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Genetic (co) variance for growth and tenderness related traits in purebred Brahman steers

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GENETIC (CO) VARIANCE FOR GROWTH AND TENDERNESS RELATED TRAITS IN PUREBRED BRAHMAN STEERS

A Thesis

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Master of Science

in

The Interdepartmental Program of Animal and Dairy Sciences

by

Joshua Dean Domingue
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Abstract

Paternal half-sib groups of Brahman bull calves were purchased at weaning from purebred Brahman producers in Louisiana. Following backgrounding and grazing on ryegrass the steers shipped to a commercial feedlot in south Texas. Steers were slaughtered in groups when they reached an approximate average endpoint weight of 535 kg and 10mm backfat. After a 24 hr chill, carcasses were ribbed, data collected, and a longissimus muscle sample taken for calpastatin assay. Two 2.54 cm thick steaks were randomly removed from the large end of the strip loin, vacuum packaged, and randomly selected for 7 and 14 days of aging. Genetic correlations and heritabilities were calculated with an animal model using MTDFREML. The means were 1.49 kg/d, 336.4kg for USDA yield grade, 58.7 cm² for ribeye area, 0.87 cm for fat thickness, 2.12 for percent kph, 2.34 for USDA yield grade, and 390.3 for marbling score which equals a high select USDA quality grade. Other means were 10.60 and 10.59 for purge loss after 7 and 14 days aging, 21.07 and 21.56 for percent cooking loss, 4.57 and 3.85 kg for shear force after 7 and 14 days aging. Factors influencing shear force were marbling score, purge loss after 7 day aging, purge loss after 14 day aging, cook loss after 7 day aging, cook loss after 14 day aging, and calpastatin. Heritabilities for growth and carcass traits were similar to those of non-Brahman cattle. Heritabilities for cooking traits were low. Tenderness as affected by moisture loss during the thawing and cooking process needs to be studied further.
Chapter I

Introduction

Brahman breeding is incorporated into most commercial cow-calf operations in the southern United States to take advantage of hybrid vigor. The advantages of the Brahman breed are predominantly adaptability, heat tolerance, and disease and parasite resistance as straightbreds, as well as growth rate and reproductive efficiency when used in crossbreeding. Producers in this region use varying degrees of Brahman breeding in their programs. Thus, Brahman influenced calves are being marketed through all segments of the beef industry.

The major concern facing the beef industry over the past several years has been the lack of consistency at the consumer level (Brooks et al. 2000). The current USDA quality grading system uses skeletal maturity and marbling to sort carcasses into their respective grades. The problem with this is the weak relationship that has been shown between marbling and tenderness (Marshall, 1994). Wheeler et al. (1994) reported that marbling accounts for approximately 5% of the variation in palatability traits and there were both tough and tender carcasses within each USDA quality grade. This suggests that the current quality grading system is not effective in segregating carcasses based on palatability.

Tenderness is a critical aspect of palatability and there are several factors that affect it and several more that are used to enhance it (Savell et al., 1999). Cross et al. (1976) reported that cooking influenced beef tenderness. The method of cooking, duration of cooking time, degree of doneness, and final internal temperature all affect beef tenderness. Akinwunmi et al. (1993) reported that steaks became increasingly tougher and less juicy with increased internal temperature. There seems to be a common assumption among scientists and consumers alike that steaks that loose more fluids during thawing and cooking are tougher. However, little literature is available on moisture loss of beef steaks during thawing and cooking.
Consumers ranked tenderness as the number one problem with consistency in beef in the 1995 Beef Audit. The fact that tenderness plays such an integral part in palatability has prompted researchers to study tenderness and the factors that affect it extensively. Koohmaraie et al. (1995) reported that among cattle of all breeds, approximately 46 percent of the variation in tenderness is genetic and 54 percent is environmental. This means that substantial improvement can be make in tenderness by more effectively applying the environmental factors that affect tenderness and continuing to evaluate and study these factors. The environmental factors that are most commonly used are time on feed, type of diet, stress, carcass chilling rate, cooking method, postmortem aging time, and electrical stimulation. The remaining variation is genetic and can be improved through selection. Selection can be within breed where animals of certain lines are identified and utilized to improve the quality of that particular breed. It can also be among breeds where producers would use certain breeds that are well known to enhance palatability traits.

The climate in the southeastern United State of high annual rainfall, high heat, and high humidity puts cattle producers in this region in an awkward situation. They need to use Brahman cattle for their adaptability, heat tolerance, growth, and fertility, but not for their carcasses traits. Brahman and Brahman influenced cattle are perceived to be tougher than *Bos taurus* breeds. Smith et al. (1998) reported that Brahman cross steers received $1.95 to $5.91 less per hundred weight than non-Brahman steers. Crouse et al. (1993) reported that beef from Brahman cross cattle are tougher than many *Bos taurus* breeds. Furthermore, higher percentage Brahman cattle are tougher than those with a lower percentage of Brahman cattle (Johnson et al., 1990). Even though Brahman cattle are tougher relative to the other breeds, there are individuals in the population that are above average for tenderness and marbling. Studies of *Bos indicus* crossbred cattle have reported moderate heritabilities for tenderness (Elzo et al., 1998), indicating that tenderness would be responsive to selection and within
breed improvement could be accomplished. Consequently, identification of Brahman sires or lines of breeding superior for carcass characteristics, especially marbling and tenderness, could increase tenderness and marbling in the Brahman Breed. The objectives of this research were to: 1) Estimate genetic parameters for shear force, purge and cooking loss, and other carcass traits. 2) Estimate genetic (co)variances among tenderness and carcass traits and calculate genetic correlations. 3) Evaluate the influences of growth and carcass traits on variation in tenderness after aging steaks for 7 and 14 d.
Chapter II
Review of Literature

Introduction

The most commonly represented segment of the beef industry in the Gulf Coast region is the cow-calf production system. Predominately, crossbreeding mating systems are used and because of hot humid summer conditions, the incorporation of Brahman germ plasm is required. This allows producers to take advantage of the added production and reproductive efficiency of crossing Brahman with either British or Continental cattle. These crosses produce progeny that are better acclimated to the environment in this region of the US. Therefore, the majority of cattle produced in this region contain some degree of Brahman inheritance. These cattle go through all phases of the industry starting with the cow-calf and ending with the consumer. Producers have received discounts for these cattle whether they market their animals at the local auction barn, through an order buyer, feedlot, or the packer (Smith et al. 1998). This price discrimination can be attributed to less desirable yield grades, USDA carcass quality grades, and measures of tenderness that are often perceived to be associated with Brahman inheritance. This puts a burden on the producer as they are more efficient by incorporating the Brahman cross cow into his herd but then they get discounted for the Brahman influence in their steer calves. For the Brahman breed to maintain a share of the market, sires must be identified that will inject growth, reproductive efficiency, and most importantly carcass quality into their progeny.

Consumers perceive tenderness to be the most important determinant in eating satisfaction. This is a problem for Brahman breeders and commercial producers who use Brahman genetics. Researchers have reported that as percentage of *Bos indicus* breeding increases, the level of tenderness decreases and the variability in tenderness increases (Damon et al., 1960; Carpenter et al., 1961; Peacock et al., 1982).

Tenderness is the most important component of beef palatability and there are several
other factors that also influence palatability. Such factors as beef flavor, amount of connective tissue, and juiciness affect eating satisfaction. Besides genetics, the method of cooking, duration of cooking time and degree of doneness also play a role in tenderness. Akinwunmi et al. (1993) reported that steaks became tougher and less juicy with increased internal temperature. It seems to be a common assumption among scientists and consumers alike that steaks that lose more water during the thawing and cooking process are tougher. However, there is little literature available to support the idea that the amount of moisture loss during the thawing and cooking process has an effect on tenderness.

**Longissimus Muscle Area**

Cross-sectional area of the longissimus muscle (ribeye area) is used to measure muscling in beef cattle. It is measured in cm² at the 12-13th rib interface, and is the only measure of muscularity used to calculate USDA yield grade. This makes it a valuable criterion for evaluating carcasses. Longissimus muscle area can also be expressed as a ratio to a unit of carcass weight.

Comerford et al (1988) found that at a constant slaughter age, Brahman cross steers ribeye area was 10 cm² smaller than those of Limousin- and Simmental-cross steers, but the Brahman-cross steers also had smaller carcasses. Similarly, Crockett et al. (1979) reported Brahman and Brahman-derivative sires produced steers with smaller ribeye areas than Maine-Anjou, Limousin, and Simmental sired steers. Also, Young et al. (1978) reported similar findings. Brahman sired steers had the smallest ribeye areas among Angus-, Hereford-, and Devon-sired steers when the trait was adjusted to a 279 kg carcass weight.

Several studies have found little difference between *Bos taurus* and *Bos indicus* breeds for ribeye area. Crouse et al. (1993) reported that percentage of Brahman had no consistent effect on ribeye area. Similarly, Herring et al. (1996) found no difference in ribeye area due to sire or dam breed from Brahman-sired steers. Koch et al. (1982) found Brahman and Sahiwal sired steers were similar in longissimus muscle area. DeRouen et al. (1992) reported among
straightbreds, Brahman-sired steers were similar to Hereford-sired steers. In another study, Paschal et al. (1995) compared growth and carcass characteristics of Angus-, Gray Brahman-, Gir-, Indu-Brazil-, Nellore-, and Red Brahman-sired F1 steers. They reported no significant differences in longissimus muscle area for these breeds when adjusted for slaughter age, although the Indu-Brazil-, Gir-, and Red Brahman-crosses tended to have larger ribeye areas than the Nellore- and Gray Brahman-crosses.

The majority of researchers have reported heritability estimates for ribeye area to be in the moderate to high range. The estimates reported by Koch et al. (1982), Van Vleck et al. (1992), and Veseth et al. (1993), ranged from 0.40 to 0.60. Likewise, Riley et al. (2002) reported a 0.44 heritability estimate in straight-bred Brahman steers for ribeye area. Lamb et al. (1990), Wilson et al. (1993), and Gregory et al. (1995) reported lower heritability estimates of 0.22 to 0.32.

Marshall (1994) summarized age-constant genetic correlations among carcass traits and indicated that selecting for reduced fat thickness would be comparable to selecting for larger longissimus muscle area and therefore increased cutability. Phenotypic correlations of ribeye area with fat thickness were small and negative as reported by Lamb et al. (1990), and Wilson et al. (1993) with values of -0.04 and -0.06, respectively. However, Koch et al. (1982) reported a genetic correlation of -0.44 between longissimus muscle area and fat thickness in Bos taurus cattle. Genetic correlations among ribeye area and marbling score were negative, ranging from -0.04 to -0.40 in studies by Koch et al. (1982), Wilson et al. (1993), and Van Vleck (1992). However, Lamb et al. (1990) and Veseth et al. (1993) reported strong positive correlations of 0.48, 0.51 and 0.57, respectively. Riley et al. (2002) reported a similar correlation of 0.44 in straight-bred Brahman steers. Moderately negative genetic correlations between ribeye area and Warner-Battler shear force were reported by Koch et al. (1982) and Van Vleck et al. (1992), indicating a favorable relationship between larger ribeye area and tenderness.
Fat Thickness

Fat thickness influences USDA yield grade, is measured at the 12th rib and is an indicator of market readiness. Animals that have a higher fat thickness will also have a higher numerical yield grade. This means they will require more fat trim and will yield less red meat. Therefore, fat thickness is an important indicator of cutability in a beef carcass.

Luckett et al. (1975) compared 260 straight-bred and crossbred steers of Angus, Brahman, Hereford, and Charolais breeding for carcass traits. They concluded that the Brahman steers had significantly less fat at the 12th rib than the average of the remaining straight-bred steers. Herring et al. (1996) compared steers sired by Brahman, Boran, and Tuli and found no significant differences among the breeds. Crouse et al. (1993) compared steers of varying degrees of Brahman inheritance. Their study found that percentage Brahman had no consistent effect on adjusted fat thickness. Still in another study by Peacock et al. (1982), they reported that Brahman breed effects were positive. Average fat thickness was reported as 0.98, 0.64, and 0.42 cm, respectively, for Angus, Brahman and Charolais. Several other researchers have reported that Brahman-sired steers are leaner than those sired by Angus or Hereford (Damon et al. 1960; Koch et al. 1982; Boyles and Riley 1991). Paschal et al. (1995) reported Brahman-sired steers as being intermediate when compared to those sired by Angus, Red Brahman, Indu-Brazil, Nellore, and Gir.

Heritability estimates for fat thickness tend to be variable in the literature. This may be caused by variation in environmental factors such as time on feed, age at slaughter, or slaughtering cattle at a constant fat thickness. Arnold et al. (1991) reported a heritability of 0.49 in a study of 2411 Hereford steers slaughtered at a weight constant end point. Gregory et al. (1995), reporting genetic parameters for purebred and composite steers, found the heritability of fat thickness was 0.25 when steers were slaughtered at an age constant end point. This is similar to findings by Lamb et al. (1990) and Wilson et al. (1993). Koch et al. (1982) reported a heritability estimate of 0.41 for fat thickness. A slightly higher estimate of
0.52 was reported by Benyshek (1981) and by MacNeil et al. (1991). An even higher estimate of 0.68 was given by Koch et al. (1978). Riley et al. (2002) reported a heritability estimate of 0.63 in a study of straight-bred Brahman steers that were fed to a similar fat thickness endpoint of 10mm. Crews and Franke (1998) reported a range of (0.02 to 0.38) for different percentage Brahman groups. The groups with ¼ to ½ Brahman breeding had higher heritability than steers with less than ¼ Brahman or those with more than ½ Brahman influence. The range in the literature appeared to be from 0.1 reported by Shanks et al. (2001) to 0.84 reported by Wheeler et al. (2001). Marshall (1994) found that the average heritability estimate for fat thickness among eight studies was 0.44. He stated that heritability estimates for fat thickness tended to be variable, and were related to the variation in slaughter end point.

Genetic and phenotypic correlations of fat thickness have been generally reported in the literature as moderate with other carcass traits. Fat thickness has been reported by most researchers to have a positive genetic correlation with marbling score. Koch (1978), Koch et al. (1982), and Lamb et al. (1990) found this genetic correlation to be moderate and positive, ranging in magnitude from 0.16 to 0.73. However, Wilson et al. (1993) estimated this correlation to be -0.13. The phenotypic correlations were also positive ranging from 0.12 to .25 (Koch et al. 1982, Lamb et al. 1990, and Wilson et al. 1993). Arnold et al. (1991) reported that reduced fat thickness was associated with larger ribeye area ($r_g = -0.37$) and reduced marbling ($r_g = -0.19$). Koch (1982) found a positive genetic correlation ($r_g = 0.26$) between fat thickness and Warner-Bratzler shear force, indicating an undesirable relationship between fat thickness and tenderness. The phenotypic correlation found by Koch et al. (1982) was near zero ($r_p = -0.01$). Riley et al. (2002) found a similar phenotypic correlation between fat thickness and loin muscle area.

**Marbling Score**

Marbling is important when evaluating beef carcasses as it is a major component in estimating USDA quality grade. USDA quality grades are estimated based on degree of
marbling (intramuscular fat) in the ribeye and skeletal maturity. Marbling is considered the primary indicator of eating quality. There are ten degrees of marbling which are assigned to carcasses. These values are then converted to USDA quality grades which are used to predict eating satisfaction and therefore influence price.

Several studies have shown that Brahman sired steers have less marbling than those sired by other breeds. DeRouen et al. (1992) evaluated 1,494 straightbred and rotational crossbred steers using Angus, Brahman, Charolais, and Hereford sires. They found that Brahman sired steers ranked last for marbling when compared to other sire breeds in the study. A study was conducted by Pringle et al. (1997) using 69 steers of varying percentage Brahman. They reported that as the percentage Brahman increased, marbling score decreased linearly. These results are similar to findings by Crouse et al. (1993) and Huffman et al. (1990) who reported that marbling decreased as percentage Brahman breeding increased.

Marbling score can be influenced by feeding regimen and market endpoint. Cattle are generally fed to a similar weight or fat endpoint. A typical endpoint would be when steers reached approximately 499 – 590 kg and/or 7.6 – 12.7 mm 12th rib fat thickness. Feeding steers to a similar fat endpoint may reduce the amount of variation in marbling. Lopes (1986) fed steers to a fat end point of 1.0 cm and reported no difference in marbling score among Hereford and Brahman-Hereford F-1 steers.

There are several estimates of heritability for marbling score in the literature. Marshall (1994) in a review summarized thirteen estimates for marbling score and reported an average of .35 and a range of 0.23 to 0.47. Riley et al (2002) reported heritability for fat thickness of straight-bred Brahman that was similar to those reported by Marshall (1994). Koch et al. (1981) reported a similar heritability estimate of 0.34. However, lower estimates of heritability were reported by Veseth et al. (1993), Wilson et al. (1993), Lamb et al. (1990), and Woodward et al. (1992) who reported a range of 0.23 to 0.33 for marbling score. Higher estimates were shown by Koch et al. (1982), Benyshek et al. (1982), Van Vleck et al. (1992),
and Gregory et al. (1995) who reported estimates of 0.40 to 0.48. Elzo et al. (1998) reported lower heritabilities of 0.13, 0.19 and 0.23 for ½, ¼ and ⅛ Brahman steers. Crews and Franke (1998) reported a range from 0.09 to 0.37. Estimates for British cattle ranged from 0.26 to 0.35 as reported by Arnold et al. (1991), Verseth et al. (1993), and Wilson et al. (1993). Marbling score heritability from GPE studies at US MARC Germ Plasm Evaluation ranged from 0.4 to 0.71 (Van Vleck et al. 1992, Barkhouse et al., 1996; Wheeler et al., 2001) and estimates from the US MARC Germ Plasm Utilization Project were 0.45 to 0.55 (Gregory et al., 1995). Shackelford et al. (1994) measured actual longissimus intramuscular fat content and reported a heritability of 0.93.

Koch et al. (1982) reported a negative genetic correlation (-0.25) between marbling score and shear force. Marshall (1994) stated that marbling seemed to have a positive, but relatively weak, relationship with palatability. He went on to state that a genetic correlation indicates that selection for increased marbling might be antagonistic to selection for improved cutability and perhaps increased muscling. This does not mean that improvement cannot be made in both traits although, as improvement in one or both traits may be slowed when compared to selection for just one trait.

**Shear Force**

Shear force is an objective measure of the amount of force required to shear a 1.27 cm core sample of cooked meat. It is used as an indicator of meat tenderness and therefore, predicts the potential eating experience that would be attained from a particular steak. The idea of shearing a sample of cooked meat was established in the late 1920's by K. F. Warner and his associates (Warner, 1952). This instrument was later refined by L. J. Bratzler (Bratzler, 1932). The development of the Warner-Bratzler shear device revolutionized the way meat is evaluated by providing researchers an objective means of evaluating cooked meat. This technology remains the most widely used method for measuring meat tenderness (Wheeler et al., 1996).
Tenderness is perceived to be the most important factor involved in providing the consumer with a pleasurable eating experience. Reasons for variation in tenderness are not clearly understood and no commercially applicable device is available to reliably and consistently predict tenderness of an intact carcass. Several studies have shown that breed has a substantial effect on tenderness. It has been clearly shown in the literature that cattle of *Bos indicus* breeding are less tender that those of *Bos taurus* breeding (Koch et al. 1982). Shear force values were higher in purebred Brahman when compared to all other breed types. This is consistent with DeRouen et al. (1992) who reported that Brahman-sired steers ranked last among Angus-, Charolais-, and Hereford-sired steers for shear force. Results from Luckett et al. (1975) also show that Brahman ranked last in shear force when compared to British breeds. Bidner et al. (2002) found no difference among breed groups for shear force at 3 day aging. However, Angus steaks had lower shear force values and higher sensory tenderness scores than steaks from steers sired by Brahman-derivative breeds when aged 10 days. Pringle et al. (1997) reported that shear force after 5 and 14 days of aging was higher for purebred Brahman steers than in all other breed types. Similar results have been shown with crossbred cattle that contain Brahman breeding. O’Connor et al. (1997) found that beef from ⅜ *Bos indicus* cattle aged more slowly and was less tender at 4, 7, 14, 21, and 35 days postmortem than beef from *Bos taurus* cattle. It has even been shown that as percentage of Brahman or *Bos indicus* breeding increases Warner-Bratzler shear force values increase and sensory panel tenderness ratings decrease (Pringle et al., 1997, Shackelford et al., 1994, Johnson et al., 1990, Huffman et al., 1990). Crouse et al. (1993) stated that shear values increased 0.73 kg for each 25 percent increase in Brahman breeding and 1.32 kg for Sahiwal. Koch et al. (1982) found that 14 percent of Brahman and 20 percent of Sahiwal crossbreds fell below the desired tenderness levels, and that *Bos indicus* cattle were more variable in tenderness than *Bos taurus* cattle.

Heritability estimates for tenderness as reported in the literature appear to be low to
moderate. Van Vleck et al. (1992) reported a heritability of 0.09 for tenderness. Gregory et al. (1995) reported a low heritability estimate of 0.12 when measuring tenderness on composite steers. Shackelford et al. (1994) and Koch et al. (1982) reported higher heritability estimates of 0.53 and 0.31, respectively. Marshall (1994) reported that estimates of heritability for tenderness were highly variable in the literature. Summarizing several studies, he reported an average heritability of 0.37 for tenderness.

Warner-Bratzler shear force has a favorable or near zero phenotypic and genetic correlation with other carcass traits. Phenotypic correlations of shear force with marbling score were found to be -0.12 and -0.18 by Koch et al. (1982) and Van Vleck et al. (1992), respectively. They also reported a negative genetic correlation of shear force with ribeye area and marbling score, which would suggest that heavier muscled cattle and those with increased marbling would be more tender. However, they did report an unfavorable positive genetic correlation between fat thickness and Warner-Bratzler shear force. Additionally, Van Vleck et al. (1992) reported a negative genetic correlation of shear force with sensory panel tenderness rating of -0.96. Shackelford et al. (1994) reported that the genetic correlation of calpastatin activity with shear force was 0.59, indicating a strong genetic relationship between the activity of proteolytic inhibition and tenderness.

**Calpastatin**

The rate and extent of postmortem proteolysis determines final tenderness of meat. Shackelford et al. (1994). It is generally accepted that proteolysis of key myofibrillar protein breakdown is primarily responsible for the improved meat tenderness. Results of numerous experiments have indicated that the calpain proteolytic system has a major role and perhaps is mainly responsible for the meat tenderization during postmortem storage. The calpain system, which consists of two calcium-requiring enzymes, \( \mu \)-calpain and m-calpain, and an inhibitor, calpastatin, is believed to be the primary proteolytic enzyme system involved in postmortem tenderization of aged beef as indicated by Koohmaraie et al. (1995). Recent research has
established a relationship between calpastatin and beef tenderness. Calpastatin activity, measured at 24-h postmortem, has been implicated as a cause of beef tenderness differences between *Bos taurus* and *Bos indicus* cattle (Whipple et al. 1990). High calpastatin levels tend to be related with higher shear values while lower levels tend to be related to lower shear force values. Shackelford et al. (1994) suggested that selection for low calpastatin may be especially useful for improving beef tenderness in *Bos indicus* breeds and composites, because of their inherently high calpastatin activities and corresponding tendency to produce less tender beef. Calpastatin activity at 24 hours postmortem, on average, explains about 40 percent of the variation in beef tenderness (Koohmaraie et al. 1995). This indicates that differences in calpastatin activity are related to meat tenderness.

The decreased tenderness associated with *Bos indicus* breeding seems to be highly related to increased calpastatin activity at 24-h postmortem (Whipple et al., 1990, Shackelford et al. 1991). Shackelford et al. (1994) reported that *Bos indicus* steers were tougher and had higher calpastatin levels at 24-h postmortem than other breeds studied. Similar results were found by O’Connor et al. (1997) who evaluated Brahman composite breeds compared to *Bos taurus* composite breeds. They found that the *Bos indicus*-sired steers had higher calpastatin levels, lower panel tenderness rating, and higher shear force values when aged 7, 14, 21 or 35 days. Sixty-nine steers of varying percentage Brahman breeding were evaluated by Pringle et al. (1997) who reported that calpastatin activity increased linearly with increasing percentage Brahman breeding. In addition to indicating a strong positive relationship between percentage Brahman and calpastatin, these authors also reported a strong negative relationship between percentage Brahman inheritance and marbling score.

Shackelford et al. (1994) conducted a study using both *Bos taurus* and *Bos indicus* breeds of cattle and reported a high heritability estimate of 0.65 for calpastatin. He further stated that calpastatin accounted for a significant portion of the genetic variation in shear force measurement. O’Connor et al. (1997) reported a heritability estimate of 0.15 for 24-h
calpastatin activity. Several researchers have evaluated the correlation between calpastatin activity and other carcass traits. Shackelford et al. (1994) reported a phenotypic correlation of 0.27 between calpastatin and shear force. This estimate is lower than the 0.66 correlation reported by Whipple et al. (1990) and 0.39 reported by Shackelford et al. (1991). These studies suggest that lower calpastatin levels are associated with increased beef tenderness. A high genetic correlation between postrigor calpastatin and Warner-Bratzler shear force suggests that it may be possible to improve meat tenderness by selection against calpastatin as reported by Shackelford et al. (1994). A moderate genetic correlation of \( r_g = 0.61 \) was found between 24-h calpastatin and marbling and low genetic correlations with calpastatin and shear force at 7, 14, 35 day aging. Wulf et al. (1996) reported simple correlations between calpastatin and marbling score of -0.19 and calpastatin and shear force of 0.09. Pringle et al. (1997) found that within the calpain proteinase system, \( \mu \)-calpain activity was correlated to tenderness measures; however, calpastatin was not correlated with tenderness, except that calpastatin activity increased incrementally with increasing percentage of Brahman breeding.
Chapter III

Materials and Methods

Introduction

This chapter will describe the characteristics of the data and type of animals used for the research. Management of the cattle both backgrounding and in the feedlot, carcass collection, cooking procedures, the statistical procedures used, and the components of the model will be explained.

Source of Data

Paternal half-sib groups of Brahman bull calves were purchased at weaning from purebred Brahman producers throughout the state of Louisiana. Each producer was notified about the project by a letter explaining the nature of the study and was asked to support the research by contributing calves. The producers were asked to consign a minimum of five calves per sire. For calves to be eligible they had to be born in the spring and weaned in the fall and weigh over 226 kg. Producers were given the average price paid for large framed heavy muscled feeder calves sold at auction markets in Louisiana the week the calves were delivered. Arrangements were made for calves to be transported to the LAES Central Research Station Ben Hur Farm at weaning. Five years of data were available for this study.

In the initial year (1996), 104 Brahman calves were purchased. They represented 23 sires. Of those 104 initial steers, 4 were lost in April 1997 while on rye grass due to lungworm infestation. Three were lost in the feedlot; one to bloat, one to sickness, and one to structural problems. Ninety-seven steers completed the study and were slaughtered for carcass data.

The second year seventy-three calves were attained from 16 sires. One calf was sold in May of 1998 at the local auction market because of unthriftiness. Seventy-two steers completed the study and were slaughtered.

In year three, seventy-four calves were purchased and these calves were by 15 sires.
Three calves were lost in the feedlot. Seventy-one calves were slaughtered.

In year four, 127 calves were attained from Louisiana producers. They represented 31 sires. All calves were shipped to the feedyard. Four calves were lost in the feedlot due to various health problems. One hundred twenty three calves completed the study in this year.

In the final year, producers consigned eighty-nine calves to the study by 21 sires. On November 19th a cold front came through and killed 10 calves. Seventy-nine calves were shipped to King Ranch Feedyard and seventy-four were slaughtered to complete the study.

**Management**

Calves were castrated, dehorned if necessary, given appropriate vaccinations and dewormed within two weeks of arrival. The herd health program was under the direction of the Large Animal Clinic in the School of Veterinary Medicine at Louisiana State University. Each individual calf was ear notched and tagged with an LSU identification number for future use when taking measurements.

After processing, calves were placed on regrowth common bermuda (*Cynodon dactylon*) and dallisgrass (*Paspalum dilatatum*) pastures with access to about four pounds per head per day of a high roughage corn based diet (12 percent protein) and native hay. Ryegrass (*Lolium multiflorum*) became available for grazing in early December. Calves were placed on ryegrass and stocked at approximately 295 to 318 kg of calf per acre. Calves were observed daily for sickness and unsoundness.

The first group of steers was placed on ryegrass December 3, 1996. Steers were implanted with Synovex growth implants and a weight and hip height measurement was taken as the steers went on ryegrass. All steers were weighted every 28 days to monitor growth rate. After a grazing period on ryegrass, a final weight and hip height measurement was taken on May 26th and steers were taken off ryegrass and shipped to King Ranch Feedyard in Kingsville, Texas.

The second group of steers was placed on ryegrass December 10, 1997. Steers were
implanted with Ralgro growth implants and initial weight and hip height was taken at that time. Steers were weighted every 28 days to monitor growth. After 147 days on ryegrass, a final weight and hip height measurement was taken and steers were removed on May 6th and shipped to the King Ranch Feedyard.

The third group of steers was placed on ryegrass December 14, 1998. Steers were implanted with Ralgro growth implants and initial weight and hip height was taken at this time. Steers were weighed every 28 days to monitor growth. After 147 days on ryegrass, a final weight and hip height measurement was taken and steers were removed on May 6th and shipped to the King Ranch Feedyard.

The fourth group of calves was placed on ryegrass November 30, 1999. Steers were implanted with Ralgro growth implants and an initial weight and hip height were taken at this time. Steers were weighed every 28 days to monitor growth. Due to the large number of calves on study, two loads of calves were shipped to the King Ranch Feedlot. After 106 days on ryegrass, a final weight and hip height measurement were taken and the first group of steers was removed on March 15th. The second group was on ryegrass for 157 days and was shipped on April 5th.

The fifth and final group of calves was placed on ryegrass December 19, 2000. Steers were implanted with Ralgro growth implants and an initial weight and hip height measurement were taken at that time. Steers were weighed every 28 days to monitor growth. After 80 days on ryegrass, a final weight and hip height measurement was taken and steers were removed on March 9th and shipped to the King Ranch Feedlot.

**Feedlot and Slaughter**

Steers were implanted upon arrival at the feedlot, were fed as a single group and weighed periodically until slaughter. The steers were fed until they reached approximately 10 mm of 12th rib fat thickness and a slaughter weight near 535 kg, as determined by the feedyard personnel.
The first group of steers went on feed May 28, 1997. The steers were slaughtered in two groups. The first slaughter group consisted of 45 head and was slaughtered on October 28th. The second group consisted of 52 head and was slaughtered on November 20th. This group was on feed for an average of 165 days.

The second group of steers went of feed May 7, 1998. These were also harvested in two groups. The first slaughter group consisted of 41 head and was slaughtered on September 10th. The second group consisted of 31 head and was slaughtered on September 24th. In the second year steers were on feed for an average of 133 days.

The third group of steers went on feed March 29, 1999. The steers were harvested in two groups. The first group consisted of 40 head and was slaughtered on August 19th. The second group consisted of 31 head and was slaughtered on September 8. In the third year steers were on feed for an average of 123 days.

The fourth group of steers was shipped in two separate groups; the first group went on feed March 15, 2000. The second group went on feed April 5th. The steers were harvested in four groups. The first group consisted of 28 head and was slaughtered on July 31st. The second group consisted of 28 head and were slaughtered on August 18th. The third group consisted of 33 head and was slaughtered on September 4th. The final group of 34 steers was slaughtered on September 28th. In the fourth year steers were on feed for an average of 156 days.

The fifth group of steers went on feed March 9, 2001. There steers were harvested in three groups. The first group consisted of 30 head and was slaughtered on August 10th. The second group was made up of 23 head and was slaughtered on September 7th. The third group consisted of 21 head and was slaughtered on September 21st. In the fifth year steers were on feed for an average of 162 days.

All steers were slaughtered at Sam Kane Beef Processors, Corpus Christi, Texas. The average age of slaughter was 545 ± 51 days. All steers were high voltage (over 400 volts)
electrically stimulated during slaughter. Carcass data was recorded at the plant by Dr. Joe Paschal and associates from the Texas A & M Extension Center, Corpus Christi, Texas. A muscle tissue sample (15g) was collected after a 24 hr chill for measurement of clapastatin enzyme. Calpalstatin assays were run at Central Community College, Hastings, Nebraska by Dr. Georgiana Whipple-Van Patter, following the procedures of Whipple et al. (1990) and Shackelford et al. (1994).

**Cooking and Shear Force Measurements**

A wholesale primal loin was obtained from the right side of each carcass and transported (2°C) to the Louisiana State University Agricultural Center Meat Lab. In the first two years of the project, two 2.54 cm steaks were removed and in the third through fifth years, three steaks were removed from the large end of the rib section. All steaks were vacuum-packaged, aged, and frozen. The first two years, steaks were randomly assigned to either 7 day or 14 day aging. For years three through five, steaks were randomly assigned to 7 day, 14 day, or 7 / 7 day aging. In the 7 / 7 day aging process steaks are aged seven days, and then frozen after the steaks are thawed they are aged for an additional seven days prior to cooking. After aging for 7 or 14 days, steaks were then frozen at -20°C until Warner-Bratzler shear force analyses were conducted. Steaks aged for 7 and 14 days were thawed for 24 hours at 2°C prior to cooking. Each steak was individually weighed (bag weight) then blotted dry with a paper towels and weighed again (steak weight). The difference between the two weights was defined as purge loss. A thermocouple was placed in the geometric center of thawed steaks, which were then place on a Farberware Open-Hearth grill (455N, Bronx, NY). Steaks were cooked to 35°C, were then turned and cooked to a final internal temperature of 70°C (AMSA, 1995). The steaks were allowed to cool to room temperature and weighed (cooked weight); the difference between the cooked weight and the steak weight was defined as cooking loss. Cooked steaks were then stored at 2°C for 24 hours at which time six cores were removed parallel to the muscle fiber orientation from each steak. Peak shear force was
measured on each core using a Warner-Bratzler shearing device (crosshead speed = 100 Mm/m) attached to an Instron Universal Testing Machine (Instron Corporation, Canton, MA). The average of the six shears from each steak was used as the shear force value for that steak.

**Statistical Procedures**

The data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) and Multiple Trait Derivative-Free Restricted Maximum Likelihood (MTDFREML). Proc Mixed was used to identify model components. Contemporary group was defined as year and slaughter group. There were 13 contemporary groups in the study. Estimation of the genetic parameters in this model involved partitioning phenotypic covariances between relatives into its components using the degree of relationship between animals. A linear mixed model for one trait can be written as follows:

\[ Y = X\beta + Z\mu + e, \]

where \( Y \) is a vector of observations for a particular trait, \( X \) is the known incidence matrix relating observations to the respective fixed effect, \( \beta \) is a vector of fixed effects (contemporary groups), \( Z \) is a known incidence matrix relating observations to random animal effects; \( \mu \) is a vector of random effects and \( e \) is a vector of residual effects.

Heritabilities were estimated using the animal model with the Multiple Trait Derivative Free Restricted Maximum Likelihood (MTDFREML) software program of Bowman et al. (1995). The full genetic covariance matrix was constructed by entering pedigree information on every animal in the study. Four generations of pedigree information were available for each steer in the project. Heritabilities were estimated using single-trait analyses. Starting values of the genetic and environmental variances for single-trait analyses were estimated using results from the PROC MIXED procedure in SAS (2002). Single-trait analyses were run at low \((10^{-3})\) and later to higher \((10^{-6} \text{ and } 10^{-9})\) levels of convergence.

Genetic correlations were calculated with a two-trait animal model using MTDFREML. Two-trait analyses were run at \(10^{-6}\) and then at \(10^{-9}\) levels of convergence.
Starting values for the program were the values obtained in the single trait analyses.

The influences of several traits on shear force after 7 and 14 d aging of steaks were evaluated with PROC GLM in SAS. The model to evaluate factors influencing shear force after aging of steaks for 7 d included contemporary group, sire of steer, marbling score, purge loss after aging for 7 d, cooking loss after aging for 7 d, and calpastatin. A similar model was run for shear force after aging steaks for 14 d, but purge loss after aging for 14 d and cooking loss after aging for 14 d replaced the values for 7 d aging. Sire was included as a random independent variable in both analyses. Independent variables marbling score, purge loss, cooking loss, and calpastatin activity were included in the models as covariances. Partial regression coefficients were used to determine the change in shear force per unit change in the independent variables described above.
Chapter IV

Results and Discussion

Descriptive Statistics

Means, standard deviations, coefficients of variation, and ranges of all traits are shown in Table 1. Four hundred and thirty steers were studied over a five-year period. The mean for feedlot average daily gain was $1.49 \pm 0.23$ kg/d and ranged from 0.64 to 2.51 kg/d. This mean is larger than the means reported by Crockett et al. (1979), Herring et al. (1996), and Riley et al. (2002). Paschal et al. (1995) reported a higher feedlot average daily gain of 1.60 kg/d. Devillier (2003) reported a mean average daily gain of $1.4 \pm 0.2$ kg/d for 1,491 steers processed through the Louisiana Calf to Carcass program. Wyatt et al. (2002) reported least square mean feedlot average daily gains on Brahman composite breed groups that ranged from 1.12 to 1.30 kg/d with a pooled standard error of 0.07.

The mean hot carcass weight was $336.4 \pm 36.9$ kg and ranged from 196 to 423 kg. This mean is within the range of 227 to 408 kg that the beef industry recommends. Hot carcass weight in this study was higher than the 283.4 kg mean reported by Riley et al. (2002) and the pooled-across-study mean of 291 kg reported by Marshall (1994). A mean hot carcass weight of $346.7 \pm 36.1$ kg on Louisiana steers was reported by Devillier (2003). Bidner et al. (2002) reported hot carcass weights ranging from 313 to 388 kg for Brahman composite groups of steers.

Ribeye area ranged from 58.7 to 109.7 cm² with a mean of $86.0 \pm 8.7$ cm². This mean is larger than the mean of 74.2 cm² for Brahman-sired steers reported by Marshall (1994) and it is close to the estimate that he gave for continental breeds. Riley et al. (2002) reported a lower estimate of 72.5 cm² on purebred Brahman steers and heifers. Bidner et al. (2002)
reported longissimus muscle area means ranging from 70.0 to 86.2 cm$^2$ for Brahman composite breed groups. Devillier (2003) found that Louisiana born steers averaged $84.8 \pm 10.3$ cm$^2$ when fed and harvested in the Oklahoma panhandle.

Table 1. Descriptive statistics for growth, carcass, and tenderness traits of Brahman steers.

<table>
<thead>
<tr>
<th>Trait$^1$</th>
<th>n</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Coefficient of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADG, kg</td>
<td>430</td>
<td>1.49</td>
<td>.23</td>
<td>0.64</td>
<td>2.51</td>
<td>15.4</td>
</tr>
<tr>
<td>HCWT, kg</td>
<td>430</td>
<td>336.4</td>
<td>36.9</td>
<td>195.9</td>
<td>422.7</td>
<td>11.0</td>
</tr>
<tr>
<td>LMA, cm$^2$</td>
<td>430</td>
<td>86.0</td>
<td>8.7</td>
<td>58.7</td>
<td>109.7</td>
<td>10.1</td>
</tr>
<tr>
<td>FT, cm</td>
<td>430</td>
<td>0.87</td>
<td>0.42</td>
<td>0.13</td>
<td>2.80</td>
<td>47.8</td>
</tr>
<tr>
<td>MS, units</td>
<td>430</td>
<td>390.3</td>
<td>61.7</td>
<td>220.0</td>
<td>680.0</td>
<td>15.8</td>
</tr>
<tr>
<td>YG, units</td>
<td>430</td>
<td>2.34</td>
<td>0.68</td>
<td>0.80</td>
<td>4.70</td>
<td>29.1</td>
</tr>
<tr>
<td>KPH, %</td>
<td>430</td>
<td>2.12</td>
<td>0.43</td>
<td>0.50</td>
<td>3.50</td>
<td>20.3</td>
</tr>
<tr>
<td>CALP, units</td>
<td>355</td>
<td>4.51</td>
<td>1.22</td>
<td>1.83</td>
<td>9.16</td>
<td>27.1</td>
</tr>
<tr>
<td>PL7, %</td>
<td>423</td>
<td>10.60</td>
<td>3.35</td>
<td>3.20</td>
<td>28.80</td>
<td>31.6</td>
</tr>
<tr>
<td>PL14, %</td>
<td>426</td>
<td>10.59</td>
<td>3.10</td>
<td>3.00</td>
<td>20.70</td>
<td>29.3</td>
</tr>
<tr>
<td>CL7, %</td>
<td>425</td>
<td>21.07</td>
<td>4.09</td>
<td>5.90</td>
<td>34.70</td>
<td>19.4</td>
</tr>
<tr>
<td>CL14, %</td>
<td>426</td>
<td>21.56</td>
<td>3.94</td>
<td>8.60</td>
<td>42.50</td>
<td>18.3</td>
</tr>
<tr>
<td>SF7, kg</td>
<td>428</td>
<td>4.57</td>
<td>1.21</td>
<td>1.96</td>
<td>9.89</td>
<td>26.5</td>
</tr>
<tr>
<td>SF14, kg</td>
<td>427</td>
<td>3.85</td>
<td>0.86</td>
<td>1.67</td>
<td>7.04</td>
<td>22.2</td>
</tr>
</tbody>
</table>

$^1$ADG=average daily gain, HCWT=hot carcass weight, LMA=longissimus muscle area, FT=fat thickness, MS=marbling score, KPH=kidney, pelvic, and heart fat, CALP=calpastatin, YG=yield grade, PL7=purge loss after 7 d aging, PL14=purge loss after 14 d aging, CL7=cooking loss after 7 d aging, CL14=cooking loss after 14 d aging, SH7=shear force after 7 d aging, SH14=shear force after 14 d aging.
Fat thickness for Brahman steers in this study averaged 0.87 ± 0.42 cm 24 hr postmortem and ranged from 0.13 to 2.80 cm. This mean value is smaller than the mean of 1.3 cm found by Riley et al. (2002) and 11.7 mm reported by Marshall (1994). Devillier (2003) reported an average fat thickness of 1.1 ± 0.5 cm with ranges from 0.1 to 3.1 cm. Bidner et al. (2002) found that fat thickness ranged from 8.6 to 11.1 mm at harvest for groups of Brahman composite steers.

Percent kidney, pelvic, and heart fat averaged 2.12 ± 0.43 with a range of 0.50 to 3.50 percent. These data are consistent with that reported by Riley et al. (2002) who found an estimate of 2.29 percent. Marshall et al. (1994) reported a slightly higher estimate of 2.8 percent.

USDA yield grade averaged 2.34 ± 0.68 and ranged from 0.80 to 4.70. This mean yield grade would be acceptable for most pricing grids in the beef industry. The estimate is lower than the 3.08 reported Riley et al. (2002) and also lower than estimates reported by Crockett et al. (1979), Cundiff et al. (1993), Paschal et al. (1995), and Herring et al. (1996). Bidner et al. (2002) also reported slightly larger estimates of yield grade ranging from 2.7 to 3.3 for Brahman composite steers. Yield grade averaged 2.7 ± 0.8 in Louisiana calves fed and harvested in Oklahoma (Devillier, 2003).

Marbling score is a subjective measurement of the amount of intramuscular fat found in the longissimus muscle at the 12th rib interface. Marbling scores are defined as follows: 200 to 299 - traces of marbling, 300 to 399 - slight marbling, 400 to 499 - small amounts of marbling, 500 to 599 - moderate marbling, and 600 to 699 - modest marbling. Marbling score and maturity are used to determine USDA quality grades. The most common USDA quality grades are Standard, Select, Choice and Prime. A steak with small marbling would be
assigned a USDA choice minus quality grade. Marbling score in these Brahman steers averaged 390.3 with a range of 220 to 680. The mean degree of marbling suggests that on average these steers graded high Select to low Choice, which is target of the beef industry. These data are similar to the estimate of 380 for marbling score reported by Cundiff et al. (1993) for Brahman-sired steers. However, the estimate found in this study is higher than the estimate of 324 for marbling score reported by Riley et al. (2002) on straight bred Brahman steers and heifers. It is lower, however, than the average marbling score of 475 reported by Marshall (1994).

Purge loss was calculated on steaks after thawing before cooking. Average purge losses were 10.60 ± 3.35 and 10.59 ± 3.10 percent, respectively, for 7 and 14 day aged steaks.

Average cooking losses were 21.07 and 21.56 percent, respectively, for steaks aged 7 and 14 day. The range for cooking losses after aging 7 day was 5.90 to 34.70 percent. The range for cooking loss for 14 day aged steaks was 8.60 to 52.50 percent. These means are slightly lower than those reported by Whipple et al. (1990) who evaluated crossbred steers from Hereford, Angus, and Sahiwal sires. Their mean estimates were 26.1, 28.0, and 29.6 percent for H X A, 3/8 SAH, and 5/8 SAH, respectively. Wheeler et al. (1999) reported lower estimates of 3.3 and 18.2 percent for thaw loss and cooking loss, respectively.

The average shear force of after 7 day aging was 4.57 kg with a range of 1.96 to 9.89 kg. The mean for shear force after 14 day aging was 3.85 kg with a range of 1.67 to 7.04 kg. This suggests that aging steaks for 14 day increases tenderness compared to steaks aged for 7 days. The mean shear force for the 14 day aged steaks is close to the 3.63 kg, or 8 lb, which is considered tender. The mean shear force values in this study are considerably lower than mean shear force estimates of 5.58 and 5.27 kg for 7 and 14 day aged steaks reported by Riley.
et al. (2003), and 8.1 kg for Brahman-sired calves reported by Cundiff et al. (1994). However, mean estimates of shear force are similar to that reported by Herring et al. (1996) who reported 3.6 kg for Brahman-sired calves. Several studies have reported that as percentage Brahman inheritance increases tenderness decreases (Damon et al. 1960, Marshall 1994, Pringle et al. 1997). Wheeler et al. (1990) reported that meat from purebred Brahman cattle that was not electrically stimulated was less tender and more variable in tenderness than that from other breed types, but electrical stimulation reduced those differences. O’Connor et al. (1997) reported breed differences in shear force after aging involving Brahman crossbred cattle; means for *Bos taurus* crossbred steers decreased more rapidly and to a lower shear force value with aging than the shear force means for *Bos indicus* crossbred steers. Electrical stimulation may affect amounts of additive genetic variation for shear force. Electrical stimulation has been shown to accelerate proteolytic enzyme activity (Rhee and Kim, 2001). Benefits of electrical stimulation appear to be greater for Brahman or crossbred Brahman cattle than for *Bos taurus* cattle (Ferguson et al., 2000).

**Heritabilities**

Estimated additive, residual, and phenotypic variances and heritabilities for average daily gain, hot carcass weight, longissimus muscle area, 12th rib fat thickness, marbling score, percent kidney, pelvic, and heart fat, USDA yield grade, shear force for 7 day aged steaks, shear force for 14 day aged steaks, purge loss for 7 day aged steaks, purge loss for 14 day aged steaks, cooking loss for 7 day aged steaks, cooking loss for 14 day aged steaks and calpastatin activity are given in Table 2.

The heritability estimate for average daily gain was 0.33 ± 0.13. This estimate is intermediate within the range of heritability estimates of 0.19 to 0.57 reported by Marshall
(1994) in a review paper. This estimate is also consistent with the estimates of 0.19 to 0.44 
reported by Lamb et al. (1990) for Hereford bulls, Shackelford et al. (1994) in crossbred cattle 
from the GPE and GPU study at MARC, and Gregory et al. (1995) for GPU straightbred 
cattle. However, it is less than the estimate of 0.64 reported by Riley et al. (2002) for 
straightbred Brahman steers and heifers fed and slaughtered in Florida.

Table 2. Additive genetic, residual, and phenotypic variances and heritabilities for all traits\(^1\).

<table>
<thead>
<tr>
<th>Trait</th>
<th>Va</th>
<th>Ve</th>
<th>Vp</th>
<th>Heritability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average daily gain</td>
<td>0.013</td>
<td>0.026</td>
<td>0.039</td>
<td>0.33 ± 0.14</td>
</tr>
<tr>
<td>Hot carcass weight</td>
<td>479.3</td>
<td>374.0</td>
<td>853.3</td>
<td>0.56 ± 0.15</td>
</tr>
<tr>
<td>Longissimus muscle area</td>
<td>35.08</td>
<td>33.28</td>
<td>68.36</td>
<td>0.51 ± 0.16</td>
</tr>
<tr>
<td>Fat thickness</td>
<td>0.051</td>
<td>0.085</td>
<td>0.136</td>
<td>0.38 ± 0.18</td>
</tr>
<tr>
<td>Marbling score</td>
<td>1195.4</td>
<td>1970.8</td>
<td>3166.2</td>
<td>0.38 ± 0.15</td>
</tr>
<tr>
<td>Kidney, pelvic, heart fat</td>
<td>0.000</td>
<td>0.167</td>
<td>0.167</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>Yield grade</td>
<td>0.179</td>
<td>0.189</td>
<td>0.368</td>
<td>0.49 ± 0.17</td>
</tr>
<tr>
<td>Shear force at 7 d aging</td>
<td>0.305</td>
<td>0.714</td>
<td>1.019</td>
<td>0.30 ± 0.14</td>
</tr>
<tr>
<td>Shear force at 14 d aging</td>
<td>0.124</td>
<td>0.472</td>
<td>0.596</td>
<td>0.21 ± 0.11</td>
</tr>
<tr>
<td>Cooking loss at 7 d aging</td>
<td>0.000</td>
<td>15.200</td>
<td>15.000</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>Cook loss at 14 d aging</td>
<td>1.878</td>
<td>13.197</td>
<td>15.075</td>
<td>0.12 ± 0.10</td>
</tr>
<tr>
<td>Purge loss at 7 d aging</td>
<td>0.591</td>
<td>4.430</td>
<td>5.021</td>
<td>0.12 ± 0.10</td>
</tr>
<tr>
<td>Purge loss at 14 d aging</td>
<td>0.464</td>
<td>2.510</td>
<td>2.974</td>
<td>0.17 ± 0.13</td>
</tr>
<tr>
<td>Calpastatin</td>
<td>0.369</td>
<td>0.466</td>
<td>0.836</td>
<td>0.44 ± 0.18</td>
</tr>
</tbody>
</table>

\(^1\) Va = additive genetic variance, Ve = residual variance, Vp = phenotypic variance. 
Heritability = Va/Vp.
Components of the USDA yield grade equation most likely have been more heavily researched than other carcass traits. The heritability estimate for hot carcass weight was found to be $0.56 \pm 0.15$. This is similar to the heritability estimate of 0.55 reported by Riley et al. (2002). It is also within the range of heritability estimates reviewed by Marshall (1994); 0.31 to 0.68. Other estimates of heritability on *Bos indicus* cattle come from the study of Elzo et al. (1998) who evaluated straightbred Brahman and cattle with $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{8}$ Brahman inheritance with the other breed fraction being Angus. They reported heritability estimates of 0.39, 0.3, 0.37, and 0.37, respectfully. Crews and Franke (1998) estimated heritabilities within and across three breed groups of steers of differing degrees of Brahman inheritance. The three groups included steers of greater than $\frac{1}{2}$ Brahman, $\frac{1}{4}$ to $\frac{1}{2}$ Brahman, and those with less than $\frac{1}{4}$ Brahman. They reported significant heterogeneity of variance due to the different breed groups for hot carcass weight; however, there was a relatively narrow range for heritability estimates of 0.28 to 0.35 for the three breed groups.

The heritability of longissimus muscle area is estimated to be $0.51 \pm 0.16$ and is in the upper end of the range of heritability estimates (0.01 to 0.60) reported by Marshall (1994). The estimate from this study is also similar to the estimate of 0.53 for Brahman steers and greater than that for percentage Brahman steers (0.32 to 0.34) reported by Elzo et al. (1998). Crews and Franke (1998) reported significant heterogeneity of variance among the different breed groups for longissimus muscle area and a range of 0.40 to 0.75 within and across breed groups.

The 12th rib fat thickness estimate of heritability was $0.38 \pm 0.18$. This results is similar to those reported by Marshall (1994) who found that the average heritability estimate for fat thickness among eight studies was 0.44. Our result is also midway between the range
of heritability estimates of 0.10 reported by Shank et al. (2001) and 0.84 found by Wheeler et al. (2002). This large range of heritability estimates can be attributed to factors such as age at slaughter, time on feed and slaughtering cattle at a constant fat thickness. Arnold et al. (1991) reported a heritability of 0.49 for fat thickness on 2,411 Hereford steers slaughtered at a weight constant end point. Gregory et al. (1995) reporting genetic parameters for purebred and composite steers, found the estimate of heritability of fat thickness to be 0.25 when steers were slaughtered at age constant end points. The heritability estimates for fat thickness reported by Lamb et al. (1990) and Wilson et al. (1993) are similar to the estimate found in the current study. Koch et al. (1982) reported a heritability estimate of 0.41 for fat thickness. A slightly higher estimate of 0.52 was reported by Benyshek (1981) and by MacNeil et al. (1991). An even higher estimate of 0.68 was given by Koch et al. (1978). Riley et al. (2003) reported a heritability estimate of 0.63 in a study of straightbred Brahman steers that were fed to a similar fat thickness end point of 10 mm. Crews and Franke (1998) reported fat thickness heritability estimates ranging from 0.02 to 0.38 for different percentage Brahman groups.

The heritability estimate for marbling score of $0.38 \pm 0.15$ is within the range of estimates (0.23 to 0.47) reported by Marshall (1994) and is close to his average heritability estimate of 0.35. Riley et al (2002) reported a slightly higher heritability of 0.44 for straightbred Brahman steers and heifers. Koch et al. (1982) reported a similar estimate of 0.34. Slightly lower estimates of heritability were reported by Veseth et al. (1993) and Wilson et al. (1993). Their estimates ranged from 0.23 to 0.33. Higher estimates of heritability for marbling score were reported by Koch et al. (1982), Benyshek et al. (1982), Van Vleck et al. (1992), and Gregory et al. (1995). Their estimates ranged from 0.40 to 0.48. Elzo et al. (1998) reported low estimates of heritability of 0.13, 0.19 and 0.23 for $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{8}$ Brahman
steers, respectively. Crews and Franke (1998) reported a range of heritability estimates from 0.09 to 0.37, which is consistent with the present study. Estimates of heritability for British cattle appear to be similar to that of Brahman cattle.

There is considerable variation among the heritability estimates for percent kidney, pelvic and heart fat reported in the literature. The heritability of percent kidney, pelvic, and heart fat for steers in this study was zero. This is because the additive genetic variance for kidney, pelvic and heart fat was zero. Estimates of heritability for kidney, heart, and pelvic fat for Brahman, percentage Brahman, and Angus steers were lower than 0.14 in the study by Elzo et al. (1998). Wheeler et al. (2001) and Veseth et al. (1993) reported heritability estimates of 0.28 and 0.37, respectively, for percent kidney, pelvic, and heart fat. Koch et al. (1982) reported a high estimate of 0.83.

The USDA yield grade heritability estimate of 0.49 ± 0.17 is closest to the range of 0.08 to 0.47 reported by Crews and Franke (1998). It is slightly higher than the estimate of 0.24 given by Lamb et al. (1990). However, it is much smaller than the estimates of 0.71, 0.76, and 0.85, reported respectively, by Riley et al. (2002), Wulf et al. (1996), and Wheeler et al. (2001).

Estimates of heritability for percent purge loss for steaks aged 7 and 14 day was 0.12 ± 0.10 and 0.18 ± 0.13, respectfully. The heritability estimates for cooking loss of steaks aged 7 and 14 day aging were 0.00 and 0.12, respectfully. Again, the additive genetic variance for cooking loss after aging steaks for 7 day was zero. There appears to be no literature available on heritability estimates of these traits to compare to heritability estimates found in this study.

Estimates of heritability for shear force of steaks aged for 7 and 14 day was 0.30 ± 0.14 and 0.21 ± 0.11, respectfully. These estimates are similar to those reported in the
literature for *Bos taurus* cattle, which indicates that *Bos taurus* and *Bos indicus* cattle have similar genetic variation for shear force. Heritability estimates in the current study are consistent with estimates of 0.29 and 0.24 for 7 and 14 day shear force reported by Wheeler et al. (2001). These estimates are also similar to the weighted average of 0.29 reported by Koots et al. (1994) and weighted heritability averages of 0.21 reported by Burrow et al. (2001).

The heritability estimate for calpastatin was 0.44 ± 0.17. This estimate is lower than the estimate of 0.65 reported by Shackelford et al. (1994) who studied both *Bos taurus* and *Bos indicus* breeds of cattle. He further stated that calpastatin accounted for a significant portion of the genetic variation in shear force measurements. These studies would indicate that selection for decreased calpastatin activity could lead to increased tenderness. O'Conner et al. (1997) and Riley et al. (2003) reported lower estimates of heritability for calpastatin activity at 0.15 and 0.07, respectively.

**Genetic Correlations**

Genetic correlations were calculated with a two-trait animal model. Several traits were missing one or more observations across steers. Steers with a missing observation were deleted from the analysis when that trait was analyzed. This allowed the calculations of standard errors for genetic correlations. In this study we were interested in genetic correlations between measures of tenderness, shear force after aging steaks for 7 day and shear force after aging steaks for 14 day, and other traits in the study. Because of small numbers of steers studied on this project standard errors were relatively large.

The genetic correlations between feedlot average daily gain and shear force after steaks were aged 7 and 14 day were -0.21 ± 0.34 and -0.19 ± 0.35, respectfully (Table 3). The negative signs indicate that genes that influence higher average daily gains tend to influence
more tender steaks. Koch et al. (1982) found near zero genetic correlations between shear force and postweaning gain and hot carcass weight. However, Shackelford et al. (1994) reported a genetic correlation between postweaning gain and shear force of -0.44. Similarly, they also reported genetic correlations between hot carcass weight and shear force after aging for 7 and 14 day of -0.42 and -0.19, respectively. This is reasonable since faster gaining cattle within a pen of cattle will tend to have heavier hot carcass weights.

Table 3. Genetic correlations between shear force variables and other growth and carcass variables.

<table>
<thead>
<tr>
<th>Trait</th>
<th>7-d shear force</th>
<th>14-d shear force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average daily gain</td>
<td>-0.21 ± 0.34</td>
<td>-0.19 ± 0.35</td>
</tr>
<tr>
<td>Hot carcass weight</td>
<td>-0.43 ± 0.28</td>
<td>-0.48 ± 0.31</td>
</tr>
<tr>
<td>Fat thickness</td>
<td>-0.81 ± 0.27</td>
<td>-0.36 ± 0.38</td>
</tr>
<tr>
<td>Longissimus muscle area</td>
<td>0.10 ± 0.30</td>
<td>-0.00 ± 0.30</td>
</tr>
<tr>
<td>Marbling score</td>
<td>-0.37 ± 0.29</td>
<td>-0.01 ± 0.36</td>
</tr>
<tr>
<td>Yield grade</td>
<td>-0.85 ± 0.30</td>
<td>-0.66 ± 0.30</td>
</tr>
<tr>
<td>Kidney, pelvic, and heart fat</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>Calpastatin</td>
<td>0.71 ± 0.24</td>
<td>0.66 ± 0.24</td>
</tr>
<tr>
<td>Cooking loss after 7 d aging</td>
<td>0.00 ± 0.00</td>
<td>- -</td>
</tr>
<tr>
<td>Cooking loss after 14 d aging</td>
<td>- -</td>
<td>-0.09 ± 0.44</td>
</tr>
<tr>
<td>Purge loss after 7 d aging</td>
<td>0.00 ± 0.00</td>
<td>- -</td>
</tr>
<tr>
<td>Purge loss after 14 d aging</td>
<td>- -</td>
<td>0.93 ± 0.53</td>
</tr>
<tr>
<td>Shear force after 7 d aging</td>
<td>- -</td>
<td>0.95 ± 0.53</td>
</tr>
</tbody>
</table>

No standard errors could be estimated because of missing values.
Small genetic correlations of 0.10 ± 0.30 and -0.01 ± 0.30 were found between longissimus muscle area and Warner-Bratzler shear force after aging steaks for 7 and 14 day. These estimates are smaller than the moderately negative genetic correlations between longissimus muscle area and shear force reported by Koch et al. (1982) and Van Vleck et al. (1992) that used a similar aging treatment. Standard errors are larger than the genetic correlations.

The genetic correlations between 12th rib fat thickness and 7 day and 14 day shear force were -0.81 ± 0.27 and -0.36 ± 0.38, respectively. Fatter carcasses seem to have an advantage in tenderness in this study. Koch et al. (1982) and Van Vleck et al. (1992) found similar negative genetic correlations between fat thickness and shear force. Van Vleck et al. (1992) also reported a positive genetic correlation of 0.74 between fat thickness and sensory panel tenderness.

High negative genetic correlations of -0.85 ± 0.30 and -0.66 ± 0.30 were found between USDA yield grade and shear force after aging for 7 and 14 day. This would indicate that tenderness increases as cutability decreases. These estimates are larger than the -0.16 reported in a review by Marshall (1994). Pringle et al. (1997) reported that neither USDA yield grade nor any of the carcass traits used to determine yield grade were significantly correlated with shear force. Gregory et al. (1995) reported a genetic correlation of zero for percent retail product and shear force.

The genetic correlations of marbling score with shear force were different for the two aging treatments. The genetic correlation for marbling score and shear force of 7 and 14 day aged steaks were -0.37 ± 0.29 and -0.01 ± 0.36 respectively, indicating greater tenderness with increased marbling. Koch et al. (1982) and Van Vleck et al. (1992) found favorable
genetic correlations between marbling score and shear force of -0.25 and -0.53, respectfully. Shackelford et al. (1994) reported a genetic correlation of -0.57 between marbling score and shear force. These studies would indicate a favorable relationship between marbling and tenderness. Van Vleck et al. (1992) reported a genetic correlation of 0.74 between marbling score and sensory panel tenderness. Marshall (1994) in a review of genetic parameters for cattle traits reported that marbling score seemed to have a positive, although relatively weak association with palatability.

The genetic correlations of 7 and 14 day aged steak shear force and calpastatin was 0.71 ± 0.24 and 0.66 ± 0.24, respectfully. These values are higher than most reports in the literature. Riley et al. (2003) reported a genetic correlation of 0.73 for calpastatin and shear force after aging steaks for 7 day in straightbred Brahman steers and heifers. A genetic correlation of 0.66 between calpastatin and shear force was reported by Whipple et al. (1990) while Shackelford et al. (1994) reported a genetic correlation of 0.59 between shear force and calpastatin. In another paper Shackelford et al. (1991) reported a slightly lower genetic correlation of 0.39 between calpastatin and shear force. These studies suggest that selection for lower calpastatin levels would increase beef tenderness. A high genetic correlation between post-rigor calpastatin and shear force suggests that it may be possible to improve meat tenderness by selection against calpastatin as reported by Shackelford et al. (1994). Pringle et al. (1997) found that calpastatin and shear force genetic correlations increased linearly with increasing percentages of Brahman breeding.

Genetic correlations were calculated between traits measured after 7 day of aging or between traits measured after 14 day of aging, but not between traits measured after 7 day of aging and shear force after 14 day of aging. The genetic correlations of cooking loss and
purge loss with shear force varied among the aging periods. The additive genetic variance of cooking loss after aging steaks for 7 day was zero, so all genetic correlations that included cooking loss after 7 day aging were also zero. In contrast, there was a high correlation (0.91) between purge loss after aging for 14 day and 14 day shear force. This would support the idea that steaks that loose more moisture while freezing and thawing are tougher when cooked. However, the genetic correlation between cooking loss after aging for 14 day and shear force was -0.09 ± 0.44. This is a relatively low genetic correlation and probably not different from zero, but suggests that teaks lost more moisture during cooking might be more tender.

**Variables Influencing Shear Force**

Single trait mixed model analyses were run to evaluate the influence of selected independent variables on shear force after steaks were aged for 7 and 14 days. Partial regression coefficients resulting from a reduced analyses after deleting independent variables that were not significant are given in Table 4. Significant independent variables were marbling score, purge loss after 7 day aging, purge loss after 14 day aging, cooking loss after 14 day aging and calpastatin. None of the following independent variables significantly influenced shear force at 7 or 14 day aging when all independent variables were included in the model: average daily gain, hot carcass weight, longissimus muscle area, fat thickness, kidney, pelvic and heart fat, yield grade, or hump height.

The partial regression coefficient of shear force after aging for 7 day on marbling score was -0.00219 ± .00092 (p < 0.01). Marbling score units range over a 100-point scale for a particular marbling score range. Slight marbling ranges from 300 to 399 points. Thus, changing marbling score 100 points (a complete marbling grade) would reduce shear force for 7 day aged steaks by 0.219 ± 0.09 kg. The regression of shear force after aging steaks for 14
day on marbling score was not statistically significant. Cooking loss after aging steaks 7 day significantly influenced shear force on 7 day aged steaks. One percent increase in cooking loss increased 7 day shear force by 0.09717 ± 0.01344 kg (p < 0.1). Also, increasing calpastatin level one unit increased 7 day shear force by 0.24090 ± 0.06116 kg (p < 0.01). Table 4. Regression coefficients and standard errors for the regression of shear force on marbling score, purge loss, cooking loss and calpastatin using a linear mixed sire model.

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>7-d aging</th>
<th>14-d aging</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS</td>
<td>-0.00216 ± 0.00092**</td>
<td>0.00018 ± 0.00072</td>
</tr>
<tr>
<td>PL7</td>
<td>0.00890 ± 0.02341</td>
<td>- -</td>
</tr>
<tr>
<td>PL14</td>
<td>- -</td>
<td>0.05223 ± 0.02549*</td>
</tr>
<tr>
<td>COOK7</td>
<td>0.09717 ± 0.01344**</td>
<td>- -</td>
</tr>
<tr>
<td>COOK14</td>
<td>- -</td>
<td>0.07294 ± 0.01060**</td>
</tr>
<tr>
<td>CALP</td>
<td>0.24090 ± 0.06116**</td>
<td>0.21087 ± 0.04914**</td>
</tr>
</tbody>
</table>

1MS = marbling score, PL7 = purge loss after 7 d aging, PL14 = purge loss after 14 d aging, COOK7 = cooking loss after 7 d aging, COOK14 = cooking loss after 14 d aging, CALP = calpastatin.
* P < .05
** P < .01

A one percent increase in purge loss after 14 day aging increased 14 day shear force by 0.05223 ± 0.02549 (p < 0.05). Also, a one percent increase in cooking loss after 14 day aging increased shear force after 14 day aging by 0.07249 ± 0.01060 kg (p < 0.01). In addition, a one unit change in calpastatin assay was associated with a 0.21078 ± 0.04914 kg (p < 0.01) change in shear force after 14 day aging.
There is limited information in the literature about influences of purge loss and cooking loss on measures of tenderness. Wheeler et al. (1999) reported that cooked temperature was different among cooking end points, and, thus cooking loss increased with increased end point temperature. He went on to state that steaks that were cooked to higher internal temperatures were tougher. Akinwunmi et al. (1993) also reported that steaks became increasingly tougher and less juicy with increased internal end-point temperature.
Chapter V

Summary and Conclusion

There is a common perception that straightbred Brahman steers do not perform as well as English or Continental cattle in the feedlot. However, the means for the traits recorded in this study would indicate that the performance of these cattle would be acceptable by the current beef industry standards. The means for growth and carcass traits were: average daily gain 1.49 kg/d, hot carcass weight 336.4 kg, ribeye area 58.7 cm², fat thickness 0.87 cm, percent kph 2.12, USDA yield grade 2.34, and marbling score 390.3 which equals a high Select USDA quality grade. These carcass means indicate the Brahman steers have the ability to fit many of the carcass grids currently in place. The means for cooking and tenderness traits were: purge loss 10.60 and 10.59 percent for 7 and 14 day aging respectively, cooking loss 21.07 and 21.56 percent 7 and 14 day aging, shear force after 7 day aging was 4.57 kg, shear force after 14 day aging was 3.85 kg, calpastatin was 4.51. The mean shear force value for 14 day aged steaks is below 3.63 kg (eight pounds) which is considered tender by industry standards.

Estimates of variance components and genetic parameters were similar to previous estimates reported in the literature. Thus genetic (co)variation of Brahman steers is similar to that of other breeds. Heritabilities for growth and carcass traits were mostly moderate to high \( (h^2 > 0.3) \) except for kph which had a heritability of zero. The heritabilities for cooking traits were low \( (h^2 < 0.18) \) and cooking loss for 7 day aged steaks had a heritability of 0.0. These low heritabilitys would suggest that improvement through selection would be slow. Heritabilities estimates for shear force of 7 and 14 day aged steaks were 0.30 and 0.21, respectively. This would indicate that improvement in tenderness can be made through
selection in Brahman cattle.

Genetic correlations revealed a strong association of hot carcass weight, yield grade, and calpastatin with shear force for steaks aged 7 and 14 days. Marbling score was strongly correlated (-0.45) with shear force at 7 day aging, but the correlation was near zero at 14 day aging. The genetic correlations of cooking loss and purge loss at 7 day with shear force at 7 day aging were near zero. However, there was a strong genetic correlation (0.91) of purge loss at 14 day with WBS. This would support the idea that steaks that lose more moisture after thawing are tougher.

Factors influencing shear force were marbling score, purge loss after 7 day aging, purge loss after 14 day aging, cook loss after 7 day aging, cook loss after 14 day aging, and calpastatin. The remaining traits did not significantly influence shear force and were removed from the regression model.

Brahman cattle play a vital part of the cow-calf industry in the southeastern United States. It essential to have Brahman genetics that can perform in the feedlot, meet the carcass requirements of the packers, and be tender enough to satisfy the demands of the consumer. The results of this study indicate Brahman cattle can meet the demands of the beef industry. The heritabilities suggest that genetic improvements can be made through selection for most carcass and tenderness traits. Tenderness as affected by moisture loss during the thawing and cooking process needs to be studied further. More research needs to be conducted to evaluate straightbred Brahman cattle and identify those individuals that can improve the breed.


Vita

Josh Domingue was born on January 20, 1976, in Lafayette, Louisiana. He is the son of Kelly and Cecile Domingue. He graduated from Carencro High School in May of 1994 and then attended Louisiana State University at Eunice for two years. He then transferred to Louisiana State University at Baton Rouge for completion of his degree. In August 1999 he received his Bachelor of Science degree in agricultural business. After graduation he decided to further his education by entering graduate school. In the fall 1999 he enrolled at Louisiana State University to pursue a Master of Science degree in animal science with emphasis in beef cattle breeding and genetics.