$) MFI values for stimulated and non-stimulated carcasses. Sire 432H had the highest ($P < 0.05$) MFI values for both. Family 96, sired by 432H, had the highest ($P < 0.05$) MFI values from non-stimulated carcasses and family 80, sired by 551G, had the lowest ($P < 0.05$) MFI value (Table 52). Within the same sire, 551G, Family 76 had the lowest ($P < 0.05$) WBS value from electrically stimulated carcasses illustrating that the meat from these carcasses would be the most tender. Family 81, sired by 437J had the highest ($P < 0.05$) WBS value from electrically stimulated carcasses, indicating that meat from these carcasses would be the toughest. Sired by 432H, family 73 had the highest ($P < 0.05$) WBS value from non-stimulated carcasses. Family 83, sired by 437J, had the lowest ($P < 0.05$) WBS value from non-stimulated carcasses. When comparing the non-stimulated sides with the electrically stimulated sides, all shear values decreased and the ranking of tenderness among the families changed as well. Many carcasses that were on the "tough end" were rearranged and after stimulation were on the more "tender end" of the list. For the pairs of sides, the standard error was smaller for most of the electrically stimulated carcasses as well indicating a decrease in variation. Riley, Savell, Smith, and Shelton (1980) and Savell, Smith, and Carpenter (1978) reported that electrical stimulation increases tenderness and decreases WBS values in lamb and beef.

Table 50
Least squares means ± standard errors for MFI[a] by contemporary group

Group	MFI ES[b]
1	--
2	--
3	114.07[c] ± 3.87
4	120.06[cd] ± 14.25
5	139.03[d] ± 3.42
6	121.96[cd] ± 6.53
P-value	0.0460

[a] MFI = Myofibrillar fragmentation index.
[b] ES = electrically stimulated; NON = non-electrically stimulated.
Within a column, means lacking a common letter (c-f) differ (*P* < 0.05).

Table 51
Least squares means ± standard errors for MFI[a] by sire

Sire	MFI ES[b]	MFI NON[b]
297J	128.04[d] ± 5.16	125.26[d] ± 5.45
432H	133.76[d] ± 5.68	131.25[d] ± 5.97
437J	117.14[c] ± 5.03	125.36[d] ± 5.05
551G	116.18[c] ± 5.22	111.21[c] ± 5.33
P-value	0.0057	0.0184

[a] MFI = Myofibrillar fragmentation index.
[b] ES = electrically stimulated; NON = non-electrically stimulated.
Within a column, means lacking a common letter (c-d) differ (*P* < 0.05).

Table 52
Least squares means ± standard errors for MFI[a], and WBS[b] by family (sire)

Sire Family	MFI NON[c]	WBS ES[c] (N)	WBS NON[c] (N)
297J			
70	122.35[efg] ± 8.60	27.65[ef] ± 1.61	34.41[def] ± 2.80
71	113.13[def] ± 7.57	27.93[ef] ± 1.53	38.22[efg] ± 2.64
95	140.30[g] ± 7.91	26.77[def] ± 1.78	36.90[efg] ± 3.12
432H			
72	112.55[def] ± 7.56	26.94[ef] ± 1.48	35.10[ef] ± 2.58
73	--	25.07[def] ± 2.80	48.41[g] ± 4.93
82	127.55[efg] ± 11.26	23.86[de] ± 2.60	28.15[de] ± 4.59
96	153.64[g] ± 7.70	27.79[ef] ± 1.49	29.29[de] ± 2.59
437J			
74	--	27.83[ef] ± 3.14	32.25[def] ± 5.55
75	129.77[fg] ± 10.5	23.73[de] ± 2.03	30.35[de] ± 3.36
81	113.26[def] ± 6.25	30.35[f] ± 1.37	34.91[ef] ± 2.37
83	128.55[fg] ± 8.12	25.24[def] ± 1.86	27.65[d] ± 3.27
97	129.86[fg] ± 7.59	30.16[f] ± 1.67	33.37[def] ± 2.91
551G			
76	--	19.10[d] ± 3.42	41.43[fg] ± 6.04
77	112.62[def] ± 8.77	27.78[ef] ± 1.60	38.25[efg] ± 2.79
80	99.93[d] ± 7.63	27.22[ef] ± 1.55	40.62[fg] ± 2.52
84	101.65[de] ± 7.63	25.11[def] ± 1.92	37.65[efg] ± 3.14
98	130.65[fg] ± 12.51	27.11[ef] ± 2.28	31.56[def] ± 4.02
P-value	0.0008	0.0426	0.0494

[a] MFI = Myofibrillar fragmentation index.
[b] WBS = Warner Bratzler Shear Force.
[c] ES = electrically stimulated; NON = non-electrically stimulated.
Within a column, means lacking a common letter (d-g) differ ($P < 0.05$).

Slaughter day within contemporary group was significant for variation in CIE L*, a*, b* values from electrically stimulated carcasses (Tables 53-55). This could be due to slaughter or cooler conditions affecting the color of the meat at the time of harvest. Sire and slaughter day within contemporary group accounted for variation in CIE L* values from non-electrically stimulated carcasses (Table 56). Because there is no stimulation masking the color effect, there appears to be some contribution by sire to the lightness value (L*). Slaughter day within contemporary group accounted for variation in CIE a* value (Table 57). Table 58 displays CIE b* value fixed effects and shows that contemporary group and slaughter day within contemporary group accounted for some of the variation in this color value.

Table 53
CIE L* value (from electrically stimulated carcasses) fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.87	0.4825
Sire	2.36	0.0735
Family(Sire)	0.71	0.7438
Slaughter day(Contemporary group)	16.64	<0.0001
Age(Contemporary group)	0.64	0.6703

Table 54
CIE a* value (from electrically stimulated carcasses) fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.33	0.8564
Sire	1.55	0.2034
Family(Sire)	1.08	0.3840
Slaughter day(Contemporary group)	8.24	<0.0001
Age(Contemporary group)	0.44	0.8211

Table 55
CIE b* value (from electrically stimulated carcasses) fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.14	0.9673
Sire	1.82	0.1454
Family(Sire)	1.08	0.3774
Slaughter day(Contemporary group)	10.73	<0.0001
Age(Contemporary group)	0.19	0.9669

Table 56
CIE L* value (from non-electrically stimulated carcasses) fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.51	0.7249
Sire	3.06	0.0297
Family(Sire)	1.31	0.2189
Slaughter day(Contemporary group)	10.14	<0.0001
Age(Contemporary group)	1.19	0.3149

Table 57
CIE a* value (from non-electrically stimulated carcasses) fixed effects

Effect	F Value	*P*-Value
Contemporary group	1.93	0.1071
Sire	1.97	0.1204
Family(Sire)	0.73	0.7182
Slaughter day(Contemporary group)	7.51	<0.0001
Age(Contemporary group)	1.46	0.2064

Table 58
CIE b* value (from non-electrically stimulated carcasses) fixed effects

Effect	F Value	*P*-Value
Contemporary group	2.43	0.0499
Sire	2.19	0.0910
Family(Sire)	1.44	0.1509
Slaughter day(Contemporary group)	7.31	<0.0001
Age(Contemporary group)	1.87	0.1027

CIE L* least squares means from non-stimulated carcasses stratified by sire are shown in Table 59. Steers sired by 432H had the highest ($P < 0.05$) L* value indicating the lightest color. Table 60 shows the least squares means for b* color value from non-stimulated carcasses by contemporary group. Contemporary group 1 had the lowest ($P < 0.05$) b* value and 2 had the highest ($P < 0.05$) b* value. Because this difference was found between contemporary groups, environmental effects, for example, chilling conditions, stress during larriage, or other differences due to slaughter personnel or conditions, would be expected to play a role in this color variation.

Table 59
Least squares means ± standard errors for CIE L* values[a] by sire

Sire	L* NON
297J	38.04[b] ± 0.72
432H	40.88[c] ± 0.82
437J	38.89[b] ± 0.71
551G	39.01[b] ± 0.68
P-value	0.0297

[a] ES = electrically stimulated; NON = non-electrically stimulated.

Table 60
Least squares means ± standard errors for CIE b* values[a] by contemporary group

Group	b* NON
1	16.66[b] ± 0.59
2	25.88[d] ± 0.74
3	21.08[c] ± 0.57
4	20.84[c] ± 1.65
5	25.16[d] ± 0.51
6	--
P-value	0.0499

[a] ES = electrically stimulated; NON = non-electrically stimulated.

Table 61
Dissected *M. longissimus thoracis* percentage fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.42	0.8324
Sire	5.96	0.0007
Family(Sire)	1.61	0.0847
Slaughter day(Contemporary group)	1.58	0.0736
Age(Contemporary group)	0.46	0.8387

Table 62
Dissected external fat percentage fixed effects

Effect	F Value	*P*-Value
Contemporary group	1.14	0.3413
Sire	3.84	0.0107
Family(Sire)	2.92	0.0007
Slaughter day(Contemporary group)	1.03	0.4246
Age(Contemporary group)	1.13	0.3447

Table 63
Dissected seam fat percentage fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.57	0.7251
Sire	2.42	0.0675
Family(Sire)	0.83	0.6301
Slaughter day(Contemporary group)	0.64	0.8530
Age(Contemporary group)	0.44	0.8516

Table 64
Dissected channel fat percentage fixed effects

Effect	F Value	*P*-Value
Contemporary group	1.68	0.1424
Sire	0.56	0.6420
Family(Sire)	1.51	0.1155
Slaughter day(Contemporary group)	1.16	0.3026
Age(Contemporary group)	1.55	0.1648

Table 65
Dissected total fat percentage fixed effects

Effect	F Value	*P*-Value
Contemporary group	1.09	0.3676
Sire	3.41	0.0187
Family(Sire)	1.18	0.2940
Slaughter day(Contemporary group)	0.83	0.6621
Age(Contemporary group)	0.93	0.4740

Table 66
Dissected lean trim percentage fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.62	0.6843
Sire	3.74	0.0121
Family(Sire)	1.70	0.0643
Slaughter day(Contemporary group)	1.17	0.2963
Age(Contemporary group)	0.74	0.6176

Table 67
Dissected bone percentage fixed effects

Effect	F Value	*P*-Value
Contemporary group	1.92	0.0935
Sire	3.11	0.0277
Family(Sire)	0.91	0.5437
Slaughter day(Contemporary group)	0.88	0.5933
Age(Contemporary group)	1.69	0.1254

Dissected *M. longissimus thoracis* percentage fixed effects are shown in Table 61, and sire had a significant effect on the percentage. Sire and family nested within sire accounted for variation in dissected external fat percentage (Table 62). Fixed effects for dissected seam and channel fat are shown in Tables 63 and 64. None of the variables evaluated were found to contribute to variation in these. Sire had a significant effect on dissected total fat, lean trim, and bone percentage (Tables 65-67).

Least squares means and standard errors for dissection components stratified by sire are shown in Table 68. Sire 437J produced steers with the highest ($P < 0.05$) percentage of *M. longissimus thoracis* and the lowest ($P < 0.05$) percentage of external fat and total fat. Steers sired by 551G had the lowest ($P < 0.05$) percentage of lean trim and the highest ($P < 0.05$) percentage of bone. Least squares means and standard errors for dissected external fat percentage by family nested within sire are presented in Table 69. Family 74, sired by 437J, produced steers with the lowest ($P < 0.05$) external fat percentage and family 77, sired by 551G, had the highest ($P < 0.05$) external fat percentage.

Table 68

Least squares means ± standard errors for dissection components (%) by sire

Sire	LD[a]	External fat	Total fat	Lean trim	Bone
297J	17.59[b] ± 0.45	12.63[c] ± 0.57	36.79[c] ± 1.04	29.28[c] ± 0.60	15.72[b] ± 0.44
432H	18.74[bc] ± 0.50	11.14[bc] ± 0.63	36.84[c] ± 1.14	28.12[bc] ± 0.66	15.67[b] ± 0.48
437J	19.82[c] ± 0.46	10.49[b] ± 0.59	33.42[b] ± 1.06	29.37[c] ± 0.62	16.76[bc] ± 0.45
551G	17.94[b] ± 0.44	12.36[c] ± 0.55	37.26[c] ± 1.00	27.06[b] ± 0.58	17.02[c] ± 0.42
P-value	0.0007	0.0107	0.0187	0.0121	0.0277

[a] LD = *M. longissimus dorsi.*

Within a column, means lacking a common letter (b-c) differ ($P < 0.05$).

Table 69
Least squares means ± standard errors for dissected external fat (%) by family (sire)

Sire Family	External fat
297J	
70	$12.34^{bc} \pm 0.87$
71	$11.44^{abc} \pm 0.82$
95	$14.11^{cd} \pm 0.97$
432H	
72	$10.82^{ab} \pm 0.82$
73	$10.30^{ab} \pm 1.53$
82	$12.43^{bc} \pm 1.42$
96	$11.03^{ab} \pm 0.81$
437J	
74	$8.13^{a} \pm 1.72$
75	$11.45^{abc} \pm 1.04$
81	$10.13^{b} \pm 0.73$
83	$10.70^{ab} \pm 1.01$
97	$12.04^{bc} \pm 0.90$
551G	
76	$11.23^{abc} \pm 1.87$
77	$15.82^{d} \pm 0.87$
80	$11.97^{bc} \pm 0.78$
84	$9.91^{ab} \pm 0.98$
98	$12.86^{bc} \pm 1.25$
P-value	0.0007

Within a column, means lacking a common letter (b-d) differ ($P < 0.05$).

None of the fixed effects for proximate analysis moisture and fat were significant (Tables 70 and 71). Sire and slaughter day within contemporary group were found to account for variation in proximate analysis protein (Table 72). Contemporary group and the regression of age within contemporary group were found to be significant for proximate analysis ash (Table 73). Least squares means for proximate analysis protein values stratified by sire are shown in Table 74. Steers sired by 437J had the highest ($P < 0.05$) protein percentage. Table 75 displays least squares means for proximate analysis ash values by contemporary group. Contemporary group 4 had the lowest ($P < 0.05$) percentage of ash.

Table 70
Proximate analysis moisture percentage fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.51	0.7720
Sire	0.53	0.6603
Family(Sire)	1.14	0.3276
Slaughter day(Contemporary group)	1.17	0.2962
Age(Contemporary group)	0.41	0.8743

Table 71
Proximate analysis fat percentage fixed effects

Effect	F Value	*P*-Value
Contemporary group	0.63	0.6758
Sire	1.10	0.3513
Family(Sire)	1.14	0.3276
Slaughter day(Contemporary group)	1.53	0.0870
Age(Contemporary group)	0.53	0.7830

Table 72
Proximate analysis protein percentage fixed effects

Effect	F Value	*P*-Value
Contemporary group	1.03	0.3989
Sire	3.28	0.0219
Family(Sire)	1.46	0.1356
Slaughter day(Contemporary group)	1.69	0.0475
Age(Contemporary group)	1.13	0.3444

Table 73
Proximate analysis ash percentage fixed effects

Effect	F Value	*P*-Value
Contemporary group	2.60	0.0269
Sire	0.60	0.6138
Family(Sire)	0.82	0.6337
Slaughter day(Contemporary group)	0.40	0.9841
Age(Contemporary group)	2.64	0.0176

Table 74
Least squares means ± standard errors for proximate analysis protein values (%) by sire

Sire	Protein
297J	$12.35^{a} \pm 0.28$
432H	$12.55^{a} \pm 0.31$
437J	$13.40^{b} \pm 0.29$
551G	$12.62^{a} \pm 0.27$
P-value	0.0219

Within a column, means lacking a common letter (a-b) differ ($P < 0.05$).

Table 75
Least squares means ± standard errors for proximate analysis ash values (%) by contemporary groups

Group	Ash
1	$1.93^{b} \pm 0.19$
2	$1.54^{ab} \pm 0.23$
3	$1.17^{a} \pm 0.19$
4	$0.63^{a} \pm 0.48$
5	$1.70^{b} \pm 0.17$
6	$0.68^{a} \pm 0.26$
P-value	0.0269

Within a column, means lacking a common letter (a-b) differ ($P < 0.05$).

CHAPTER V

SUMMARY

Many meat quality, USDA quality and yield grade factors were correlated with weaning temperament scores. As the temperament scores increased (poor temperament), several meat quality factors decreased. Fat thickness, weight, and marbling all decreased as temperament scores got worse. No correlation was found between WBS values and weaning temperament traits. Quality grade, live weight, and hot carcass weight were shown to decrease as yearling temperament score increased. Yearling gregariousness was positively correlated with WBS from both the stimulated and non-stimulated sides, indicating that as temperament score increased, so did the shear value demonstrating an increase in toughness.

Many contemporary group, sire, and family(sire) differences were found among meat quality traits. Because the distribution of families and sires within contemporary groups were fairly even, one would expect differences between groups to be caused by environmental factors. Steer from contemporary group 1 had the lowest MFI value and the highest ash percentage. Steers from contemporary group 2 and 6 had the highest MFI values. The largest ribeye area and the lowest ash percentage were from steers from contemporary group 4. Contemporary group 5 had steers with the smallest ribeye area, but again, these were fed the shortest length of all groups.

Sire 297J had steers with the lowest (calmest) weaning and yearling temperament scores, the most 12th rib fat thickness, adjusted fat thickness, highest numerical yield grade, and the heaviest live weights. These data are supported by other studies as others have reported that cattle with calm temperaments tend to be heavier and put on more fat. Steers sired by 432H had the most youthful lean, skeletal, and overall maturity, the highest USDA quality grade (Choice 09), largest ribeye area, the highest dressing percentage, highest MFI values from both electrically stimulated and non-stimulated carcasses, and the highest L* value, indicating that these steers would have the lightest lean color. Steers with the highest (poorest) weaning and yearling overall temperament scores, least fat thickness and adjusted fat thickness, lowest USDA yield grade, the lowest percentage of dissectible external and total fat, and the highest percentage of protein were sired by 437J. Sire 551G produced steers with the lowest quality grade, Select 77, smallest ribeye area, the lightest live weight, lightest hot carcass weight, lowest MFI values, lowest percentage of lean trim, and the highest percentage of bone.

Differences due to family nested sire were supportive of the data found for sires. Family 71, sired by 297J, had the lowest (calmest) weaning and yearling overall temperament scores and the heaviest live weight, supporting previous data reported. Family 72, sired by 432H, had the most youthful lean maturity and the highest USDA quality grade. Family 82, sired by 432H, had steers with the largest ribeye area and heaviest hot carcass weight, but this is confounded with contemporary group because all animals were in one contemporary group that was fed for one of the longest feeding times. Family 96, sired by 432H, had the highest MFI value from non-electrically stimulated carcasses. Steers from family 73, also sired by 432H, had the highest Warner-Bratzler shear value from non-stimulated carcasses. Steers from family 74, sired by 437J, had the highest weaning and yearling overall temperament scores, indicating a poor temperament, and also displayed the least fat thickness, least adjusted fat thickness, lightest live and carcass weights, and the lowest percentage of dissected external fat percentage. Family 81, sired by 437J, had steers with a high overall weaning and yearling temperament score and the highest WBS value from electrically stimulated carcasses. Also sired by 437J, family 83 produced steers with the lowest Warner-Bratzler shear force values from non-stimulated carcasses. Steers from family 76, sired by 551G, had the most advance lean maturity, the smallest ribeye area, and the lowest Warner-Bratzler shear force values from electrically stimulated carcasses. Family 77, sired by 551G, had steers with the most fat thickness, adjusted fat thickness, and the highest external fat percentage. Also sired by 551G, family 80 had steers with the lowest MFI value from non-stimulated carcasses. Family 84, sired by 551G, had the lowest USDA quality grade.

Many differences were found between contemporary groups, sires and families. Many of the cattle that possessed high (poor) temperament scores also had light live and carcass weights and small fat thicknesses, as well as lower degrees of marbling and USDA quality grades than those with calmer temperaments. The trend for cattle with calm temperaments seemed to be for the animals and carcasses to be heavier in weight and have more fat, both subcutaneous and intramuscular. Electrical stimulation also proved to decrease Warner-Bratzler shear force values and reduce variation in tenderness.

These data, indicate that there is a relationship between temperament and meat quality traits among sires and families. More research is needed to determine this relationship, but this population demonstrates variation and should prove to be useful for QTL mapping.

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