EFFECT OF CASTRATION TECHNIQUE ON BEEF CALF PERFORMANCE
RESIDUAL FEED INTAKE, AND INFLAMMATORY RESPONSE

By

THOMAS MICAJAH WARNOCK III

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To my parents, Tommy and Pam Warnock
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EFFECT OF CASTRATION TECHNIQUE ON BEEF CALF PERFORMANCE, RESIDUAL FEED INTAKE, AND INFLAMMATORY RESPONSE

By

Thomas Micajah Warnock III

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The objective of this study was to examine the effect of castration method on daily feed and water intake, calf performance, residual feed intake, and inflammatory reaction. Brangus (n = 45) and Angus (n = 30) male calves weighing 226 ± 34 kg (200 ± 26 days of age) were placed in a GrowSafe 4000 feed intake facility 7 days post weaning (15 calves/pen; 7-8 calves/feed node). Body weight gain, feed intake, and water intake were recorded over an 84-d period. Calves were offered a mixed diet (TDN = 67.3% and CP = 12.2%, DM = 89%) ad libitum. Calves were adapted to the facility for 21 d prior to the start of the trial. Shrunken BW was recorded on d 0, 14, and 84; full BW was recorded on d 7, 28, 42, 56, and 70. On d 0 calves were assigned to one of five treatments (n = 15 head/treatment): 1) control steers were castrated surgically prior to weaning at an average age of 52 d (range: 8-85 d) (CON); 2) intact bulls (BULL); 3) bulls castrated by the Callicrate Bander (No-Bull Enterprises, LLC, St. Francis, KS; BAN); 4) bulls castrated surgically using the Henderson castration tool (Stone Mfg & Supply Co., Kansas City, MO; HEN) and 5) bulls castrated surgically utilizing emasculators (SUR). During the first 14 days post-castration (post-castration period), BAN calves gained slower (P = 0.009) than CON (0.10 vs. 0.68 kg/d) and tended to gain...
slower (P = 0.08) than BULL calves (0.10 vs. 0.48 kg/d). In addition, CON calves gained more (P = 0.04) than HEN and SUR, 0.68, 0.24, and 0.22 kg/d, respectively. Average daily gain for d 0 to 84 was similar for all treatments. Feed intake for the first 14 days post-castration as well as over the entire 84 d experiment was similar (P = 0.76 and P = 0.92, respectively). When feed intake was compared as a % of BW, intake d 0 to 14 and d 0 to 84 was similar (P > 0.10) for all treatment groups. Water intake for the first 14 days post-castration and over the entire 84 d experiment were similar (P = 0.38 and P = 0.72, respectively) for all treatment groups. Residual feed intake from d 0 to 14 was decreased (P < 0.05) for CON and BULL compared to SUR and intermediate and similar (P > 0.10) to BAN and HEN. Residual feed intake d 0 to 84 and G:F ratio d 0 to 14 and d 0 to 84 were similar (P > 0.10) among all treatments. Plasma ceruloplasmin concentration tended to be different (P = 0.10) among treatments during the post-castration period. CON had decreased (P < 0.05) plasma ceruloplasmin concentration compared to BULL and HEN during d 0 to 14 and tended to have decreased (P = 0.05) plasma ceruloplasmin concentration compared to SUR. BULL, BAN, HEN, and SUR had similar (P > 0.10) plasma ceruloplasmin concentration d 0 to 14. Plasma haptoglobin concentration was similar (P> 0.10) among treatments d 0 to 14. Our results indicate that method of castration did not have a long-term impact on performance or efficiency of weaned calves.
CHAPTER 1
INTRODUCTION

Castration of male beef calves may potentially cause pain and a subsequent period of decreased performance as a result of decreased appetite. Feed efficiency may also be negatively affected by this pain induced period of poor performance. Knowledge of which castration methods elicit the least amount of pain and reduction in performance will provide beef producers with improved animal husbandry practices.

Castration is a common animal husbandry practice in the United States. Castration of male beef calves eliminates intact male behavior and improves the decreased quality grade, tenderness and consumer acceptability observed in beef from intact male calves (Lents et al., 2006; Seideman et al., 1982). It is known that invasive methods of castration induce some degree of pain in male calves evidenced by decreased performance and morbidity post-castration (Stafford et al., 2002; Brazle, 1992). There are numerous methods of castration commonly used on beef operations (NAHMS, 1997). Identifying methods of castration that cause decreased stress on the calf will provide producers with a production practice that sacrifices the least amount of productivity, and a means of being pro-active about potential animal welfare concerns.

Currently, feed efficiency is commonly discussed in the beef industry. If a particular castration technique causes a decreased stress on a calf thus decreasing the lag in performance, and reduction in appetite then that method may be advantageous in the way of feed efficiency.

Feed efficiency in beef production systems is quantified in several ways, such as feed to gain ratio (F:G), gain to feed ratio (G:F), and residual feed intake (RFI). Feed to gain ratio and G:F are measured as unit of feed consumed per unit of weight gain and
units of weight gain per unit of feed consumed, respectively. These methods may be useful; however, selecting for improved ratios can cause a subsequent increase in cow size. Residual feed intake, however, is divergent of mature body size and growth rate. Residual feed intake is the units of feed consumed above or below what the calf was expected to consume for a given body size and growth rate. Methods of castration that result in decreased poor performance and increased feed efficiency could potentially decrease RFI. These animals consume less feed than they were expected, while maintaining similar average daily gain and body size as their counterparts.
Castration can increase the value of male beef calves. Troxel and Barham (2007) reported that in 2000 and 2005 steers sold through Arkansas sale barns received premiums of $6.02 ± 0.08 and $6.48 ± 0.09/45.45 kg over the mean of all calves ($92.91 and $118.32/45.45 kg) selling price, respectively. The reasons for this are numerous, but mostly pertain to desirability of castrated over intact males within the United States beef industry. There are clearly defined segments in the beef industry: the seedstock producer, the cow/calf producer, stocker/backgrounder, feedlot operator, and packer. All of these segments play an intricate role in why castration is essential from a management, facilities, quality, marketing, and consumer acceptability standpoint.

Castrates differ from intact males with regards to gain, carcass characteristics, carcass composition, and meat quality. Seideman et al. (1982) reported that the disadvantages associated with intact males are aggressive behavior, undesirable odors and flavors, lower quality grade, lower meat tenderness, and undesirable meat color.

**Purpose of Castration**

More than 17 million male calves between the ages of 1 d and 1 year of age are castrated annually in the United States (Lents et al., 2006). Castration can effectively reduce or diminish intact male behavior and undesirable carcass attributes that are observed in intact males. Consumers in the U.S. value the tenderness, juiciness, and flavor associated beef from castrated male beef calves (Heaton et al., 2004).

Cow-calf producers often cite concerns of decreased growth rate associated with castration of male calves (Lents et al., 2006). Consequently, many intact male calves
will be sold at weaning. The task of castration often falls on the first buyer of the calf shortly after weaning. Unfortunately, castration becomes increasingly traumatic as calves grow older and heavier.  

In the United States the majority of male calves finished in commercial feedlots are castrates, however this is not true in all countries around the world. Some countries utilize the intact male for beef production because of their advantages in terms red meat yield, and efficient growth compared to castrates (Seideman et al., 1982).

**Methods of Castration**

In the beef industry there are many accepted methods of castration for beef cattle. Some methods are more suitable for certain situations compared to other methods. The methods available for castration can be broadly classified as surgical and bloodless. Surgical methods are more invasive and perceivably more painful than bloodless methods of castration. Surgical methods are comprised of practices such as knife cutting, emasculator method, and Henderson castrating tool (Stone Manufacturing and Supply Co., Inc., Kansas City, MO 64127). Bloodless methods are available through banding techniques, Burdizzo emasculatormes, and chemical castration. In 1997 the United States National Animal Health Monitoring System (NAHMS) reported that 55.4 percent of cow-calf producers utilized surgical castration as the primary method of castration for male beef calves. However, herd size tended to be a factor in the method used. This was evidenced by 80.5 % of operations with ≥ 300 head utilizing surgical castration. Operations with 50 head or less were almost equally split between a using surgical method (49.4 %) or a banding method (43.7 %; NAHMS, 1997).
**Surgical methods**

Surgical castration can be accomplished through a variety of methods and combinations of methods. Jensen et al. (2006) describes that the initial incision or opening of the scrotum can be accomplished via a knife or scalpel. The testicles should be pushed into the upper portion of the scrotum with the lower half of the scrotum being removed, this provides adequate drainage. In Addition, a Newberry castrating knife (Jorgensen Laboratories, Loveland, CO 80538) may be utilized during the surgical castration procedure. This tool is used to incise the scrotum on the sides leaving an anterior and posterior flap for access to the testicles and drainage. Once the scrotum has been incised using any of these methods, the testicles must be removed by severing the spermatic cords, scraping of the spermatic cord to facilitate gradual separation of the tissues and vessels, gently pulling the testicle until the spermatic cord breaks, utilization of the emasculator tool, or applying the Henderson castration tool. The same author adds that the emasculator is an option for removing the testicles during surgical castration by cutting the spermatic cord while also crushing the blood vessels to mitigate post castration bleeding and hemorrhage. Furthermore, the Henderson castration tool is a process designed to be more effective on older bulls. The tool is designed to fit into a variable speed drill and clamped on the spermatic cord proximal to the testes. The drill is then slowly rotated until the testicle is removed by approximately 20 rotations of the drill (Jensen et al., 2006).

**Bloodless methods**

Bloodless castration is comprised of a variety of methods that may also successfully accomplish castration of male cattle with minimal blood loss and perceivably less stress. Capucille et al. (2002) reports that these methods involve
interrupting the blood supply to the testes and scrotum without causing hemorrhaging. The processes commonly used are the elastrator, Callicrate Bander (No-Bull Enterprises, St. Francis, KS 67756), Eze Bloodless Castrator (Out West Manufacturers, St. Ignatius MT 59865), California Bander (Inosol, LLC, El Centro, CA 92243), and emasculatomes. Elastrators stretch the small rubber bands to allow it to be applied around the scrotum as close to the body as possible. The Callicrate Bander and Eze Bloodless Castrator require larger elastic tubes that are fitted around the scrotum and then tightened by a ratcheting mechanism on the tool. A metal grommet is then cramped around the band to hold tension on the band. The tools have been designed with a tension indicator because under-tightening may cause complications and over-tightening may potentially lead to broken bands and unsuccessful castration. The California Bander differs more than the other methods, however it does require large elastic bands. The bands are manually stretched around the scrotum and fitted into a metal clip, which hold tension on the band.

There is a risk of anaerobic infections such as tetanus when utilizing these banding methods. It has been recommended that calves be vaccinated with tetanus toxoid 7 to 10 days prior to banding and boostered at castration to mitigate the risk of tetanus. (Anderson, 2007)

Another method of bloodless castration is the emasculatome method. This method facilitates the castration of calves without the potential complication associated with either surgical castration or the banding procedure. The emasculatome accomplishes castration by crushing the spermatic cords without incising the scrotum; thus there is no open or bleeding tissue. However, this method is intended for use in young immature
male calves as older/heavier bulls tend to have larger cremaster muscles that may hinder proper crushing of testicular vasculature (Capucille et al., 2002).

**Experiments evaluating castration method**

Previous research has focused on method of castration and the subsequent effects on calf performance, mortality, morbidity, stress response, and carcass parameters. Zweiacher et al. (1979) compared the effects of elastrator ligation and emasculation, two methods of surgical castration, on feeder calf performance (180 and 175 kg average BW). The elastrator ligation process included exposure of the testicles by partial removal of the scrotum and placing an elastrator band on each spermatic cord. The testicles were then removed by severing the spermatic cord with emasculators two to four cm below each elastrator band. The ligation bands were applied in order to minimize post-castration hemorrhaging.

In other studies, researchers have compared surgical castration and the bloodless banding procedure. Chase et al. (1995) studied the effects of surgical castration utilizing the Newberry knife and emasculator versus the banding method using large rubber bands (EZE Bloodless Castrator) on bulls nearing maturity (average BW 420 ± 12.1 kg). Surgical castration in this study was carried out by incising the scrotum with a Newberry knife. The testicles were then removed by applying the emasculator to each individual spermatic cord. Banding was carried out using latex rubber bands applied with the EZE Bloodless Castrator where an individual latex rubber tube was fitted around the scrotum as close to the testicles and as far from the body as possible.

Lents et al. (2001) compared banding with large latex bands and surgical castration via knife cutting utilizing 120 ± 2 kg suckling bull calves. The bander was used to ratchet the elastic band tight around the scrotum with the testicles in the distal
portion of the scrotum. The surgical treated bulls were castrated by removing the distal third of the scrotum, exposing the testicles, and severing the spermatic cords with a knife. In another study done by Lents et al. (2006) the surgical castration by scalpel was evaluated in comparison with banding with small rubber bands. The banding method was carried out by pulling the testes into the distal portion of the scrotum and two small rubber bands were applied proximal to the testes. Surgical castration was performed by removing the lower third of the scrotum, testicles were exposed and spermatic cords severed utilizing a scalpel.

Stafford et al. (2002) evaluated the response of two to four month old calves with a mean BW of 95.5 ± 0.97 kg to five different methods of castration. The methods of castration were banding with small rubber bands, banding with large latex bands, surgical castration by pulling testicles, surgical castration with testicles removed by emasculators, and bloodless castration by emasculatomes.

Immunization against gonadotropin-releasing hormone (GnRH) or GnRH-keyhole limpet hemocyanin (KLH) has been shown to be effective in diminishing bullish behavior and maintaining comparable feedlot performance and carcass merit to conventionally castrated steers. Adams and Adams (1992) investigated feedlot performance of GnRH immunized Bos taurus calves (278.8 ± 2.8 kg) by observing unimmunized bulls (intact male calves), GnRH immunized one time calves, and GnRH immunized with booster 8 weeks after first immunization calves in a feedlot setting. Gonadotropin releasing hormone antigen injections were administered subcutaneously in the dorsal portion of the neck. Price et al. (2003) described that through the same immunization procedure used in Adams and Adams (1992) that they observed a decrease in bullish behavior in
the feedlot. A comparison of these methods and results will be discussed in subsequent sections.

**Stress associated with castration**

When male cattle are castrated by any of the methods discussed, a certain level of pain is elicited. This pain may potentially cause poor calf performance as a result of decreased feed and water intake. It may be that the pain is not the sole inhibitor of performance but that suppressed immune function resulting from release of glucocorticoids during an inflammatory reaction leads to increased incidence of morbidity and subsequent loss of appetite. In an attempt to quantify pain it may be advantageous to evaluate blood constituents, plasma concentrations of some blood constituents may be pivotal in determining acuteness and duration of pain potentially elicited by an inflammatory response to stressors such as castration.

Quantifying pain associated with animal husbandry practices such as castration is extremely difficult and somewhat subjective. There are parameters that researchers may be able to monitor and assist them in making assumptions with respect to how much pain the animal may be experiencing and the duration of that pain response. Some of the physiological, behavioral, and performance responses have been reviewed by Capucille et al. (2002). Physiological responses including cortisol concentrations, acute phase protein concentrations, and white blood cell counts may be monitored. Behavior can potentially serve as an indicator of pain and or stress, deviations in behavior from status quo or that of the controls are viewed as response to pain.

Chase et al. (1995) observed the effects that surgical castration (SUR) and banding (BAN) had on plasma cortisol concentration and white blood cell counts using older intact male calves of three different breeds; Angus (400 ± 11.6 kg, 21.4 ± 0.24
Plasma cortisol concentration for surgically castrated calves increased immediately post-castration compared to BAN. However, 2 d post castration plasma cortisol concentration for both SUR and BAN were similar, both being higher than that of controls. Castration impacted white blood cell counts. Surgically castrated calves and BAN had 20.2 and 25% greater white blood cell counts d 2 post castration compared to controls. The acute pain response associated with SUR was immediate and of short duration, from d 0 pre-treatment to d 0 post castration plasma cortisol levels increased for SUR 3.2 ng/mL. The pain response associated with BAN was delayed, of less initial intensity, and also short in duration, from d 0 pre-treatment to d 0 post castration plasma cortisol increased 0.1 ng/mL. Day 0 pre-treatment to d 2 post- castration plasma cortisol increased 2.0 ng/mL for SUR, 1.1 ng/mL for BAN and decreased 1.6 ng/mL for CON (castrate vs. CON P < 0.04).

Other researchers reported that banding of Friesian cross calves (95.5 ± 0.97 kg, 2 to 4 mo) with large latex bands elicited an immediate and significant increase in the plasma cortisol concentration above pre-treatment concentrations. The increase in plasma cortisol concentrations in banded calves was significantly greater than that of the surgically castrated calves between 0.5 and 2.5 h post castration. In surgically castrated calves there was a numerical increase in plasma cortisol concentration over the pre-treatment concentration (Stafford et al., 2002). Thus, it is possible that age and/or weight may be a factor in stress response associated with castration.

Friesian bulls of intermediate age (173 ± 2 kg) were utilized to compare the effects of castration method on plasma cortisol concentration (Fisher et al., 1996). The authors
reported that surgical castration and emasculatome castration method caused an acute increase in plasma cortisol concentrations post castration and it remained elevated for up to 8 h. In addition, the surgically castrated calves had a greater peak and mean plasma cortisol concentration than did the emasculatome castrated calves. This may indicate that surgically castrated calves had a greater initial stress and inflammatory response (Fisher et al., 1996).

In two experiments conducted by Fisher et al. (2001) Angus, Angus x Friesian, and Simmental calves (399 ± 2.8 kg; Exp. 1) and Angus calves (238 ± 3.4 kg; Exp. 2) were castrated by surgical or banding methods. Plasma cortisol concentrations and plasma haptoglobin concentrations were observed daily as indicators of pain response to the respective castration methods. Plasma cortisol concentrations were not different for the two castrate groups in Exp. 1; however, plasma cortisol concentration on d 7 and 14 post castration were significantly lower for intact bulls compared to surgical castrates (34 nmol/L vs. 60 nmol/L; 43 nmol/L vs. 73 nmol/L, respectively). Plasma haptoglobin was observed to evaluate the inflammatory response to castration. The plasma haptoglobin concentrations for the surgically castrated male calves were significantly greater compared to the banded and intact bulls on d 1, 2, and 4; with banded and intact bulls being similar. After d 4 concentrations of plasma haptoglobin were similar regardless of treatment. Another acute phase protein, fibrinogen, was analyzed from blood samples collected and results closely mirrored those of the plasma haptoglobin concentrations in Exp. 1. In Exp. 2 there were no differences in plasma cortisol concentration regardless of castration method. Plasma haptoglobin concentration was significantly greater for surgical castrates than for banded calves on d 2 and 4.
Capucille et al. (2002) suggested that the growing concern for the welfare of our food animals and the pain associated with these management practices. These authors concluded that the largest barrier to developing more stringent policies for mediation of pain associated with animal agriculture management techniques is the inability to accurately assess pain in animals. In addition, anthropomorphism can be very problematic with regards to the public perception of common management practices such as castration, dehorning, tail docking, and ear notching. The complexities and subjectivity associated with applying human responses to experiencing pain to animal behavior and responses to stress and pain stimuli may be intensely misunderstood (Capucille et al., 2002). Erickson (1984) suggests that pain is a complex physiological phenomenon; it is hard to define satisfactorily in human beings and it is extremely difficult to recognize and interpret in animals.

**Utilizing pain mitigation techniques**

It is evident that methodology for quantifying pain in beef cattle remains unclear. Applying the best method for reducing the pain response to an injurious procedure will benefit the welfare of animals (Ting et al., 2003). Thirteen month old cattle (307 ± 5.3 kg) were castrated by the emasculatomes and then administered an anti-inflammatory (ketoprofen; K), local anesthesia (lidocaine HCL; LA), or caudal epidural anesthesia (lidocaine HCL and xylazine HCL; EPI). The effects of analgesics on plasma cortisol, acute phase proteins, and interferon-gamma production were recorded. Systemic analgesia with K was more effective in mitigating the acute pain response (cortisol) and suppressed immune function associated with emasculatome castration than LA or EPI. In addition, K or EPI were more effective than LA at minimizing pain-related behavioral
displays (Ting et al., 2003). It may be possible to ameliorate the pain associated with castration by administering certain analgesics.

Stafford et al. (2002) observed that in 2 to 4 month-old-calves (95.5 ± 0.97 kg) if local anesthesia was administered prior to banding with large latex bands or banding with small rubber rings, acute pain and distress associated with both bloodless methods of castration was virtually eliminated. In the same experiment, when surgical castration was applied either by severing spermatic cords or broken by traction, the local anesthesia was successful in decreasing pain during the incision but otherwise did not mitigate the pain and inflammatory response. Administration of ketoprofen along with local anesthesia virtually eliminated the acute pain response associated for both surgical methods over the 5 d trial.

**Effects of Castration on Performance**

As a result of pain, stress, and suppressed immune function, decreased performance and morbidity in male calves post castration is commonly observed. The method of castration that causes the least amount of decreased performance may be the method that causes the least pain and stress, resulting in a reduction in animal welfare concerns. Brazle (1992) conducted two field trials to evaluate the effects of different methods of castration on the health and performance of stocker cattle. All calves were vaccinated, treated for external and internal parasites and implanted prior to the study. In the first experiment, 496 crossbred steer and bull calves (115 kg) were purchased from sale barns in the Southeast United States. The purchased bull calves were either surgically castrated (n = 190) or banded with small rubber rings (n = 188) and compared to purchased steer calves (n = 118). Average daily gain of purchased steers was significantly greater compared to surgically castrated calves and the banded
calves (0.84 kg/d vs. 0.74 and 0.66 kg/d, respectively). Morbidity, mortality, and cost associated with medical treatment were reported to be similar among all treatments.

In the second experiment, 60 mixed breed steers and bulls (300 kg) were purchased. Steers (n = 20) were compared with surgically castrated bulls (n = 20) and calves banded with large latex bands (n = 20). Purchased steers grew significantly faster than banded calves evidenced by increased average daily gain (0.93 kg/d vs. 0.72 kg/d), and purchased steers gained similarly to the surgically castrated calves (0.93 kg/d vs. 0.80 kg/d). Other research has demonstrated that calves banded at 2 to 3 months-of-age had significantly greater average daily gain compared to bulls surgically castrated at 2 to 3 months-of-age or calves left intact (Lents et al., 2001). Lents et al. (2001) also reported that bulls banded at weaning tended to have decreased average daily gain during the 50 d post weaning.

Faulkner et al. (1992) used 6 to 9 mo old crossbred calves (214 ± 19 kg) to investigate performance of male calves castrated surgically utilizing the Newberry knife to incise the scrotum and the emasculator to remove testes compared to intact male calves. Surgically castrated calves had significantly decreased average daily gain compared with intact bulls (0.26 kg/d vs. 0.42 kg/d, respectively). Feed intake was similar between castrates and intact male calves, however G:F was significantly increased for intact male calves compared to castrates.

It may be that younger/lighter male calves experience less pain, stress, and decreased performance as a result of castration. Bruns and Pritchard (2004) observed that bulls banded at 9 months-of-age grew slower for 29 days post banding than bulls surgically castrated at 2 to 3 months-of-age. The bulls banded at 9 months-of-age had
significantly greater dry matter intakes and were less efficient as evidenced by greater F:G compared to bulls castrated at 2 to 3 months-of-age. This suggests that castrating bulls at younger ages may allow for healing prior to those calves entering a feedyard.

Lents et al. (2006) performed two experiments to investigate the effect of method and timing of castration on beef calf performance. In Exp. 1 bulls banded and implanted at 2 to 3 months-of-age had significantly greater pre-weaning gain than bulls surgically castrated and implanted at 2 to 3 months-of-age but were similar to control bulls; 0.94 kg/d, 0.90 kg/d and 0.91 kg/d, respectively. In this same study it was reported that implanted steers banded at weaning had significantly decreased average daily gain during a 50 d post-weaning period than both implanted steers banded at 2 to 3 months-of-age and those surgically castrated at 2 to 3 months-of-age (0.43 kg/d vs. 0.49 kg/d and 0.48 kg/d, respectively). In Exp. 2 it was observed that steers banded at birth and steers banded and implanted at birth had greater BW at weaning compared to intact bulls (245.0 kg, 241.3 kg, and 234.1 kg, respectively). Lents et al. (2006) concluded that delaying surgical or banding castration procedures to later than 6 months-of-age reduced body weight gain for at least 30 days post-castration. The authors surmised that producers should castrate bull calves as young as possible to decrease stress response and poor performance. These results indicate that leaving male calves intact until weaning to maximize pre-weaning performance is not truly advantageous because of the physiological factors regulating growth. In addition, utilizing growth promoting implants in those early castrates may allow similar growth compared to their intact counterparts.
Immunization against GnRH may be an effective method of chemical castration. Adams and Adams (1992) utilized 278.8 ± 2.8 kg Bos taurus calves to compare GnRH immunized steers to intact male calves. Results indicated that immunization decreased gain numerically but not statistically. In another experiment, Adams and Adams (1992) compared feedlot performance of intact male calves (CON), GnRH immunized steers (Anti-GnRH), and surgically castrated steers (CAST; 325.2 ± 2.8 kg). Results indicated that CON and Anti-GnRH gained similarly but both gained more than CAST. The authors suggest that GnRH is an effective immunogen in male cattle. This method of immunocastration may be an alternative to invasive methods like surgical castration. However, the authors indicated that the immunization against GnRH is most effective when carried out prior to significant testicular development. The application of these hormonal and chemical methods of castration in the U.S. is uncommon coupled with being labor intensive.

**Effect of Castration on Carcass Merit and Meat Quality**

Seideman et al. (1982) reported that intact males grow more rapidly, utilize feed more efficiently, and produce a higher yielding carcass compared to castrated male beef calves. However, the disadvantages of the intact male include aggressive behavior; undesirable odors and flavors; lower quality grade; lower meat tenderness and undesirable meat color. Price et al. (2003) reported that actively immunizing male calves against GnRH may mediate bullish behavior in the feedlot, therefore reducing bruising, and potential reduced meat quality caused by sex hormones. Castration of male calves alters the physiological status of the calf, as a result the composition of growth changes. Typically, castrated males deposit increased amounts of subcutaneous fat as well as depositing increased intra-muscular fat. Castration of male calves
facilitates the production of cattle that will yield a more consumer acceptable product. (Heaton et al., 2004).

In a review by Field (1971), it was reported that interest in utilizing intact male calves for meat production was growing. This growth was thought to be due to the declining demand for animal fat, increased emphasis on efficiency, and the need for greater quantities of red meat for our rapidly growing population. However, the demand for leaner beef is not what is being observed in the marketplace today. Some research indicates that consumers are willing to pay more for steaks that have higher marbling both as a function of sensory ratings and visual evaluation (Killinger et al., 2004; Platter et al., 2005). Ability to select cattle that will manifest greater intramuscular fat at harvest has become increasingly difficult to accomplish through genetic selection and can be done to some extent without increasing subcutaneous fat (Gwartney et al., 1996).

Some experiments reviewed by Field (1971) indicated that intact male calves had a 17% advantage over castrates in average daily gain, and bulls were shown to be 13% more efficient. Marbling scores were greater in steers than bulls, with percent intramuscular fat supporting this subjective evaluation. In other studies reviewed by Field (1971) it was reported that young bulls may have enough intramuscular fat to grade choice. This may be a function of the lack of Continental breed type influence in the cattle utilized in these studies. When Adams and Adams (1992) evaluated the carcass characteristics of male beef calves actively immunized against GnRH, they reported that immunized steers and control bulls performed similarly in terms of yield grade, longissimus muscle area, and hot carcass weight. However, surgically castrated steers in this same study had significantly increased yield grade, significantly decreased
longissimus muscle area, and lighter hot carcass weights compared to control bulls and immunized steers.

**Effect of Age at Castration on Carcass Characteristics**

In a study evaluating age at castration and its effects on growth and carcass quality, Knight et al. (2000) reported that calves castrated by banding with small rubber bands at birth had increased subcutaneous fat depth, bulls castrated at 12 months-of-age had the least, and bulls castrated at 6 months-of-age were intermediate. In another study, Knight et al. (1999) observed the effects of the interval between castration and slaughter and its subsequent effects on carcass characteristics. The authors indicated that bulls produced carcasses that were 10-14% heavier than steers and they concluded that for the intervals from castration to slaughter examined in this trial, post-pubertal castration changed meat quality attributes of bulls to those more like steers while other characteristics changed more slowly and were finally intermediate between bulls and steers. However, it was not possible to capture the weight gain advantages of intact male calves, castrate them at 17 months-of-age, and generate the meat quality of steers. They conceded that castrating bulls at different ages could provide producers with a technique for manipulating meat quality attributes.

Worrell et al. (1987) indicated that it may be possible to improve carcass quality of late castrates or intact male calves by longer feeding periods; however, this may also increase cost of production, decrease feed efficiency, and decrease average daily gain. Champagne et al. (1969) reported that when comparing intact males with calves castrated at birth, 2, 7, and 9 months-of-age; it was observed that intact males had decreased intramuscular fat and subsequently decreased carcass grade compared to that of castrates. This agrees with a study performed by Heaton et al. (2004) where late
castrated calves had significantly lower marbling scores than that of early castrated male calves or those castrated at weaning. The authors reported male calves castrated at 9 months-of-age had significantly lower marbling scores and carcass grades than all other castrate groups. Similar results were observed with respect to carcass fat cover; bulls had significantly less than the castrate groups, and the calves castrated at 9 months-of-age had significantly decreased subcutaneous fat compared to other castrate groups. As expected, bulls had larger longissimus area than castrates, with all the castrate groups being similar.

Bulls had a significantly higher maturity score indicating that bulls may have darker lean and increased amounts of ossification in the cartilaginous buttons along the spinal column. Overall, yield was significantly greater for bulls compared to the castrates. The results from sensory panel and Warner-Bratzler shear were similar among all groups. However, juiciness ratings were slightly numerically greater for bulls even thought they had less marbling and lower carcass grades. Heaton et al. (2004) suggested that in sensory panel evaluating consumer acceptability of early castrated male calves, calves castrated at weaning, and late castrated male calves; the early castrates were found to be more desirable with respects to tenderness, juiciness, flavor, and overall acceptability compared to the weaning castrates and the late castrates.

There appears to be pain and distress associated with most methods of castration, the severity and duration remains unclear. It is possible that the decreased performance resulting from this pain and distress and subsequent morbidity can be mediated to some extent by castrating at earlier ages and lighter weights, utilizing analgesics and possible application of implants to increase gains and efficiency. The pain and distress that is
assumed to be present at the time of castration and post castration may be a point of concern from an animal welfare standpoint. Attention must be given to this matter in order to be proactive about the realities of food animal production and the common management practices that are utilized within the beef industry such as castration. The value of boxed beef is what typically dictates the value of beef carcasses and beef carcass value is what typically determines live cattle price to a certain extent. Therefore, implementing management strategies that do not compromise carcass merit and meat quality would potentially be valuable to continuation of beef production that yields consumer acceptable product and hopefully lends itself to satisfactory monetary returns for the producers.

Feed intake and efficiency are difficult to measure and often not reported in castration studies. Many of the decreases in performance observed in late castration studies are due to decreased feed and water intake and a subsequent numerically greater F:G. New technologies allow for the measurement of these parameters on an individual basis. Through technological advancements like the GrowSafe® System (GrowSafe Systems Ltd., Airdrie, Alberta, Canada) it is possible to monitor feed intake, water intake, individual feed efficiency, and feeding behavior all while being in a group fed pen.

**Residual Feed Intake**

Providing feed to animals is a major cost in all animal production systems. In extensive grazing systems the inclusion of supplemental feedstuffs remains a major cost, second only to fixed costs (Herd et al., 2003). Efficiency of utilization of these supplements under grazing conditions is often unknown, and on an individual basis is unknown in grain feeding conditions. Variation between animals in converting feed
supplements into body tissue is important in determining net income in beef production systems (Koch et al., 1963).

Historically feed efficiency has been quantified through feed conversion ratio (FCR) however this can potentially be misleading in that a calf that has decreased feed intake and decreased gain can have the same FCR as a calf that has increased feed intake and increased gain. Selecting for increased FCR can also lead to increased mature BW in the cow herd, thus increasing nutritional requirements. Measuring feed efficiency is costly and difficult to quantify precisely in beef cattle (Herd et al., 2003).

First proposed by Koch et al. (1963) is the concept of residual feed intake (RFI). Residual feed intake is the difference between the actual feed intake and the expected feed intake for a given body weight (BW) and growth rate. Residual feed intake is divergent of BW and growth rate (Herd and Arthur, 2009). Low (negative) RFI values are desirable, indicating that the animal consumed less feed than it was expected to for a certain body size and growth rate. Conversely, high (positive) RFI values are animals that consumed more feed than expected therefore being less efficient.

Residual feed intake has been evaluated by many researchers with respect to the physiological basis (Herd and Arthur, 2009), genetic variation (Herd and Bishop, 2000), biological basis (Carstens and Kerley, 2009), and effect on meat quality (Baker et al., 2006). Recent research evaluating RFI through utilization of the Calan gate system (Herd and Bishop, 2000), and the GrowSafe feed intake system (Elzo et al., 2009) have studied efficiency through feeding pelleted, forage-based rations and concentrate diets, respectively. Although there have been relationships reported between RFI and production traits, the heritability of RFI remains unclear. In order for the relationship
between RFI to be advantageous to producers for use in selection there must be a moderate level of heritability to make genetic progress. Herd and Bishop (2000) report an estimate of RFI heritability at 0.16 in Hereford cattle, which agrees with a recent study with crossbred cattle where heritability was estimated at 0.19 (Elzo et al., 2009). Archer et al. (2002) reported a heritability estimate in Angus, Hereford, and Shorthorn cattle of 0.23. Arthur et al. (2001) indicated that the heritability of RFI in Angus cattle is 0.39.

**Utilization of the GrowSafe System**

The GrowSafe system makes monitoring feed intake, water intake, and feeding behavior more simple. Through the use of individual radio frequency identification (RFID), each animal is identified and when the animal approaches the feed/water bunk the RFID is recorded. The GrowSafe system measures the amount of feed consumed through the difference of the amount present prior to the animal arriving at the bunk and the amount present after the animal leaves the bunk. The measurement of water intake is recorded the same way. The GrowSafe system continuously monitors these feeding events throughout the day and night and records the time of day and amount consumed at each feeding event.

GrowSafe technology also enables researchers to record the feeding behavior. This is accomplished through capturing time of day, trips to the bunk within a day and head down feeding events within a trip to the bunk. Through this technological advancement there has been much research on effect of genotype, phenotype, and physiological variation on RFI (Herd and Bishop, 2000; Elzo et al., 2009; Nkrumah et al., 2007a; Carstens and Kerley, 2009; Herd and Arthur, 2009). Research on the effect of variation in RFI on performance, reproduction, and carcass characteristics has been
conducted (Castro-Bulle et al., 2007; Bingham et al., 2009; Herd and Bishop, 2000; Baker et al., 2006). However, very little research has been conducted in the area of how common animal husbandry practices can affect individual performance and RFI in beef calves. In the beef industry, management practices such as castration are necessary to produce the type of beef our consumers demand. This management practice can be successfully carried out through a variety of different techniques. However, the method of castration could potentially have different effects of beef calf performance and RFI. The ability to select castration methods that decrease the negative effect on calf performance and feed efficiency would be valuable to the beef industry.

**Genetic and Phenotypic Basis**

In young Hereford bulls it was reported that phenotypic and genetic variation does indeed exist in feed intake that is independent of body size and growth rate (Herd and Bishop, 2000). This research indicated that because of this variation it should be possible to implement selection to reduce feed intake without effecting BW and growth rate, the phenotypic variance associated with feed intake in this study was 20.56 kg. Residual feed intake was genetically and phenotypically independent of ADG ($r = 0.09 \pm 0.29$ and $r = -0.01 \pm 0.05$, respectively), mature cow weight also appeared to be genetically independent of RFI measured during a post-weaning performance test ($r = -0.09 \pm 0.26$). Residual feed intake had high genetic and phenotypic correlations with both feed conversion ratio ($r = 0.70 \pm 0.22$ and $r = 0.61 \pm 0.03$, respectively) and lean feed conversion ratio (feed intake/(weight gain * predicted carcass lean content); $r = 0.72 \pm 0.18$ and $r = 0.63 \pm 0.03$, respectively; Herd and Bishop, 2000). This may potentially indicate that while selection for low RFI may not affect growth rate and body
size it will segregate the more efficient animals that eat less from those animals that are similar in body size and growth rate however consume increased amounts of feed.

**Physiological Basis**

Herd et al. (2004) reported that there are likely to be at least 5 major physiological processes that can potentially explain variation in RFI. These processes are: 1) intake of feed; 2) digestion of feed (associated energy cost); 3) metabolism (anabolism and catabolism associated with and including variation in body composition); 4) activity; and 5) thermoregulation. As feed intake increases the amount of energy expended to digest the feed increases, this amount of energy expended is known as the heat increment of feeding (HIF). Knowing that selection for RFI is associated with inter-animal variation in feed intake, animals that eat less, for the same level of performance, could be expected to have a lower HIF.

Digestion of feedstuffs plays an important role in the overall efficiency of an animal. It is known that increased feed intake leads to increased ruminal passage rate which affects both the site and extent of digestion (Church, 1988). It may be that the increased intake by high RFI cattle decreases the absorption of nutrients and therefore limit their ability to meet maintenance requirements causing these cattle to have higher intakes for the same level of growth and body size.

Differences in body composition may also contribute to the variation in RFI because lean tissue accretion requires less energy per unit of gain than fat (1.24 vs. 9.39 kcal/g; Carstens and Kerley, 2009). The differential in energy cost is due to a greater variation in protein turnover, than in fat gain. Any variation in composition of gain or the body can affect the apparent efficiency of nutrient utilization (Herd et al., 2004).
Carstens and Kerley (2009) stated that energy expenditures associated with consuming feed are strongly related to the amount of time spent eating but not eating rate (feed consumed per unit time). Therefore, differences in time spent eating and frequency of meals consumed may contribute to the inter-animal variation in RFI due to the activity related energy expenditures.

The primary route for energy loss is evaporative heat loss through respiration. However, no studies have investigated the effect of respiration rate on RFI. A biological/physiological basis for RFI remains unclear and more research is needed to segregate the mechanisms that contribute the most to this inter-animal variation. However in studies that investigate these mechanisms in cattle divergently selected for low RFI indicate that the variation in function of these physiological mechanisms may be small and hard to detect (Herd and Arthur, 2009)

**Feeding Behavior**

There are many factors that can potentially affect efficiency of feed utilization in beef cattle. Lancaster et al. (2009) using Angus bulls (n = 341; initial BW = 371.1 + 50.8 kg) receiving a corn silage based diet through a GrowSafe feed intake facility, that low RFI bulls had significantly shorter meal duration (min/d) than medium and high RFI bulls, with medium RFI bulls being intermediate and different than both high and low RFI bulls (92.93, 99.25, and 107.24 min/d, respectively). Meal frequency was significantly decreased for low and medium RFI bulls compared to high RFI bulls (7.28 and 7.64 vs. 8.17 events/d). In addition, duration of time spent at the feed bunk with head down was significantly decreased for low RFI bulls compared to medium and high RFI bulls, with medium being intermediate and different than both low and high RFI bulls (41.99, 45.31, and 49.48 min/d, respectively). Meal eating rate was found to be
similar for low, medium, and high RFI bulls. This would indicate that the more efficient bulls did not feed as often and did not consume as much total feed as less efficient bulls. These results are in agreement with a study done by Nkrumah et al. (2007a) using steer calves sired by Angus, Charolais, and hybrid bulls of similar BW (353 + 61 kg).

Conversely, in another study utilizing 115 Brangus heifers (236 + 10.7 days of age) being fed a roughage based diet through a Calan gate feeding facility, meal duration (219.6 vs. 219.9 min/d) and meal frequency (15.06 vs. 14.75 events/d) were similar for low and high RFI heifers. However, head down duration was significantly greater for low vs. high RFI heifers (151.7 and 123.5 min/d, respectively; Bingham et al., 2009) and meal eating rate was significantly decreased for low compared to high RFI heifers (41.7 vs. 49.5 g/min), indicating that the most-efficient heifers spent more time feeding per day than the least-efficient heifers. However, it was concluded that the lack of competition for feed in this experiment, as a result of the calan gate system, may have altered feeding behavior (Bingham et al., 2009).

Golden et al. (2008) observed little differences in overall feeding behavior between low and high RFI feedlot cattle during two separate experiments. During Exp. 1 cattle were fed a traditional feedlot ration containing roughage and during the second experiment cattle were fed a ration containing no roughage. The most significant observation in terms of feeding behavior was that low RFI calves had significantly decreased eating bouts per day than did high RFI feedlot cattle in both experiments. In Exp. 1, high RFI cattle ate 18.2 meals/d while low RFI cattle ate 11.0 meals/d. In addition, in Exp. 2, high RFI cattle ate 17.6 meals/d compared to low RFI cattle which
ate 14.5 meals/d. The authors reported that overall, limited differences were observed in feeding behavior between low and high RFI feedlot cattle. The results of these experiments indicate increased variability of feed intake per eating bout throughout the day for low RFI feedlot cattle. Golden et al. (2008) did not report any differences in digestibility, rate of digestion or gastrointestinal passage rate.

Thiago et al. (1992) reported that frequency of feeding had no significant effect on digestibility between hay and silage diets, however increased meals/d tended to remove the diurnal variation in rumen pH. Wales et al. (2004) hypothesized that decreasing the diurnal variation in ruminal pH would increase digestion of forages being grazed, when ruminal pH was low. Wales et al. (2004) found that maintaining a constant pH at approximately 6.1 did increase digestion of forages in a grazing situation when pH was low (5.6). Thiago et al. (1992) also reported that feeding frequency had no significant effect on passage rate. These results indicate that variation in feeding events/day may not have a physiological impact on digestion and absorption of feedstuffs.

**Carcass Parameters**

Previous studies have demonstrated that RFI has a minimal effect on carcass parameters (Baker et al., 2006; Castro Bulle et al., 2007; Cruz et al., 2010). However, Nkrumah et al. (2007b) reported that high RFI cattle had increased back fat thickness compared to their high RFI counterparts with medium RFI being intermediate and similar to low RFI cattle. Interestingly, in this experiment similar (P = 0.21) marbling scores were also observed among low, medium, and high RFI cattle. This work is in agreement with results published by Lancaster et al. (2009). These results indicate that selection for low RFI may be used to reduce feed intake and have little to no impact on
carcass characteristics and quality, or selection for low RFI may decrease back fat thickness while maintaining adequate intramuscular fat and subsequent quality grade.
CHAPTER 3
EFFECT OF CASTRATION TECHNIQUE ON BEEF CALF PERFORMANCE, RESIDUAL FEED INTAKE, AND INFLAMMATORY RESPONSE

Introduction

It is customary for cow/calf operators to castrate male beef calves prior to weaning. However, some calves are not castrated until after weaning. Several methods of castration are available and the decision of which method to utilize may be a function of the type and size of the calf (Zweiacher et al., 1979). Larger and older calves have larger testicles and increased blood flow to the testes, causing the calf to be susceptible to increased blood loss. This blood loss can be eliminated if a bloodless means of castration is used. However these methods also have risk, and may be problematic in terms of anaerobic infections like tetanus.

Several studies have demonstrated that male beef calves endure an observable degree of pain when castrated (Fisher et al., 1996; Ting et al., 2003). This pain increases in acuteness and duration as the calf’s age, BW, and testicular size increases (Chase et al., 1995; Stafford et al., 2002). All methods of castration cause significant acute pain and distress; however, surgical castration is suggested to be more painful initially evidenced by increased plasma cortisol (Stafford et al., 2002). Pain and inflammation may also affect the growth rate and efficiency of beef calves (Fisher et al., 1997, Ratcliff et al., 2005). If specific methods of castration can be utilized to lessen the pain then theoretically growth rate and efficiency may be maximized.

Several studies have documented decreased gains in castrated calves compared to intact male calves but there has been minimal research on the effect of castration on feed efficiency (Brazle, 1992; Faulkner et al., 1992). There have been no studies investigating the effect of castration stress on residual feed intake (RFI) and whether
variation in RFI exists among calves castrated by different methods. There have also been no studies evaluating the effect of the Henderson Castrating Tool (Stone Manufacturing and Supply Co., Inc., Kansas City, MO) on beef calf performance or feed efficiency.

The objective of this experiment was to evaluate the rate of growth, feed intake, water intake, RFI, and inflammatory reaction of male beef calves in response to different methods of castration during the feedlot phase.

**Materials and Methods**

**Animals and Treatments**

Seventy-five male Angus (n = 30) and Brangus (n = 45) calves (214 ± 3.2 kg) were obtained from the University of Florida Santa Fe Beef Unit (Alachua, FL). All procedures during this experiment were approved by the University of Florida’s institutional animal care and use committee (IACUC). Calves were weaned for seven d prior to transport 349 km to the North Florida Research and Education Center’s (NFREC) GrowSafe® feed efficiency facility in Marianna Florida. Calves arrived at NFREC in a single semi-load. The arrival date was 22 d prior to the initiation of the experiment. A pre-experimental period (acclimation period) began on d -21 and lasted until d 0 (day of castration). Calves were stratified by breed, age, and weaning weight and randomly allocated to one of five treatments (n = 15 calves/treatment): 1) control steers (CON) were castrated surgically prior to weaning at an average age of 52 d (8-85 d); 2) intact bulls (BULL); 3) bulls castrated by the Callicrate Bander (No-Bull Enterprises, LLC, St. Francis, KS; BAN); 4) bulls castrated using the Henderson castration tool (HEN; Stone Mfg & Supply Co., Kansas City, MO); and 5) bulls castrated surgically (SUR). The experiment was comprised of two data collection periods, post-castration period (d 0 –
14), and overall period (d 0 – 84). Calves were randomly assigned to one of five pens so that all treatments were equally represented in all pens.

Calves were vaccinated pre-trial against IBR, BVD, BRSV, PI3 (Cattle Master Gold, Pfizer Animal Health), blackleg (Ultra Choice 7, Pfizer Animal Health), and treated for internal and external parasites (Ivomec® Epirnex, Merial). Over the entire trial calves showing signs of respiratory disease were recorded and treated with Draxxin® (tulathromycin, Pfizer Animal Health) at label dose. Sixteen percent (n = 12) of calves were treated for respiratory disease one time, 11% of all calves (n = 7; 58% re-treat) were re-treated for respiratory disease and 1 calf was treated a third time. These calves were treated across the first 4 wk of the experiment and after d 28 no cattle were treated during the remainder of the experiment. The calves were offered a mixed diet (TDN = 67.3% and CP = 12.2%, DM = 89%) ad libitum.

Calves assigned to the BAN, HEN and SUR treatments were castrated on d 0. Castration was performed by trained technicians under the supervision of a University of Florida veterinarian. Castration was completed by the same technician in the same manner for each calf for each treatment group. All calves on all treatments were vaccinated subcutaneously with 500 units of tetanus antitoxin on d 0. Banded calves were restrained in a chute, the band was applied around the scrotum proximal to the testes. The elastic band was tightened by a ratcheting tool until adequate tension was applied, a metal grommet was then crimped around the band to hold tension and reduce blood to the scrotum and testes and subsequent sloughing of the scrotum and testes.
Henderson castrated calves were restrained in a chute and castrated by incising the scrotum with a Newberry knife, leaving an anterior and posterior flap. Testes were then exposed and removed by the Henderson® castrating tool. The castrating tool was clamped on each spermatic cord individually and rotated by a cordless drill approximately 20 rotations until the cords severed. Surgically castrated calves were restrained in a chute and castrated by incising the scrotum with a Newberry knife, leaving an anterior and posterior flap. Testes were then exposed and spermatic cords were crimped using an emasculator.

**Sampling and Analysis**

Shrunk BW were obtained on d 0, 14, and 84. In addition, full BW were recorded on d 7, 28, 42, 56, and 70. All cattle were weighed in the morning and at approximately the same time for each weigh date. On days that shrunk BW were recorded, access to feed and water was removed by 1900 h the previous evening. Calves were individually weighed utilizing a Digistar® digital scale. After each weigh date calves were returned to their respective pen immediately.

Feed intake and water intake were recorded using the GrowSafe® system. Trips to the feed bunk and head down feeding events were also recorded through utilizing radio frequency identification tags.

Blood samples were collected from a sub-sample of the cattle at the beginning of the experiment to investigate stress and inflammation resulting from castration. Three pens (15 calves/pen) were sampled by blood collection via jugular venipuncture on d 0, 2, 6, 9, 12 and 15. Plasma was extracted from blood samples by centrifugation at 1,500 x g, was then stored at – 20 °C until analyzed for concentrations of ceruloplasmin and haptoglobin.
Plasma ceruloplasmin oxidase activity was measured in duplicate samples by using the colorimetric procedures described by Demetriou et al. (1974). The intraassay CV of duplicate samples was controlled to values of ≤10%. Ceruloplasmin concentrations were expressed as milligrams per deciliter, as described by King (1965). Interassay variation of both acute-phase protein assays were controlled by CV limits of ≤10%, as a result of a control sample analyzed in duplicate within each individual assay run. When the interassay CV exceeded 10%, all samples contained in the individual run with the control sample exceeding the average by the greatest were reanalyzed. This step was repeated until the results of standard pools for all runs resulted in a CV of ≤10% (inter-assay variation = 5.13 %; intra-assay CV variation = 3.05 %).

Plasma haptoglobin concentrations were determined in duplicate samples by measuring haptoglobin-hemoglobin complexing by the estimation of differences in peroxidase activity (Makimura and Suzuki, 1982). Results are expressed as arbitrary units resulting from the absorption reading x 100 at 450 nm. For samples with an absorption reading of ≤0.010, the intraassay CV of duplicate samples was controlled to values of ≤20%, and for samples with an absorption reading of ≥0.010, the intraassay CV of duplicate samples was controlled to values of ≤10% (inter-assay variation = 5.46 %; intra-assay CV variation = 3.37 %; Hepburn et al., 2009)

Data were analyzed by the MIXED procedure of SAS 9.2 (SAS Inst. Inc., Cary, NC). The model included the main effects of treatment, breed, day. All variables quantified by day or by week were analyzed using repeated measures. Least square means are reported with standard errors, means were separated for comparison by PDIFF. All variables with P-values of ≤ 0.05 were reported as differences, all variables
with P-values between 0.05 and 0.10 were reported as tendencies and anything greater than 0.10 was considered non-significant. All two-way interactions found to be significant at P < 0.10 for a particular variable were included in the model for that variable.

**Results and Discussion**

**Average Daily Gain**

Average daily gain (ADG) during the post-castration period (d 0 to 14) tended (P = 0.06) to be affected by treatment (Figure 3-1). All castrated calves gained less (P < 0.05) than CON with BULL being intermediate and similar (P = 0.23) to other treatments. Angus and Brangus calves had similar (P = 0.19) ADG during the post-castration period (Figure 3-2).

Average daily gain over the entire experiment (d 0 to 84) was similar (P = 0.40) for all treatment groups (Figure 3-3), indicating that castrated calves were able to compensate and recover from castration regardless of castration method. Angus calves (P = 0.06) had greater ADG than Brangus calves from d 0 to 84 (0.94 vs. 0.84 kg/d; Figure 3-4). Our results indicate that all methods of castration reduce ADG compared to control steers during the first 14 days after castration but by d 84 ADG was similar regardless of castration technique.

These results imply that method of castration does not impact ADG long term. A study by Lents et al. (2006) indicated that calves banded or surgically castrated at 2 to 3 mo of age gain differently from time of castration to weaning (2 to 3 mo to 7 to 8 mo of age). Calves banded at 2 to 3 mo of age had increased (P < 0.05) ADG pre-weaning compared to calves surgically castrated at 2 to 3 mo of age and intact male calves gained similarly (P > 0.05) to both castration methods pre-weaning (0.94, 0.90, and 0.91
kg/d, respectively). However, 50 days post-weaning no difference (P > 0.05) was observed between calves banded or surgically castrated at 2 to 3 mo of age (0.49 and 0.48 kg/d, respectively). Calves banded at weaning gained less (P < 0.05) than both calves banded and surgically castrated at 2 to 3 mo of age (0.43 vs. 0.49 and 0.48 kg/d, respectively), no control treatment was present in the post-weaning period (Lents et al., 2006). This study differed from the current experiment with respect to age and weight at the time of castration. In the current experiment calves were weaned prior to castration. This may indicate that method is not as important as timing of castration.

When bulls (300 kg) of unknown age, origin, and breed were used to evaluate the effect of castration on performance. Purchased steers gained faster (P < 0.05) in a 110 d post-castration study compared to banded bulls with surgically castrated bulls being intermediate and similar to both groups (Brazle, 1992). In another experiment utilizing calves (115 kg) of unknown age, origin, and breed purchased in Southeastern sale barns, Brazle (1992) observed that in a 33 d post-castration period calves purchased as steers gained faster (P < 0.05) compared to surgically castrated and banded calves. Surgical and banding castration treatments gained similarly over the 33 d trial. In agreement with the current study it appears that method is not as important as castration timing and BW of calves at castration. In addition, with heavier cattle, banding may not be as non-invasive and short term in pain response as initially believed.

Average daily gain was evaluated by period from d 7 to 70 (Figure 3-5). It appears that ADG from d 7 to 28 is affected by method of castration. However, ADG d 28 to 42, d 42 to 56, and d 56 to 70 was similar regardless of castration method, indicating that at some point after d 28 and before d 42 all treatments began to gain similarly. Average
daily gain was evaluated from d 7 to 28 (un-shrunken BW; Figure 3-6). ADG was affected (P = 0.001) by treatment d 7 to 28. BAN calves gained less (P < 0.05) d 7 to 28 compared to CON, BULL, HEN, and SUR. Castration method may not be as important from a growth rate standpoint in the long term; however, there was a delayed suppression of gain in BAN calves during the early post-castration period. Ratcliff et al. (2005) reported that weaned beef calves (210 ± 14.5 kg) castrated surgically tend to gain more (P < 0.10) than banded calves in the 50 d after castration, however no controls were present. This indicates that there was a difference in the duration of decreased performance associated with different methods of castration, however in the long term all castration and control treatments were gaining similarly at d 42 and after.

**Feed Intake**

Daily feed intake from d 0 to 14 (post-castration period) was similar (P = 0.76) for treatment groups (Figure 3-7). An interaction (P = 0.03) between treatment and day was detected for daily feed intake d 0 to 14 (Figure 3-8). Henderson castrated calves consumed less (P < 0.05) than CON, BULL, and BAN on d 0 and tended to eat less (P = 0.1) feed than CON on d 2; however, ate similarly to SUR on both days. BAN calves tended to consume less (P = 0.1) feed than both CON and SUR calves on d 10 and BULL and CON calves on d 14. These results would indicate that there is some loss of appetite as a result of surgical castration early post-castration evidenced by HEN eating less than CON early post-castration; however, this is not supported by SUR as they were intermediate and similar to both CON and HEN.

It appears that early post-castration there may be a difference in feed intake of calves castrated with emasculators versus Henderson castrating tool, however no clear trend was observed. It is apparent that there is a delayed effect of banding on daily feed
intake manifesting itself by a clear decrease in feed intake on d 10 and 14, the duration of this lag in feed intake is unknown. Decreased intake post-castration may be a function of increased pain and inflammation. Chase et al. (1995) indicated that the lag could exist until d 24 to 28 in calves banded with large latex bands compared to surgically castrated calves.

Angus calves had decreased (P = 0.007; Figure 3-9) average daily feed intake compared to Brangus calves during the post-castration period (5.1 vs. 6.4 kg/d). An interaction (P = 0.03) between breed and day was detected for daily feed intake d 0 tp 14 (data not shown). There was a trend indicating Angus calves consumed less (P < 0.05) feed than Brangus calves on d 0, 1, 4, 7, 8, 9, 10, 11, 12 and 14. Mader et al. (2006) suggested that hot, humid conditions with intense solar radiation coupled with low wind speed can increase animal heat load, resulting in reduced performance, decreased animal comfort, and death. Feed intake is decreased in hot weather, the temperature at which Bos taurus cattle begin to consume less feed and sacrifice performance is 25 °C if protected from solar radiation (Hahn, 1995). In the current experiment, cattle were housed in an open air barn and ambient temperatures exceeded the threshold for environmental stress in Bos taurus cattle described by Hahn (1995). During the post-castration period, all days were at or above 25°C (Figure 3-20), suggesting Angus steers may have been experiencing increased heat stress and a subsequent loss of appetite.

Feed intake over the entire trial (d 0 to 84) was analyzed by week (12 wk). Mean weekly feed intake (1 to 12) was not impacted by treatment (P = 0.92; Figure 3-10). An interaction (P = 0.05) between treatment and week was detected for feed intake (Figure
3-11). BAN calves tended to have decreased (P < 0.10) weekly feed intake compared to CON in wk 2, HEN in wk 4 and BULL in wk 11. CON, BULL, HEN and SUR calves had similar weekly feed intake throughout the entire trial. These results support our gain data and suggest that BAN calves may have a delayed stress response resulting in decreased feed intake. Others have found that castrated calves tend to eat less (P < 0.05) than intact male calves early post-castration and similar 28 d post-castration (Fisher et al., 1997). There is little data available with respect to individual calf feed intake as it relates to method of castration.

Feed intake was not impacted by breed over the entire 84 d experiment (P = 0.31). However, a breed x week interaction (P = 0.04) was detected for feed intake wk 1 – 12 (Figure 3-12). Angus calves consumed less (P < 0.05) feed than Brangus calves in wk 2 and 3 and tended to consume less (P < 0.10) feed than Brangus calves in wk 4 and 5. Angus and Brangus calves consumed similar (P = 0.97) amounts of feed in wk 1, 6, 7, 8, 9, 10, 11 and 12. Historical climatic data was collected and evaluated for the entire experiment (Figure 3-13). The decreased feed intake observed in wk 2, 3, 4, and 5 may have been due to the high ambient temperature.

When feed intake was evaluated as a % of BW d 0 to 14 (data not shown) and d 0 to 84 (Figure 3-14), treatment had no impact (P = 0.75). Breed did not impact (P > 0.10) feed intake as a % of BW from d 0 to 14 (data not shown). However, Angus calves consumed a greater (P = 0.04) amount of feed as a % of BW over the entire trial (d 0 to 84; Figure 3-15). Earlier analyses indicated that there was a difference in absolute feed consumption between breeds with Brangus consuming the most. However, these results indicate that Angus calves were actually consuming more feed. This
phenomenon is a function of the variation observed in feed consumption between calves of differing BW. Brangus calves had increased (P = 0.0004) average BW d 0 to 84 compared to Angus calves (270 ± 5 kg and 242 ± 6 kg, respectively). On an as-fed basis Brangus were reported to have consumed more feed however this is what would be expected from heavier calves regardless of breed.

Feeding behavior was not impacted (P = 0.34) by treatment early post-castration (Figure 3-16). There was a trend for all treatments to have decreased trips to the bunk on d -1 and 0. This is attributed to the shrink period on d -1 and the time spent out of the pen while being processed on d 0. On d -1, 0, 1, and 2 all treatments had similar number of trips to the feed bunk. These results indicate that not only was weekly feed intake not altered by castration method, but feeding behavior was not impacted by the stress of castration early post-castration.

**Water Intake**

Water intake was similar (P = 0.38) among treatment groups from d 0 to 14 (data not shown). An interaction (P = 0.005) between treatment and day was detected for water intake d 0 to 14, but no clear trends were evident (Figure 3-17). Angus calves had a decreased (P < 0.0001) average daily water intake during the post-castration period compared to Brangus calves (38.3 vs. 44.9 L/d, respectively). An interaction (P = 0.03) between breed and treatment was detected for mean water intake d 0 to 14 (Figure 3-18). Angus CON, BAN, HEN, and SUR calves consumed more (P < 0.05) water than all Brangus treatments d 0 to 14. However, Angus BULL consumed more (P < 0.05) water than Brangus BULL and HEN but consumed similar (P > 0.10) amounts of water compared to Brangus CON, BAN, and SUR.
An interaction (P < 0.0001) between breed and day was detected for water intake during the post-castration period (Figure 3-19). Angus calves drank more (P < 0.05) water than Brangus calves on d 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. On d 0 Angus calves consumed similar (P > 0.10) amounts of water compared to Brangus calves. Similar to feed intake, these results suggest that ambient temperature potentially played an important role in driving the differences in water consumption between Angus and Brangus calves. The highest average day time temperatures of the entire 12-wk trial were observed over the first 14 d (mean = 26 ºC; Figure 3-20).

Over the entire experiment, water intake was not impacted (P = 0.72) by treatment d 0 – 84 (Figure 3-21). Angus calves consumed increased (P < 0.0001) amounts of water compared to Brangus calves d 0 to 84 (data not shown). An interaction (P < 0.0001) between breed and week was detected for water intake d 0 to 84 (Figure 3-22). Angus calves consumed more (P < 0.05) water than Brangus calves during wk 1 to 11, and tended to consume more (P = 0.06) water compared to Brangus calves during wk 12.

The mean ambient day time and night time temperatures during the current trial were 22 and 10ºC, respectively. Lofgreen et al. (1975) suggested that there is a greater heat tolerance in Bos indicus cattle compared to Bos taurus. Hansen et al. (2007) documented that in Florida, as Brahman percentage increased water consumption decreased linearly. Winchester and Morris (1956) suggests that the rate of water consumption for Bos Taurus and Bos indicus cattle is similar between ambient temperatures of -12 and 4 ºC but diverges at temperatures above this range. This may indicate that the high ambient temperatures observed in the current experiment induced
variation in water consumption between the two breed types but high temperature does not appear to be the sole factor driving water consumption. It is known that increased dry feed intake is accompanied by increased water intake in growing cattle (Meyer et al., 2006). In the current trial, Angus calves consumed more feed d 0 to 84 (% of BW) compared to Brangus calves. The increased water consumption by Angus calves may be a result of the increased feed consumption coupled with high ambient temperature.

**Feed Efficiency**

Gain to feed ratio was similar among treatments d 0 to 14 (P = 0.28; Figure 3-23) and d 0 to 84 (P = 0.32; Figure 3-24). Angus calves were similar (P = 0.25) to Brangus calves in G:F d 0 to 14 (Figure 3-25), but had increased (P = 0.002) G:F compared to their Brangus counterparts over the 84-d trial (Figure 3-26). These results indicate that over the entire trial, Angus calves were slightly more efficient than Brangus calves. This increased efficiency observed in Angus calves d 0 to 84 could potentially be due to the tendency for Angus to gain more than Brangus d 0 to 84, coupled with the decreased absolute feed intake observed in Angus calves d 0 to 84. Our results agree with another study that indicated calves with higher Brahman percentage were less efficient in terms of feed conversion ratio (Elzo et al. 2009).

Residual feed intake (RFI) tended to be affected (P = 0.10) by treatment during the post-castration period (Figure 3-27). Control steers and BULL were similar (P > 0.10) in RFI value, but lower (P < 0.05) than SUR. BAN and HEN were intermediate and similar (P > 0.10) to CON, BULL, and SUR. These results suggest that castration did induce a change in efficiency as measured by RFI early post-castration. There is a clear trend showing that castration increased RFI, but the magnitude is small and short in duration.
Angus and Brangus calves had similar (P = 0.98; data not shown) RFI values during the post-castration period. Elzo et al. (2009) documented that calves were increasingly efficient measured by RFI as Brahman percentage increased in terms of RFI. In another study, Hansen et al. (2007) suggested that there is a linear trend indicating RFI decreases (efficiency improves) as Brahman percentage increases but the comparison of RFI between Angus and Brangus was not as clear.

Over the 84 d experiment, residual feed intake was not affected (P = 0.85) by treatment or breed (P = 0.85 and P = 0.93, respectively; Figure 3.28), suggesting that in the long term, castration does not negatively impact efficiency as measured by RFI long-term. Our data indicates that the impact of castration observed early post-castration is mitigated in the long term. There are no reports thus far of studies evaluating the impact of common animal husbandry practices such as castration on RFI, the current trial may prove that castration can be accomplished by any method without sacrificing long-term feedlot performance.

**Acute Phase Proteins**

Plasma concentration of ceruloplasmin tended to be different (P = 0.10) among treatments post-castration. CON had decreased (P < 0.05) plasma ceruloplasmin concentration compared to BULL and HEN post-castration and tended to have decreased (P < 0.10) plasma ceruloplasmin concentration compared to SUR. BULL, BAN, HEN, and SUR had similar (P > 0.10) plasma ceruloplasmin concentration post-castration, suggesting that castration does elicit an inflammatory response compared to control steers. However, in the current trial, no one method induced a higher level of inflammation early post-castration. These results may be important from an animal
welfare standpoint, there are minimal differences among castration methods and only slight differences compared to CON.

An interaction ($P = 0.02$) was detected between treatment and day for plasma ceruloplasmin concentration post-castration (Figure 3-29). All treatments had similar ($P > 0.10$) plasma ceruloplasmin concentration on d 0. CON had decreased ($P < 0.05$) plasma ceruloplasmin concentration compared to BULL and HEN on d 2; BULL, HEN, and SUR on d 6 and 9; and tended ($P < 0.10$) to be lower than BULL, HEN, and SUR on d 12; and BULL, BAN, and SUR on d 15. The delayed increase in plasma ceruloplasmin concentration in BAN as compared to CON suggests that banding induces a delayed inflammation response compared to surgical methods of castration. The increased plasma ceruloplasmin concentration levels HEN and SUR exhibited compared to CON indicates that there is an acute inflammatory response early post-castration in surgically castrated calves, however it is decreased over time. HEN and SUR were similar ($P > 0.10$) post-castration indicating that surgical castration induces an inflammation response compared to CON but neither surgical method (HEN and SUR) caused more inflammation than the other, and by d 15 it is evident that all castration methods are similar.

The effect of sex class (intact male calves vs. castrated male calves) on acute phase protein levels in calves exposed to a stressor remains unclear. Qiu et al. (2007) reported that heifers had greater ($P < 0.001$) plasma ceruloplasmin concentration compared to steers post weaning and transportation, however sex was not important ($P = 0.31$) for other acute phase protein concentrations (fibrinogen and haptoglobin) investigated in the same study. In the same study it was hypothesized that breed of calf
plays a role in acute phase protein response to stressor. In the current experiment breed did not affect plasma ceruloplasmin concentration post-castration (P = 0.19; Figure 3-30). In the first 2 weeks post-castration, these results indicate that inflammation is present early post-castration regardless of the surgical method and a delayed inflammatory response is observed when calves are banded.

Plasma concentration of haptoglobin were similar (P = 0.16) among treatments. However, CON had the numerical lowest plasma haptoglobin concentration compared to BULL, BAN, HEN and SUR. An interaction (P = 0.0002) was detected between treatment and day for plasma haptoglobin concentration post-castration (Figure 3-31). On d 2 CON had decreased (P < 0.05) plasma haptoglobin concentration compared to BULL, HEN and SUR. BULL also had decreased (P = 0.05) plasma haptoglobin concentration compared to HEN and SUR on d 2, indicating an inflammatory response in the two surgical castration methods. Additionally, BAN had decreased (P = 0.002) plasma haptoglobin concentration compared to HEN and SUR on d 2, suggesting that the acute phase protein response in BAN was delayed. CON had decreased (P < 0.05) plasma haptoglobin concentration compared to BULL on d 6 and 9. On d 6 CON had decreased (P = 0.04) plasma haptoglobin concentration compared to HEN and tended to have decreased (P = 0.06) plasma haptoglobin concentration compared to SUR. On d 15 BAN had increased (P < 0.05) plasma haptoglobin concentration compared to CON and BULL and tended to have increased (P < 0.10) Plasma haptoglobin concentration compared to HEN and SUR. These data suggest that plasma haptoglobin concentration was greater in the surgical methods early post-castration but was not different from control steers by d 9. Calves that were banded responded like controls
until d 15 when BAN had greater plasma haptoglobin concentration than CON and calves castrated surgically, indicating the delayed inflammatory response associated with banding calves. The driving factor behind the greater plasma haptoglobin concentration observed in intact male calves in the current study remains to be elucidated.

Breed did not impact plasma haptoglobin concentration (P = 0.11; Figure 3-32) post-castration contrary to some other research (Qiu et al., 2007). An interaction (P = 0.07) was detected between breed and day for plasma haptoglobin concentration (Figure 3-33). Angus calves had increased (P = 0.03) plasma haptoglobin concentration compared to Brangus calves on d 0 and tended to have increased (P = 0.06) plasma haptoglobin concentration compared to Brangus calves on d 6. On d 2, 9, 12 and 15 breed did not impact plasma haptoglobin concentration concentration (P ≥ 0.36). Our results indicate that overall the inflammatory response to castration was similar between breed post-castration. However, it is evident by the breed*day interaction that Angus calves had a greater inflammatory response to castration through d 6, but were similar to Brangus calves by d 9.

**Implications**

Male beef calves are routinely castrated prior to leaving the cow-calf operation or certainly before entering a stocker or feedlot environment. When managing weaned beef calves early post-castration in sub-tropical environments, our data would suggest that ADG is impacted for a period of less than 42 d post-castration. Surgical methods elicit more of an acute negative impact while banding resulted in a delayed suppression of gain, nonetheless 42 d post-castration all calves gained similarly regardless of castration method. Feed intake was not different early post-castration among treatment
groups; however, there was some evidence suggesting that BAN calves endured delayed suppression of intake. Feed intake over the entire trial was not affected by castration method.

Water intake was observed to be different among treatments on certain days early post-castration although water intake overall was not impacted by castration method. Feed efficiency, measured as G:F or RFI was not impacted in the long-term by castration technique. Acute phase proteins were evaluated as a measure of inflammation. Early post-castration it was evident that both types of surgical castration elicited a significant inflammatory response, this pain response was mediated by d 6. The acute phase protein response by d 15 was similar in all castration treatments, however banded calves were trending upwards indicating that there was a delayed response to castration by banding.

Early post-castration Angus and Brangus calves gained similarly, however over the entire trial there was a tendency for Angus calves to gain slightly more per day than Brangus calves. There was an observable suppression in absolute feed intake for Angus calves early post-castration. This decrease was potentially due to the increased ambient temperature during that time period. Interestingly, Angus calves had increased feed consumption on a percentage of BW basis over the entire trial.

Breed played a role in water intake during the trial. This is thought to have been a function of Angus calves drinking significantly more water due to the high ambient temperatures.

Castration should be carried out as early as possible, the method a producer chooses to utilize may not be as important as the age and weight they choose to
castrate their calves. In all measures observed in this study including stress and performance, steers previously castrated prior to weaning were preferable to late castrates. If calves are castrated pre-weaning the impact that the stress of castration will have on growth rate, feed intake, water intake, and feed efficiency is minimized.
Figure 3-1. Effect of castration technique on average daily gain d 0 – 14. Treatment effect: \( P = 0.06 \). \(^a^b\) Means with different superscripts differ \( P < 0.05 \).

Figure 3-2. Effect of breed on average daily gain d 0 – 14. Breed effect: \( P = 0.2 \).
Figure 3-3. Effect of castration technique on average daily gain d 0 – 84. Treatment effect: $P = 0.40$.

Figure 3-4. Effect of breed on average daily gain d 0 – 84. Breed effect: $P = 0.06$. Means with different superscripts differ $P < 0.1$. 
Figure 3-5. Effect of castration technique on ADG d 7 – 70 by period.

Figure 3-6. Effect of castration technique on ADG d 7 – 28. Treatment effect: P = 0.001. a, b Means with different superscripts differ P < 0.05.
Figure 3-7. Effect of castration technique on daily feed intake d 0 – 14. Treatment effect: $P = 0.76$.

Figure 3-8. Effect of the treatment*day interaction on daily feed intake d 0 – 14. Treatment*Day: $P = 0.03$. 
Figure 3-9. Effect of breed on daily feed intake d 0 – 14. Breed effect: \( P = 0.007 \). \textsuperscript{a,b} Means with different superscripts differ \( P < 0.05 \).

Figure 3-10. Effect of castration technique on weekly feed intake d 0 – 84. Treatment effect: \( P = 0.92 \).
Figure 3-11. Effect of treatment*week interaction on weekly feed intake d 0 – 84. Treatment*Week: P = 0.05.

Figure 3-12. Effect of breed*week interaction on weekly feed intake d 0 – 84. Breed*Week: P = 0.04. * Means differ P < 0.05, ** Means differ P < 0.1.
Figure 3-13. Average weekly ambient temperature readings for Marianna, FL d 0 – 84.

Figure 3-14. Effect of castration technique on average daily feed intake as a percentage of BW on an as-fed basis d 0 – 84. Treatment effect: P = 0.75.
Figure 3-15. Effect of breed on average daily feed intake as a percentage of BW on an as-fed basis d 0 – 84. Breed effect: $P = 0.04$. a b Means with different superscripts differ $P < 0.05$.

Figure 3-16. Effect of castration technique on feeding behavior early post-castration. Treatment effect: $P = 0.34$
Figure 3-17. Effect of the treatment*day interaction on water intake d 0 – 14. Treatment*Day: $P = 0.005$.

Figure 3-18. Effect of the breed*treatment interaction on daily water intake d 0 – 14. Breed*Treatment: $P = 0.03$. a,b Means with different superscripts differ $P < 0.05$. 

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Figure 3-19. Effect of the breed*day interaction on daily water intake d 0 – 14. Breed*Day: \( P < 0.0001 \). Means differ \( P < 0.05 \).

Figure 3-20. Daily ambient temperature d 0 – 14 in Marianna, FL.
Figure 3-21. Effect of castration technique on weekly water intake d 0 – 84. Treatment effect: $P = 0.72$.

Figure 3-22. Effect of the breed*week interaction on weekly water intake d 0 – 84. Breed*Week: $P < 0.0001$. * Means differ $P < 0.05$, † Means differ $P < 0.1$. 
Figure 3-23. Effect of castration technique on G:F ratio d 0 – 14. Treatment effect: $P = 0.28$.

Figure 3-24. Effect of castration technique on G:F ratio d 0 – 84. Treatment effect: $P = 0.42$. 
Figure 3-25. Effect of breed on G:F ratio d 0 – 14. Breed effect: $P = 0.25$.

Figure 3-26. Effect of breed on G:F ratio d 0 – 84. Breed effect: $P = 0.002$. $^{a,b}$ Means with different superscripts differ $P < 0.05$. 
Figure 3-27. Effect of castration technique on RFI d 0 – 14. Treatment effect: $P = 0.1$. $a, b$
Means with different superscripts differ $P < 0.05$.

Figure 3-28. Effect of castration technique on RFI d 0 – 84. Treatment effect: $P = 0.93$. 
Figure 3-29. Effect of the treatment*day interaction on plasma ceruloplasmin concentration post-castration. Treatment*Day: $P = 0.02$.

Figure 3-30. Effect of breed on plasma ceruloplasmin concentration post-castration. Breed effect: $P = 0.19$. 
Figure 3-31. Effect of the treatment*day interaction on plasma haptoglobin concentration post-castration. Treatment*Day: $P = 0.0002$.

Figure 3-32. Effect of breed on plasma haptoglobin concentration post-castration. Breed effect: $P = 0.11$. 
Figure 3-33. Effect of the breed*day interaction on plasma haptoglobin concentration post-castration. Breed*Day: $P = 0.07$. *Means differ $P < 0.05$, **Means differ $P < 0.1$. 
**APPENDIX**
**DIET COMPOSITION**

Table A-1. Ration composition

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<tr>
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<tr>
<td>Molasses</td>
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<tr>
<td>Hay</td>
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Table A-2. Nutrient composition

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<td>ADF %</td>
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</tr>
<tr>
<td>NDF %</td>
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</tr>
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<td>TDN %</td>
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<td>NEL, Mcal/lb</td>
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</tr>
<tr>
<td>NEM, Mcal/lb</td>
<td>0.69</td>
</tr>
<tr>
<td>NEG, Mcal/lb</td>
<td>0.42</td>
</tr>
<tr>
<td>Ca %</td>
<td>0.46</td>
</tr>
<tr>
<td>P %</td>
<td>0.42</td>
</tr>
<tr>
<td>Mg %</td>
<td>0.24</td>
</tr>
<tr>
<td>K %</td>
<td>1.15</td>
</tr>
<tr>
<td>Na %</td>
<td>0.44</td>
</tr>
<tr>
<td>Fe ppm</td>
<td>313.00</td>
</tr>
<tr>
<td>Zn ppm</td>
<td>84.00</td>
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<tr>
<td>Cu ppm</td>
<td>24.33</td>
</tr>
<tr>
<td>Mn ppm</td>
<td>98.00</td>
</tr>
<tr>
<td>Mb ppm</td>
<td>0.43</td>
</tr>
<tr>
<td>S %</td>
<td>0.23</td>
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</table>
LIST OF REFERENCES


BIOGRAPHICAL SKETCH

Thomas Micajah Warnock III (Trey) was born in Plant City, Florida, in 1985, to Tommy and Pam Warnock. Trey was raised in Plant City and was actively involved in church, athletics, and The National FFA Organization. Trey graduated from Plant City High School in 2003 and then attended Hillsborough Community College to earn his Associate of Arts degree. In 2005, Trey began his academic tenure at the University of Florida where he quickly found his home in the Animal Sciences Department and Alpha Gamma Rho house.

While in the Animal Sciences Department, Trey worked for the IFAS Beef Teaching Unit under Mr. Jesse Savell. Trey also was fortunate enough to complete two beef industry internships while in his undergraduate program, one in Okeechobee, Florida for the Lykes Bros. Ranch, and the other in Benjamin, Texas for the Williamson Cattle Ranch. Trey completed his Bachelor of Science degree in 2008 and quickly began his graduate program the following semester. Trey worked on a master's degree under the supervision of Dr. Todd A. Thrift in Animal Sciences and continued to work at the Beef Teaching Unit, as well as being a teaching assistant for several animal science courses including cow/calf management, beef stocker and feedlot management, meats, livestock and carcass evaluation, and large animal practicum.