IMPLICATIONS OF CASTRATION ON CATTLE PERFORMANCE EFFICIENCY

by

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ABSTRACT

Castration of male beef cattle is a common management practice in the United States. Recent anecdotal evidence suggests improved outcomes from a modified castration procedure where an incision is made in the scrotum immediately following application of a band to the scrotum. Thus, we compared the effect of various castration methods on performance using crossbred steers and bulls purchased from Producers Livestock Auction Company, in San Angelo, TX (n = 262; initial BW = 304 ± 47 kg). Calves were blocked by arrival date and stratified by body weight. (n = 7 total pens per treatment). Bulls were randomly allocated to 1 of 3 treatments: 1) band plus incision using Callicrate Bander (BAND+; n = 67); 2) band only (BAND; n = 67); 3) surgical castration (SURG; n = 66). Steers castrated prior to arrival at the feedlot served as a control: 4) Control (CON; n = 62). Cattle were weighed on d 0, 33, and 61. Dry matter intake, ADG, G:F were recorded and calculated over the 61 d period. Steers castrated upon arrival had lesser ($P < 0.01$) ADG from d 0 to 33 compared to the control group. From d 34 to d 61, ADG did not differ($P = 0.69$) among. From d 0 to 61 all castration groups had lower ADG ($P < 0.01$) than control. Dry matter intake did not differ ($P \geq 0.21$) among treatment groups d 0 to 33, 34 to 61, and 0 to 61. Gain to feed was greater for control from d 0 to 33 ($P <0.01$) and d 0 to 61 ($P < 0.01$) then cattle castrated upon arrival. From d 34 to 61 BAND cattle tended ($P = 0.08$) to have greater G:F than BAND+

and CON treatment. Under conditions of this experiment, modifying the band method of castration by making an incision in the scrotum after band placement did not affect performance of male beef cattle castrated upon feedlot arrival. Regardless of method used castration following feedlot arrival reduced growth performance of male beef calves.

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CHAPTER I

REVIEW OF LITERATURE

Introduction

Castration of male beef cattle is a common practice in the United States, with noted benefits on social behavior during confinement feeding and subsequent improvement in carcass attributes. However, castration is a painful procedure and causes a period of reduced feed intake and growth rate. The tissue damage caused by castration, reduces ADG, DMI, and G:F (Fisher et al., 1997). Bulls grow more rapidly (15 to 17%), utilize feed more efficiently (10 to 13%) and produce greater yielding carcasses with less fat and more muscle than steers at a similar age or weight end point (Arthaud et al., 1969; Field, 1971; Seideman et al., 1982).

Several castration practices have been developed over the years, including surgical, band, band plus incision, burdizzo, and chemical castration. Surgical and band castration are 2 of the most common methods used in the United States and are also the primary focus of many research studies (USDA, 2008). Recently, the development of a new practice known as band plus incision has been implemented in commercial feedlots. Some anecdotal evidence suggests improved outcomes from this modified castration procedure where an incision is made in the scrotum immediately following application of a band to the scrotum.

Purpose of Castration

Castration's Impact on Cattle Behavior

Castration causes a reduction in aggressive behavior, which can increase economic return by reducing incidence of injury to both cattle and their handlers (Tennessen et al. 1985). This reduction in aggressive behavior is particularly important in confined feeding operations, as it has been shown that cattle housed in close confinement may express aggressive behavior (Hinde, 1969). By reducing aggressive behavior, castration also reduces bruised and dark cutting carcasses at time of slaughter, which reduces discounts incurred to the producers (Jones, 1995).

Hinde (1969) argued that in nature proximity of animal's locations to one another changed the animal's behavior responses, based on an analysis of aggressive behavior in birds, chimpanzees, and fish. This idea was supported by Kelley et al. (1980) who reported that a reduction in free space led to more frequent contact and aggressive behavior in swine. Group size is also important due to the effect of social facilitation. Behaviors such as grazing or feeding may be replicated by other cattle when it is observed. Therefore, the idea of replicating observed behaviors may also be related to homosexual mounting observed in cattle (Reinhardt et al., 1978). There is not a great understanding of the meaning of non-mating mounting activity by cattle. Reinhardt et al. (1978) observed mounting in both male and female cattle as a playful behavior and speculated that the behavior lacked "aggression". Geist (1971) observed Bighorn rams mounting males lower in the hierarchy and related this behavior to both agonistic and sexual role. Mohan et al. (1991) reported bulls mounting each other was greater than bulls mounting steers. This suggested both antagonistic and sexual motive to establish dominance among bulls.

Tennessen et al. (1985) compared the behavior of bulls and steers. They reported that both bulls and steers appeared to fight when initially introduced to unfamiliar cattle; however, at all ages, bulls were found to be more aggressive. Over time, bulls also maintained a greater frequency of mounting than steers. The sexual and aggressive behavioral differences between bulls and steers are directly related to circulating hormone differences, with greater levels of aggression often appearing at the onset of puberty (Tennessen et al., 1985). An increase in testosterone during breeding season can lead to a rise in aggressive behavior in intact males. Steers were 63% less aggressive than bulls at age 9 months, furthermore, as cattle aged the gap between their aggressive behaviors increased. Steers exhibited only 32% of the number of aggressive acts of bulls by 12 months (Tennessen et al., 1985).

Hinch et al. (1982) made observations of bulls and steers in a pasture setting to determine the differences in overall activity and aggression. Bulls were mounted more often than steers, the frequency of mounting increased between 12 and 14 months of age and continued to do so until 18 months in bulls and not in steers. They also observed that bulls were socially more active than steers, this being greater as the cattle aged. Furthermore, pawing and goring levels significantly were greater for bulls than steers, but this effect was not significant until 18 months (Hinch et al., 1982). The authors observed 2 bulls performing approximately 20% of the head-pushing and 2 bulls appeared to receive 20% of the head-pushing and 25% of the mounting. Overall, castration appeared to delay the onset of aggressive behavior patterns especially for head butting and threat activities (pawing/goring) at older ages.

Growth and Carcass Attributes of Bulls and Steers

Bulls have been shown to grow more rapidly (15 to 17%), utilize feed more efficiently (10 to 13%) to a similar age or weight end point, and produce greater yielding carcasses with less fat and more muscle than steers (Field, 1971; Seideman et al., 1982). Biagini and Lazzaroni (2011) reported intact males had greater final carcass weights than cattle castrated at 5 and 12 months. Also, bulls had increased empty body weights (EBW), total blood, and head weight than steers castrated at 5 and 12 months of age (Biagini and Lazzaroni, 2011).

Castration reduces production of androgen hormones, which may reduce live weight, depending on the management system (Biagini and Lazzaroni, 2007). Castration can affect the masculine somatic characteristics (secondary sexual traits) and steers end up in a neutral morphological type between bulls and heifers. This leads to reduced development of the fore body muscles causing the neck and shoulders to be less muscular in steers than bulls (Biagini and Lazzaroni, 2007). It has been observed that bone growth differs between bulls and steers. The head and limb long bones show a different and prolonged growth in steers versus bulls (Biagini and Lazzaroni, 2011).

Butting is another behavior that is observed in cattle with more aggressive temperaments. Mohan et al. (1991) found that butting was significantly correlated with mounting and teasing and was observed most frequently in intact bulls, followed by steers, and then by vasectomized bulls. Mohan et al. (1991) also observed butting behavior of the bulls could be severe, ranging from a simple butt at the shoulder to butting of the flank and lifting of the hindquarters of the receiver off the floor.

Aggressive behavior of cattle directly prior to slaughter can lead to dark-cutting or dark firm dry (DFD) beef (Tennessen and Price, 1981). Dark firm dry is a direct consequence of physical activity or emotional stress prior to slaughter (McVeigh et al., 1982). Dark cutting meat is most common in carcasses from bulls than steers (Tarrant, 1981). Dark cutting meat is associated with having a greater pHu (pH ultimate) ($pH > 6.5$). This condition occurs when glycogen levels in the muscle at slaughter are lower than normal. This in turn results in less lactate production post- mortem and a greater pH level (Maltin et al., 2003). Research concerning the tenderness of DFD meat has been inconclusive, as some studies have found it to be more tender (Dansfield, 1981), while other studies have shown this type of meat to have greater shear force values (Wulf et al., 2002). Burson et al. (1986) and Dikeman et al. (1986) found that in most cases, meat from bulls was more variable in tenderness than meat from steers. Meat tenderness is important, as it has been identified as being closely related to the overall acceptability of beef by consumers (Chambers and Bowers, 1993). In the study conducted by Morgan et al. (1993), bull longissimus muscle had greater shear force values and lower myofibril fragmentation index (MFI) than steers. The cause for tenderness differences between bulls and steers is not well understood.

Koohmaraie (1988) indicated that the calpain proteolytic system plays a major role in postmortem tenderization. The amount of μ- calpain actively remaining has an inverse relationship to proteolysis and tenderization that has occurred during the postmortem storage (Koohmaraie, 1988). Morgan et al. (1993) reported that 24 hours postmortem μ- calpain activity tended to be greater in bulls than steers and bulls had consistently greater shear force values. Other research suggests that μ- calpain is the enzyme component that has the most significant role in post-mortem proteolysis and therefore meat tenderization (Kemp et al., 2010).

Calpastatin activity, which is an endogenous calpain inhibitor, also differs between bulls and steers. Morgan et al. (1993) observed an 81% increase in calpastatin activity within the longissimus muscle of bulls at 24 hours postmortem than from steers. The authors believed that the greater calpastatin activity in bull longissimus muscle likely decreased the amount of myofibrillar proteolysis by μ- calpain over the 7 day period and resulted in less tender meat (Morgan et al., 1993). Whipple et al. (1990) had similar findings, they observed increased tenderness in steers and heifers related to the 24- hour postmortem calpastatin activity and myofibrillar proteolysis compared to bulls (Whipple et al., 1990).

Another potential cause for increased toughness may be due to greater levels of connective tissue in bulls compared to steers (Riley et al., 1983; Crouse et al., 1985). Jeong et al. (2013) found evidence that castration may shift transcription of lipid metabolism genes in a manner that favors deposition of intramuscular fat. The lipid metabolism genes are involved in increasing adipogenesis, lipogenesis, and triglyceride synthesis (Jeong et al., 2013). However, further research is needed in this area to clarify the specific genetic pathway involved in tenderness.

Morgan et al. (1993) showed that bull carcasses had lower adjusted fat thicknesses, kidney, pelvic, and heart fat percentages, USDA yield grades, and larger longissimus muscle area. Steer carcasses had greater marbling scores and USDA quality grades. Others research suggests that there is no difference in tenderness between bulls and steers when slaughtered at comparable ages (Ntunde et al., 1977; Riley et al., 1983; Calkins et al., 1986). The differences observed between these studies and others, could be related to how carcasses were handled post mortem, or how the scientists chose to measure tenderness.

Morgan et al. (1993) evaluated sensory characteristics and hypothesized that greater shear force values in bulls would be detectable by a trained the sensory panel. However, the overall tenderness observed by the sensory panel only tended to be greater in meat from steers. Purchas et al. (2002) found bull meat to be tougher than steers using a Warner-Bratzler device, MIRINZ tenderometer, and the Instron compression measurement. Purchas et al. (2002) also used sensory evaluation to evaluate the tenderness, bulls ranked greater in 4 aspects of toughness including hardness, cohesiveness, toughness, and chewiness.

Along with tenderness, another influential factor on meat palatability is the level of marbling. Purchas et al. (2002) found that steers were fatter than bulls at the same carcass weight for all measures of fatness. Sensory panels confirmed that meat from bulls was less juicy than meat from steers. This may be attributed to 30% less intramuscular fat levels in bulls than steers (Purchas et al., 2002). Gregory and Ford (1983) also reported castrated males had greater fat thickness at the 12^{th} rib and greater marbling scores than intact males.

Greater levels of collagen can lead to less tender meat and effect overall palatability. Collagen is the most prevalent protein in mammals and it is made up of amino acid chains twisted around each other (Freeman and Company, 2000). This type of structure makes collagen strong and difficult to break down during cooking. Previous research reported there to be greater levels of collagen in bulls than steers (Cross et al., 1984; Klastrup et al., 1984) while others have found no gender differences (Crouse et al., 1985; Unruh et al., 1987).

Castration Methods

Castration is performed on male beef cattle to reduce sexual behavior, aggression, and improve meat quality; however, castration does have negative effects on health and performance. Castration practices are reported to reduce dry matter intake (DMI) and average daily gain (ADG), and increase serum cortisol and haptoglobin concentrations (Faulkner et al., 1992). These factors would indicate that there is both a physiological and an inflammatory response from castration.

Over the years several different castration methods have been developed such as surgical, band, burdizzo, chemical castration, hormonal, and recently, modifications to the band process such as banding plus making an added incision vertically down the scrotum have been proposed. Of these methods surgical and banding have been reported to be the most common (USDA, 2008), while banding and surgical castration also appear to be the focus of many studies (Moya et al., 2014; Warnock et al., 2012; Fisher et al., 2001).

Surgical castration involves making an incision through the skin of the scrotum either vertically or horizontally. Next the testicle is pulled through the incision, parietal tunic and visceral tunic membrane. A tough cord can be found at the top of the testicles containing the artery, veins, and spermatic cord. An emasculator can be used to crush and cut through the blood vessels and spermatic cord, which may reduce the chance of excessive blood loss post-castration. This procedure must be done to both sides of the scrotum. (Anderson, 2007). Surgical castration has some negative effects associated with it including; infection, hemorrhage, and in severe cases death (Gregory and Ford, 1983).

Band castration involves placing a band above the scrotum around the outside of the spermatic cord. This technique stops the blood flow to the testicles and eventually causes them to dry up and fall off. Smaller and younger calves are typically banded with an elastrator, elastrators are an instrument that simply allow the bands to be stretched far enough to go around the scrotum. They do not however apply any extra pressure to the area other than the bands pressure itself. High-tension banders such as the callicrate bander (No-Bull Enterprises, LLC St. Francis, KS) are used for larger and older calves. This type of bander makes it easier to band larger scrotums that are found on larger calves. They also have ratchets and tensioners that ensure that enough tension is applied to fully stop blood flow to the testes. A vaccination against tetanus at the time of banding to help prevent anaerobic infections is commonly recommended by veterinarians. Improper use of the bander, faulty bands, or not placing both testicles into the band can cause problems such as the testicles not fully losing blood flow. This may extend the time required fortesticles to fall off or allow a localized infection to set in (Anderson, 2007). Petherick et al. (2014) noted the use of tension banders on younger calves may not achieving the correct amount of pressure to stop blood flow to the testicles, this can lead to delayed loss of the testicles.

Another method of castration involves the use of a burdizzo instrument. The burdizzo instrument is placed above the scrotum around the spermatic cord and is restrained around the cord for about 10 seconds. This procedure is used to stop the blood flow to the testicles, and therefore kills the testicles. It is important that the instrument be in good condition for this procedure to be done effectively. The testicles usually swell after the procedure is done and eventually shrink in size (Anderson, 2007). Considerable knowledge of the anatomy and skill in the application of the burdizzo instrument are needed to provide a successful castration.

A novel method that some feedlots have started to implent involves the typical band procedure plus an incision made vertically through the outer layer of skin of the scrotum on both sides. It is hypothesized that the scrotal incision increases the rate desiccation and loss of testicles. Little research has evaluated the efficacy of this modified castration procedure.

Castration can be achieved in male cattle without physical damage to the testes or invasive surgery. Chemical castration involves injecting a toxic agent into the testicular parenchyma to cause unchangeable damage and loss of function. This method typically requires additional procedural time and a highly trained individual to perform the practice. Hormonal castration (immunocastration) uses an injection of an immunocontraceptive to induce antibody production against gonadotropin releasing hormone (GnRH), resulting in decreased production of endogenous hormones. This method requires repeated injections (AVMA, 2014). The use of immunocastration has been studied for its possible benefits in reducing aggressive behavior. The use of immunization against GnRH provides an alternative to surgical or band castration and helps eliminate some of the health and growth disadvantages associated with other castration methods (Robertson et al., 1994). Immunocastration against gonadotropin-releasing hormone was shown to reduce the secretion of testosterone, size of testicles, aggression and sexual behavior; but this effect only lasts for 6 months (Adams et al., 1993). Robertson et al. (1982) reported more frequent mounting activity by the immunocastrated cattle than bulls, which could potentially result in more injuries and dark cutters (Robertson et al., 1982). Price et al. (2003) found that immunocastration reduced butting and sparring to levels observed in steers. This practice is unlikely to be adapted any time soon due to the consumer concerns, technical difficulties, and the need for repeated injections (Finnerty et al., 1994). Overall, it appears that all forms of castration are a useful means for reducing the aggressive behavior that is associated with bulls.

Many studies use control groups that are made up of either all steers or all bulls. Bulls are used in some papers, however, in order to avoid the anabolic effects that are associated with the testosterone production in bulls, steers (castrated pre-puberty or prior to study) are often used as a control group. These factors can make it difficult to separate the effects of gender from the effects of castration. To help clarify these differences, one study compared the outcomes of cattle that had been castrated 3 months prior to the study, intact males, and cattle that were castrated at 8 months of age, or on day 69 of their study (Devant et al., 2012). It was observed that ADG and DMI were reduced during the first 2 weeks after castration had taken place, compared to the bulls or steers. (Devant et al., 2012).

Furthermore, bull's meal size was larger during the 2 week period. Devant et al. (2012) observed that bulls had greater meal duration and meal size throughout the 2 week period following the castration event compared to the recently castrated cattle and the control steers. They also observed that bulls visited the bunks less frequently than the other treatment groups (Devant et al., 2012).

Along with the differences that can be observed in bulls, steers, and recently castrated cattle, there are also differences between castration practices. In order to understand these differences, ADG is often used to measure the differences between treatments. Average daily gain can be related to the cattle welfare issues such as stress and pain caused by different practices. Stress can reduce feed intake, as cattle may be reluctant to spend time at the bunk (González et al., 2010).

González et al. (2010) observed recently castrated cattle actually increased their number of daily meals compared to steers or bulls. They hypothesized that the difference in eating behavior between bulls and control steers (castrated previously) during the 2 week period following castration was due to the bulls being stressed. They estimated that the stress came from the extra movement the bulls had during this time through the chute and processing facilities, as all cattle were handled alike. The extra handling and management practices that take place during castration would lead to greater stress levels in the bulls and the castrates. (Field, 1971).

Moya et al. (2014) found that ADG and feed intake were lower in surgically castrated cattle than in non-castrates and banded cattle during the first week after castration in both of their experiments. Banded cattle had lower feed intake and ADG on weeks 2, 3, 6, and 7 after castration when compared to non-castrates. Surgical castration is reported to result in strong acute pain and immune system response, while banded cattle tend to have these affects over a longer period of time until the scrotum falls off (Moya et al., 2014; González et al., 2010; Fisher et al., 2001). Moya et al. (2014) reported a greater intake per meal and greater number of visits per meal for banded individuals than control cattle or surgical castrated cattle. Moya et al. (2014) also observed that surgical cattle had lower meal duration during the first week after castration.

Repenning et al. (2013) found no difference in ADG between band and surgically castrated cattle. The use of ketoprofen (nonsterioidal anti-inflammatory drug with analgesic effects) may be related to the difference in ADG observations between this study and the Moya et al. (2014) study. Repenning et al. (2013) reported dry matter intake being greater in banded cattle than in surgical cattle on day 1 after castration, however no difference in DMI was observed after day 1. They reported that banded cattle had greater meal duration during the first week after castration than surgical. The banded cattle had shorter meal durations on days 12, 14, and 19; they hypothesized that this was evidence that the surgically cattle experienced an acute response, while the banded individuals had a delayed response (Repenning et al., 2013).

Warnock et al. (2012) indicated that from days 7 through 28 banded calves gained less compared to control steers, bulls, or the surgical treatment group. They also observed that all castration practices had decreased ADG compared to the control group during the first 14 days after castration, but after the initial 14 days was over the ADG of all cattle on study were similar. Dry matter intake was observed to be less in surgically castrated calves than control or banded calves in the first days after castration. On day 10, they indicated that banded calves tended to have a decreased feed intake compared to the control and surgical calves (Warnock et al., 2012).These results combined with Fisher et al. (1996) indicate that there may be a delayed DMI response due to a delayed pain and inflammation response in banded cattle. Fisher et al. (1997) found that surgically castrated cattle ate less than intact male calves from days 0 to 7 after castration, however had similar DMI from day 8 through 28.

Other methods besides DMI and ADG can be used to look for the stress responses in cattle including; the use of plasma cortisol concentration, haptoglobin concentrations, rectal temperature, and behavioral responses. It was observed that animals either increase or decrease their activity in an attempt to avoid painful stimuli (Chapman et al., 1985). Therefore, monitoring of their behavior has been shown to be a good indication of the pain that is associated with a practice. Behavioral responses can include kicking, stamping, lying and standing bouts, and overall movement. These activities are viewed as the cattle trying to escape the pain (Robertson et al., 1994).

Robertson et al. (1994) observed that banded calves had a greater level of restlessness, foot stamping, and head turning than the burdizzo or surgical groups. They also observed that all castrated groups of calves spent significantly less time suckling than the control calves. They observed that normal lying was also significantly less in banded calves than in burdizzo, control, or surgically castrated calves. While the banded calves hand an increased amount of abnormal lying, which is lying in a ventral position rather than a lateral position. Robertson et al. (1994) observed that there was a greater time spent for all abnormal posture for the banded cattle than for any other treatment group, except surgically castrated cattle on day 42.

Devant et al. (2012) observed that lying time was reduced for castrates for the first 5 days after castration. Level of activity was measured by steps per hour, and bulls showed greater levels of activity than steers. They observed that the activity of steers was 54% less than that of bulls throughout the study. It was reported that the activity of recently castrated cattle decreased at day 4 after castration and remained less than bulls and greater than that of steers throughout the duration of the study (Devant et al., 2012). The reduction in activity may be due to a reduction in serum testosterone after castration. This in turn leads to reduced sexual and agonistic interactions among cohorts.

Molony et al. (1995) observed greater restlessness, foot stamping, stretching and other activities in banded cattle than in burdizzo, control, or surgically castrated cattle. They also observed that time spent standing abnormally was significantly greater in all castrated cattle when comparing them to the control group (Molony et al., 1995). Molony et al. (1995) reported that surgically castrated, banded, and banded combined with burdizzo procedures all resulted in increased abnormal lying compared to the control steers. The authors did not find a difference between the control group and the burdizzo treatment group. González et al. (2010) determined calves banded tended to spend less time lying down as compared to those who were castrated previously (31.4± 3.00% for steers and 24.2 ± 3.00% for those later castrated). González et al. (2010) also observed that length of steps measured for the hind legs were less for those calves castrated later than those that were castrated at younger ages.

Many studies have used acute cortisol response as a method to evaluate the duration and level of pain that is caused by castration of cattle (Chase et al., 1995; Molony et al. 1995). Cortisol concentrations fluctuate based on the level and duration of a stress event (Coetzee, 2011). Robertson et al. (1994) observed peaks in plasma cortisol concentration (PCC) values shortly after the operations were completed for surgical and burdizzo treated cattle with the surgically treated cattle peaks being highest. Banded cattle showed a smaller peak similar to the control group shortly after the operation was performed. The greater levels were maintained for longer in the banded cattle than the other treatment groups (Robertson et al., 1994).

Becker et al. (2012) found no difference in cortisol concentration when comparing traditional rubber ring castration, 1 rubber ring plus Burdizzo, rubber ring plus cutting off the scrotal neck at day 9, and control bulls. Becker et al. (2012) took blood samples at a less frequent rate than Robertson et al. (1994), this may not have allowed Becker et al. (2012) to observe similar peaks. Petherick et al. (2014) found there to be an increased cortisol concentration in mature banded cattle compared to mature bulls that were surgically castrated, at 2 and 4 weeks post castration. They also observed, that at 24 hours the surgically castrated treatment group had greater cortisol levels than banded cattle (Petherick et al., 2014).

Serum haptoglobin concentration provides another method for measuring stress. Haptoglobin is a protein that is undetectable in the blood of healthy animals, but with the presence of infection or inflammation caused from tissue damage, the animal's liver produces haptoglobin in abundance (USDA, 1996). No significant difference was observed by Fisher et al. (2001) in haptoglobin level between intact and banded male cattle. Greater serum haptoglobin was observed in surgical cattle versus intact cattle (Fisher et al., 2001; Faulkner et al., 1992; Lyons-Johnson, 1998). Petherick et al. (2014) observed that the haptoglobin concentrations were greater in surgically castrated cattle on days 2, 3 and 1-week post-surgery, while banded cattle had greater haptoglobin levels at week 2 and 3 post castration. The authors also observed these levels remained greater than surgically castrated cattle until week 4 post castration. These results suggest that surgical castration may results in a more immediate response while band castration has a delayed response.

Becker et al. (2012) also used the visual observation of necrosis of the scrotal tissue as a measurement of acute and chronic pain and assessment of time for the wounds to completely heal. Necrosis began 7 (± 2) days post castration in all castrated groups. Furthermore, some researchers also observe the time it takes to slough the scrotal tissue. Becker et al. (2012) reported that it took 42 days with the traditional rubber banded calves and 30 days in the banded plus burdizzo cattle. Becker et al. (2012) determined the calves that were banded and had their scrotums removed on day 9 exhibited shorter healing time compared to traditionally banded cattle. González et al. (2010) determined only 60% of the cattle had lost their scrotums by the end of day 42, but by day 50, 84% had lost them.

Fisher et al. (2001) and Knight et al. (2000) indicated that complete loss of scrotum and content was observed as early as 28 days after banding and as late as day 56 after 14-month-old cattle were castrated. Other researchers found that rubber band castrated calves lost their scrotum and contents as early as 5 days and as late as 35 days in 21-month-old cattle (Chase et al., 1995). A possible difference between these studies may be the age at which the cattle were castrated and the amount of pressure that was applied by the band to stop blood flow to the testes and lead to degeneration and further loss of the scrotum.

Molony et al. (1995) reported that male cattle surgical castrated had a shorter healing time than banding. They observed that the peak tissue damage for the banded cattle was between 27 and 30 days, which they reported to be the time for the rubber band and scrotum to fall off. It was also reported that surgically castrated cattle had swelling for less than 9 days, while Burdizzo castrated cattle increased swelling for 2 days and then appeared to decrease over a 15 day period. In the banded cattle and banded plus burdizzo treatment groups severe swelling, inflammation, and infection was observed proximal to the rubber ring. The severity of the lesions peaked between days 15 and 18 in the combination treatment group and on days 27 and 30 in the banded group as mentioned previously. Mintline et al. (2014) observed that the first fully healed wound for surgical cattle was on day 28 and that 98% of the wounds were fully healed by day 63. Peak wound healing for surgical cattle in this study occurred from days 21 to 35. This was accompanied by increased surface temperature, which could be related to revascularization of the wound site.

Petherick et al. (2014) reported that surgically castrated cattle's scrotums measured 16.7 cm before treatment and on day 1 after treatment they measured 24 cm, then remained swollen for the first 3 weeks post-treatment before they contracted to 16 cm and remained there for the remainder of their 2 month trial. Banded cattle had increased wound scores from weeks 2 to 4 compared to surgical treatment group, until they were fully healed at 2 months post-castration. Petherick et al. (2014) concluded that surgical castration had superior welfare advantages for both young and mature bulls compared to tension banding in relation to chronic inflammation, pain, and wound healing.

Along with the common techniques discussed above, there are also some new methods of castration that have been evaluated. These include chemical castration and immunocastration. Cohen et al. (1990) found that chemical castration had decreased cortisol concentration levels as compared to surgical cattle following treatment. In order for this method of castration to be successful, individuals performing the operation must be trained properly, a point made apparent by Hill et al., (1985) in which 25% of the calves were not castrated properly.

Surgical castration has a more acute effect on blood parameters, feed intake, and ADG, while banded treatment groups appear to have a delayed response. Some researchers also observed that once past these initial time periods the cattle had similar ADG and feed intakes as other control cattle. Immunocastration and chemical castration are not yet useful in today's production settings but may become more useful as the public pushes for practices that they view to be more humane. Overall, there have not been conclusive findings that any method of castration is more practical or beneficial than the others, as many research studies vary in their finding.

Timing of Castration

During puberty testes primarily produce androgens, the most prevalent androgen is testosterone. Androgens are responsible for the development of male accessory organs, external secondary sexual characteristics and male behavior (Steen, 1995). Average daily gain can be increased up to 19% than that of steers with an increase in average daily feed intake by 3% due to anabolic properties of the androgens found in bulls (Steen, 1995). Knight et al. (1999a) suggested using a system that utilized post-pubertal castration of calves, followed by a finishing period as steers. They believed that this would allow for the production benefit of bulls and the meat quality benefits of the steers (Knight et al., 1999a). It was found with further research, however, that steers were not able to maintain all of the weight they had gained during their period as bulls, reducing the benefits of leaving the calves as bulls for a longer period of time (Knight et al., 1999b).

Mellor et al. (1991) drew blood samples to measure plasma cortisol concentration and reported that stress may be greater in older cattle than in younger cattle. Ting et al. (2005) also found that plasma cortisol response was less for 1.5 to 4.5 month old calves compared to 5.5 month old calves when using the Burdizzo method. It was also observed that the 1.5 month old calves had the lowest plasma cortisol concentration values of all of the age groups (Ting et al., 2005). Bretschneider (2005) found that weight loss increased quadratically as age of castration increased. These results indicate that castration at birth or close to birth reduces the castration associated weight loss. This was also observed by Champagne et al. (1969) and Worrell et al. (1987) as both studies observed calves castrated close to birth did not differ in weight from those castrated at weaning. Bretschneider (2005) also observed that calves castrated at weaning had increased weight loss, which put them at a weight disadvantage compared to those castrated at or near birth.

Bretschneider (2005) determined the weight loss that was occurred post-castration was due to an apoptotic process in the main testosterone-responsive muscle regions, which would be triggered by the testosterone withdrawals. It is thought that the removal of some testosterone from circulation leads to apoptosis or death of the target cells and reduction of a given area associated with those target cells (Duvall and Wyllie, 1986). In cattle, testosterone has a direct effect on specific receptors and muscle groups, including those in the neck and shoulder region where a greater number of testosterone receptors are present (Devine and Dikeman, 2004). Another part of the contribution towards this weight loss was the reduction in intake. Bretschneider (2005) found intake to be 20.5 ± 5% less during the first 2 weeks post-castration.

The observation of N retention and efficiency in cattle are other ways of evaluating the timing of castration. Biagini and Lazzaroni (2011) observed cattle castrated at 5 months had lower N retention than cattle castrated at 12 months. Both of these treatment groups had a lower level of N retention than cattle that were left intact throughout the 12 to 18 month period (Biagini and Lazzaroni, 2011). The castrated 12-month cattle had greater N use efficiency than those cattle castrated at 5 months in the 5 to 12 month period. In the period from 12 to 18 months the cattle castrated at 5 months had greater N use efficiency than those castrated at 12 months.

Other studies have focused on comparing banding or surgically castrating cattle shortly after arrival at feedlots to the purchase of steers. Berry et al. (2001) found that cattle that were castrated prior to arrival at feedlots gained 0.26 kg more and consumed 0.57 kg more feed per day than cattle that arrived at the feedlot as intact males and were castrated shortly after over a 42 day period. They found that banding bulls with latex rings shortly after arrival lead to a 16% decrease in ADG compared to the purchase of steers. González et al. (2010) determined ADG was less for those cattle that were banded on day 20 of their experiment compared to steers that had been previously castrated at 34 ± 10 days of age.

Fisher et al. (2001) observed cattle castrated post-puberty finished with a slaughter-weight equal or lower than cattle castrated pre-puberty. Researchers have also observed a linear trend for increasing fatness with decreasing age at castration. Knight et al. (2000) observed that there was no effect on carcass weight of steers castrated at birth compared to those castrated after puberty. Other researchers have not observed any difference in bone development, circumference of the cannon, height of the withers, or width of the hooks when comparing calves that were castrated at one month versus those castrated at older ages (Bagley et al., 1989). Some producers castrate when they wean the calves (USDA, 2008). Weaning itself has several adverse effects associated with it even without castration being a part of the process. This process predisposes calves to stress-associated infectious diseases (Kelley, 1985). It may be beneficial to castrate earlier not only for reduced weight loss but also reduced overall stress on the cattle.

Measurement of stress through PCC and haptoglobin of the cattle are also important observations, as the welfare of the cattle is becoming more of a focus by the public. Bretschneider (2005) observed that the stress response based on plasma cortisol concentration levels was lower in cattle castrated at≤ 6 months of age than those that were castrated at ages > 6 months. Lyons-Johnson (1998) and Bretschneider (2005) observed that the younger calves are castrated the less stress that was measured by the haptoglobin levels. Behavioral observations of different aged calves have led to similar conclusions. Robertson et al. (1994) observed less violent activity, less time in abnormal positions by 6-day-old calves, while the 42-day-old calves showed the most visible signs of pain.

Pain Medication Associated with Castration

As the public becomes more involved in the ruling of how procedures can be carried out with livestock, more focus will be placed on alleviating the pain that is associated with castration of cattle. Available methods of reducing the stress and pain that are typically associated with castration include local anesthesia and the administration of analgesics (AVMA, 2014). There are currently no analgesic drugs that are specifically approved for the use in livestock. Therefore, any drug that is used for pain relief in livestock would be classified as extra-label drug use (Smith et al., 2008). This type of use is permitted for pain abatement provided specific circumstances are met, under the Animal Medicinal Drug Use Clarification Act of 1994 (USDA, 1994). Drugs containing opioids are also subject to regulation by the U.S. Drug Enforcement Administration (Coetzee, 2011).

Another problem that can be associated with providing pain medication to cattle is the delayed onset of the medicine between application time of the drug and the analgesic activity. The added time that would need to be taken for the drugs to be completely affective would require additional handling of the cattle or would slow the cattle processing (Coetzee, 2011). Analgesics are used before castration to help lessen the incisional and inflammatory phase of the pain response by the animal. Several different analgesics are available such as, nonsteroidal anti-inflammatory drugs (NSAIDs) and sedative-analgesic combinations of opioids, α2-agonists, and *N*-methyl D-aspartate receptor antagonists (Coetzee, 2011).

Several studies have shown a reduction in PCC with the use of a multimodal analgesic protocol (González et al., 2010; Stewart et al., 2010; Stafford et al., 2002); however, few studies have focused on the practical use of these protocols. Regulatory concerns, the increased cost, and the added processing time to use the drugs have kept these processes from becoming a reality in today's production systems (Coetzee, 2011). More research and drug approval for the use in livestock will be needed before these practices can be fully adapted into today's cattle industry.

To conclude, castration reduces aggressive behavior in male cattle and improves overall meat quality, which is important in order to meet consumer expectations.

However, there are efficiency losses to the production system and added levels of stress to the cattle associated with the various castration practices, the need for improved efficiencies lead to our investigation of novel castration practices, as a means of improving performance and welfare of male cattle at the feedlot.

CHAPTER II

EVALUATION OF CASTRATION METHODS IN WEANED BEEF CATTLE

Introduction

Castration of male cattle is a common practice in the United States, as it reduces sexual activity, aggressive behavior (Tennessen et al., 1985), and the number of dark-cutting carcasses (Tarrant, 1981). However, castration of feedlot age cattle reduces ADG, DMI, and G:F when compared to males castrated at a younger age or left intact (Faulkner et al., 1992; Fisher et al., 1997). Many studies have focused on band castration versus surgical castration, as they are the most common practices used in the cattle industry (USDA, 2008). Several studies have found no performance difference between surgical and band castration techniques (Repenning et al., 2013; Bretschneider, 2005; Petherick et al., 2014). In contrast, Fisher et al. (2001) found that surgically castrated cattle had greater ADG compared to banded cattle.

The combination of band plus incision castration is currently being used in feedlots with speculation that it allows the testicles to enter the desiccation process earlier and the calf to lose the testicles faster. A decreased healing time could potentially reduce the level of stress to the cattle and decrease the economic repercussions associated with castration. The purpose of this study was to compare the band plus incision practice to band and surgical castration cattle alone. We hypothesized that the band plus incision practice would have increased ADG and improved feed efficiencies compared to the other castration practices.

Materials and Methods

Animals and Treatments

This project was approved by West Texas A & M University/ CREET Institutional Animal Care and Use Committee (protocol number 01-11-14).

Two hundred and sixty-two medium to large frame 1 crossbred steers and bulls purchased from the Producers Livestock Auction Company, San Angelo, TX (initial BW = 304 ± 47 kg) were used in this experiment. Cattle were procured between August 2014 and June 2015 and blocked by their arrival date (7 blocks). Initial processing occurred upon arrival to the feedlot, cattle were acclimated to the environment for at least 30 days before castration occured. This was done to reduce confounding of the expected motility and morbidity that occurs after cattle arrive to the feedlot and those associated with castration. Control steers **(CON)** were castrated prior to arrival at the feedlot (n = 62) with no evidence of existing castration wounds. Bulls were stratified by body weight and randomly allocated to 1 of the 3 treatment groups: 1) band plus incision (**BAND+**; n = 67); 2) Band only (**BAND**; n = 67); 3) Surgical castration (**SURG**; n = 66). The treatments were randomly allocated to pens with 1 pen per treatment for each block (n = 7 pens per treatment).

On d 0 of the study cattle were moved through the processing facilities and restrained in a hydraulic chute. All cattle were implanted with Revalor XS (Merck

Animal Health, Madison, NJ). The BAND+ cattle were banded using a Callicrate bander (No-Bull Enterprises, LLC St. Francis, KS). Bands were placed proximal to the testes and tension was applied using the ratchet, a metal grommet was then crimped around the band to hold the tension, which disrupts blood flow to the testes and scrotum. An incision was made vertically down each side of the scrotum extending from the distal 1/3 of the ventral aspect of the scrotum to the bottom tip of the testicle. The incision was made through the parietal and visceral tunics and the body of each testicle. A utility knife was used to make the incision, this type of knife provides the proper strength and stability needed to safely make the incision.

The BAND cattle were castrated using the same technique listed above but without the addition of the incision. All BAND+ and BAND cattle were given Covexin 8 (Merck Animal Health, Madison, NJ) to vaccinate against tetanus. The SURG cattle were castrated using the open surgical castration practice. For this procedure an incision was made vertically from dorsal to ventral on the lateral aspect of the scrotum. The testicle was separated from the tunic vaginalis and the testicle is removed from the scrotum. The spermatic cord located at the top of the testicles which contained the artery, veins, and vas deferens. The vas deferens was separated from the blood vessels with a scalpel followed by a pulling motion that separated the blood vessels.

Six calves were removed from study during the first period from d 0 to 33. One calf was removed on d 0 due to a high initial temperature reading, 2 were removed due to improper record keeping, and 3 were removed due to bands breaking the day after treatments were applied. The cattle that were taken off of study were not included in calculations.

Performance Data Collection and Feed Efficiency

Body weight was measured on day 0, 33, and 61 on average. Not all blocks were weighed on the same day of the experiment. The ADG was calculated by subtracting the day 0 total pen pounds from the total pen pounds on the last day of the period this was then divided by the total pen head days. Period head days were calculated by multiplying the head count in a given pen times the number of days in the period. Total pen pounds were calculated as the sum of weight for all calves in a given pen on day 0, 33, and 61.

The diet for this study can be found in Table 2.1. Daily feed offered (DFO) and Orts were recorded by pen and DM were recorded for the ration on a daily basis. Orts were subtracted off of each pens DMO (dry matter offered) during calculations. If DM were not recorded for a day, the 5 day average was used. Daily feed offered was multiplied times the DM percentage for each day to find the DMO. The DMO values for each day for a given pen were summed together to get the total DMI for d 0 to 33, 34 to 61, and 0 to 61. Gain to feed ratios were calculated by dividing the gain for each pen by the total DMI for d 0 to 33 and 34 to 61.

Mortality and morbidity data were recorded throughout the period. Morbidity was calves were determined to have a temperature ≥ 104.0 and morbid cattle were treated with Resflor Gold (Merck Animal Health, Madison, NJ). No cattle required a second treatment throughout the experiment.

Statistical Analysis

Normality of initial pen pounds (IPP), final pen pounds (FPP), DMI, G:F, Head Days, and ADG was assessed by evaluating the distribution of residuals using the PROC Univariate function of SAS (SAS Inst. Inc. Cary, NC) Homogeneity of variance was checked using the Levene's test in PROC GLM function of SAS.

Average daily gain for each period (d 0 to 33, d 34 to 61, and d 0 to 61), DMI, and G:F were analyzed using the MIXED procedure in SAS (SAS Inst. Inc., Cary, NC). Pen was considered the experimental unit. Class variables included treatment, block, and lot. Block was considered the random variable. Means were separated for comparison using the PDIFF function. All of the variables with ($P \leq 0.05$) were considered significant.

Results and Discussion

Initial BW did not differ ($P = 0.62$) among treatment groups; CON cattle weighed more ($P < 0.01$; Table 2.2) at d 33. Final BW did not differ ($P = 0.17$) among the treatments. On d 0 through 33 all castration treatments had lower ($P < 0.01$) ADG than the CON. From d 34 to d 61, ADG did not differ ($P = 0.69$) among treatments. From d 0 to 61 all castration treatments had lower ($P < 0.01$) ADG than controls.

Warnock et al. (2012) reported surgically and banded calves had decreased ADG compared to control steers during the first 14 days after castration. However, after the initial 14 days was over the ADG of all cattle on study were similar. Repenning et al. (2013) observed no difference in ADG between band and surgically castrated cattle. Moya et al. (2014) observed ADG and feed intake were lower in surgically castrated cattle than in non-castrates and banded cattle during the first week after castration in 2 separate experiments. However, banded cattle had lower feed intake and ADG during weeks 2, 3, 6, and 7 after castration when compared to non-castrates. Fisher et al. (2001) found that surgical castrated calves had greater ADG than banded calves. The reason for the difference between Fisher et al. (2001) study and the others is unclear, but cattle were in housed on pasture instead of a feedlot. Since different treatments were in different pastures, it is possible that the terrain of pastures and distance traveled to eat may have caused a difference between Fisher et al. (2001) and others.

Dry matter intake did not differ ($P \geq 0.21$) among treatments throughout the experiment. Gain to feed was greater ($P \leq 0.01$) for control cattle then all castrated treatments from d 0 to 33 and d 0 to 61. From d 34 to 61, banded cattle tended ($P \leq 0.08$) to have greater feed efficiency than control or band plus incision calves. Warnock et al. (2012) observed lower DMI in surgically castrated calves compared to control or banded calves for the first week after castration. On day 10, banded calves tended to have a decreased DMI compared to the control and surgical calves. The differences observed between these studies and ours may be due to how the data was analyzed as the other researchers analyzed DMI as a repeated measurement and we analyzed and compared the total DMI for each treatment over the entire study periods.

The reduction in ADG and DMI observed in this study are likely related to the pain and immune response that are associated with the practices. Surgical castration has been shown to result in strong acute pain and immune system response (Moya et al., 2014; Petherick et al., 2014), while banded cattle tend to have these affects over a longer period of time until the scrotum falls off (Moya et al., 2014; Robertson et al., 1994). Fisher et al. (1997) reported similar observations that castrated calves tended to eat less than intact male calves early in the post-castration period, but had similar DMI after 28 days.

An inflammatory response is activated when animal's homeostasis is disrupted from a process like castration, specifically the tissue damage from castration (Johnson, 1997). Animals will shift the partitioning of dietary nutrients away from skeletal muscle accretion towards metabolic responses that support the immune system. Cytokines are released by macrophages and other leukocytes during an immune response; this indirectly causes a reduction in feed intake because of the catabolic and anorexic effect of proinflammatory cytokines (Johnson, 1997). Macrophages secrete 3 types of cytokines: interleukin-1 (IL-1), interlukin-6 (IL-6), and tumor necrosis factor-α (TNF-α). They are known as the pro-inflammatory cytokines because they represent the first line of defense for the immune system (Johnson, 1997). Interlukin-6 has been shown to stimulate the uptake of amino acids by hepatocytes, IL-1 inhibits the anabolic effects of insulin on skeletal muscle (Klasing and Johnstone, 1991), while TNF- α increases lipolysis (Memon et al., 1994). Glucocorticoids also play a role in this; cortisol increases protein catabolism (Johnson, 1997). Combined together these factors may be the cause for the reduction in ADG that we observed in our study.

In the current study, reduced ADG observed in the castrated cattle is similar to previous research showing that castrating at a younger age and prior to arrival to the feedlot is beneficial with better gains and lower stress (Bretschneider, 2005). Ting et al. (2005) observed a reduced plasma cortisol level in 1.5 to 4.5 month old calves following castration compared to 5.5 month old calves. Bretschneider (2005) determined that weight loss increased quadratically as the age of castration increased.

Richeson et al. (2013) observed that calves that were castrated upon arrival to the feedlot had a greater risk of development of bovine respiratory disease compared to calves that were castrated prior to arrival. The added risk of disease and reduced ADG and feed efficiencies observed in calves that are not castrated prior to arrival reduces the potential for economic return.

There were no mortalities throughout this study, there were 4 morbidities, and each calf was diagnosed with respiratory disease, based on criteria set in the materials and methods. All the morbid calves came from the surgical treatment group. The reduced mortality and morbidity results of this study may be linked to the delayed application of the castration treatments to cattle. Cattle were allowed to acclimate to the feedlot and move past the initial stress that occurs following arrival to the feedlot, before treatments were applied.

To conclude, there was no observed difference in ADG or G:F for the entire 61 day period between the band plus incision practice and either of the common castration practices. This would indicate that the band plus incision practice is not any more efficacious than either the surgical or band castration practices and therefore is not a better alternative to either of these methods.

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Table 2.1 Diet Composition, DM basis

Ingredient	%
Sweet Bran	58.8
Ground Corn Stalks	19.2
Steam Flaked Corn	15.3
Nutrabase- 12	3.0
Mineral Premix	3.7

*Formulated to provide 200 mg/hd/d Rumensin 90® (Elanco Animal Health, Indianapolis, IN)
†Percent of premix (DM basis): Ca 26.0%, Na 19.95%, Mg 1.5%, K 2.7%, Cu 271.0 ppm, Se 5.32 ppm, Zn 58,700 iu/bu, Vitamin A 58,700 ppm

Table 2.2 Effects of feedlot castration on growth performance

Period	Band+[1]	Band[1]	Surgical[1]	Control[1]	SEM	*P*-value
d 0-33						
IBW, kg	302	301	301	296	4.6	0.62
FBW, kg	350[b]	344[b]	345[b]	359[a]	5.0	0.03
DMI, kg	8.64	8.15	7.94	8.66	0.399	0.22
ADG, kg	1.39[b]	1.27[b]	1.27[b]	1.86[a]	0.122	0.01
G:F	0.163[b]	0.161[b]	0.159[b]	0.220[a]	0.015	0.01
d 34-61						
IBW, kg	350[b]	344[b]	345[b]	359[a]	5.0	0.03
FBW, kg	402	397	396	409	6.1	0.17
DMI, kg	10.82	9.86	10.15	10.22	0.440	0.21
ADG, kg	1.83	1.86	1.80	1.75	0.094	0.69
G:F	0.173[x]	0.194[y]	0.184[xy]	0.177[x]	0.008	0.08
d 0-61						
IBW, kg	302	301	301	296	4.6	0.62
FBW, kg	402	397	396	409	6.1	0.17
DMI, kg	9.35	8.95	8.97	9.39	0.345	0.45
ADG, kg	1.60[b]	1.55[b]	1.53[b]	1.82[a]	0.196	0.01
G:F	0.174[b]	0.179[b]	0.176[b]	0.199[a]	0.007	0.01

[1] Band+ = band plus incision castration, band = band castration, surgical = open surgical castration, control previously castrated

[a, b] Means within a row with a different superscript letter differ by ($P \leq 0.05$).

[x, y] Means within a row without common superscripts tend to differ ($P \leq 0.10$).

6 calves were removed from study during the first period from d 0 to 33. One calf was removed on d 0 due to a high initial temperature reading, 2 were removed due to improper record keeping, and 3 were removed due to bands breaking the day after treatments were applied. The cattle that were taken off of study were not included in calculations.