THE EFFECT OF CASTRATION TIMING AND PRECONDITIONING PROGRAM ON BEEF CALF PERFORMANCE

By

AMIE MARIE TAYLOR

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To Brandon, for being my best friend and teaching me how to gig a frog.

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LIST OF ABBREVIATIONS

ACTH	Adrenocorticotropic Hormone
ADG	Average Daily Gain
APP	Acute Phase Protein
APR	Acute Phase Response
BRD	Bovine Respiratory Disease
BW	Bodyweight
BWC	Bodyweight Change
CP	Crude Protein
HPA	Hypothalamic-Pituitary-Adrenal
NAHMS	National Animal Health Monitoring System
TDN	Total Digestible Protein
UIP	Undegradable Intake Protein
USDA	United States Department of Agriculture

Abstract of Thesis Presented to the Graduate School
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Amie Marie Taylor

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This study had two objectives. First, to determine if timing of castration in nursing calves affected calf performance, primarily weaning weight. Ninety-two calves were assigned to one of two castration treatments, early (average age at castration 36 days) or late (average age at castration 131 days). Calves were stratified to treatment by birth date, breed (Angus or Brangus), and cow age. All calves were surgically castrated using the Newberry Knife to incise the scrotum and traction to remove the testes. Birth weight was similar between early and late castrates at the onset of the experiment. Actual weaning weight, adjusted 205-d weaning weight, and body weight change throughout the experimental period were all similar between early and late castrate treatments. This study suggests that delaying castration until calves were more advanced in age was not advantageous to increasing weaning weight.

The second objective was to evaluate the response of weaned calves to different feed additives within a preconditioning supplement. Specifically, alternatives to antibiotics and ionophores were evaluated to determine their effectiveness in improving calf performance and mitigating the stress response observed during the weaning process. Following stratification by bodyweight, sex, previous castration status, and

breed, 160 calves were randomly allotted to one of four treatments (n=40 calves/treatment): 1) control calves (CON) were supplemented without additives; 2) Chlortetracycline calves (CTC) were supplemented with added chlortetracycline at 350 g/hd/d; 3) Monensin calves (RUM) were supplemented with added Rumensin at 175 mg/hd/d; and 4) Actigen® calves (ACT) were supplemented with added Actigen® at 10 g/hd/d. Calf bodyweight was similar among treatments at the beginning of the trial period. Over the 52-day preconditioning period, ACT resulted in the greatest gain response. Chlortetracycline calves exhibited similar gains to ACT, which were both greater than gains exhibited by RUM. Control calves were similar to both medicated treatments, but did not gain as much as ACT. Plasma concentrations of haptoglobin and ceruloplasmin were similar among treatments; however, a day effect was observed in both acute phase proteins measured. Our results indicate Actigen® may improve calf performance as effectively as chlortetracycline during a preconditioning period of this length, but neither additive was effective at mediating stress post-weaning.

CHAPTER 1
INTRODUCTION

There are a variety of production practices cow-calf producers can implement to beef calves either before weaning, at weaning, or post-weaning. Common practices include castration, identification, health management, dehorning, growth implant administration and preconditioning. Due to the diversity and geographic range of the United States cow-calf industry, implementation of these on-farm practices can vary widely. Such differences in management not only impact the supply of calves available for beef production, but the quality and subsequent performance of calves in the stocker, feedlot, and harvesting segments (Avent, 2002). Consequently, cow-calf producers can significantly impact the value of their calves through on-farm management (Schulz et al., 2010).

Current literature illustrates a clear need to implement some of these management practices, such as castration and dehorning. However, the manner and timing at which they should be implemented is less obvious. The first objective of this study was to determine if differences in age at castration resulted in significant differences in growth during the nursing phase and at weaning. Since castration is a common practice within the United States beef industry it would be beneficial to producers if a standard time frame for castration and other calf management practices could be established.

Preconditioning, the process of weaning and preparing calves for a future phase of production (Savell, 2008), is another management practice implemented by cow-calf producers. Although the practice of preconditioning was designed to improve calf performance and health post-weaning (Lalman and Smith, 2002), literature and economic analyses available on preconditioning report variable and often conflicting

results. This leaves many producers hesitant to adopt preconditioning as an annual practice and assume the risk associated with holding calves for a period of time beyond weaning. At the same time, there is a growing demand for preconditioned calves in the stocker and feedlot segments, especially as the market for naturally-raised and organic beef expands and the use of antibiotics in food animal production is scrutinized by consumers. This phenomenon has forced producers to re-evaluate the need for preconditioning their calves either on their ranch of origin or through a custom preconditioning yard.

The second objective of this study was to evaluate the response of weaned calves to different supplemental feed additives during preconditioning. Specifically, alternatives to feed technologies like antibiotics and ionophores were evaluated. Additives identified to improve calf performance during the preconditioning phase over that of supplement or grazing alone could increase flexibility in marketing and help producers economically justify the cost and risks associated with preconditioning.

CHAPTER 2
REVIEW OF LITERATURE

Castration

Purpose

Castration, the removal or destruction of the testicles, is a common management practice within beef cattle operations of the United States. Approximately 60% of cow-calf producers castrated their male calves prior to sale (USDA-NAHMS, 2007). There are several reasons producers would choose to castrate before marketing calves, with the primary reason being driven by market demand and economics.

Castrated calves are generally valued higher in the market place compared to their non-castrated male contemporaries. Troxel et al. reported that steers in Arkansas sale barns consistently sold at a premium compared to bulls in the feeder calf market (Troxel and Barham, 2007; Troxel et al., 2002). Steers received a premium of $4.63 $\pm$ 0.08/45.45 kg and $6.48 $\pm$ 0.09/45.45 kg over the average selling price of all calves sold through Arkansas markets in 2000 and 2005, respectively (Troxel and Barham, 2007). This trend can also be observed in feeder calf markets throughout the United States, not just in Southeastern sale barns. In a similar study conducted by Smith et al. (2000), bulls sold in 1997 and 1999 at Oklahoma auction barns were discounted relative to steers. In 2009, model-estimated prices for feeder calves marketed through sale barns in Kansas and Missouri showed that at weights of 250 kg bulls received discounts of up to $5.91/45.45 kg compared to similar weight steers (Schulz et al., 2009). These results indicate producers could lose approximately $20 per head to $30 per head, depending upon market conditions, if they fail to castrate male calves prior to sale.

The premiums associated with castrated males over that of their intact counterparts are due in part to the current structure of the United States fed beef cattle industry. The vast majority of beef produced in the United States is sourced from cattle fed in confined feedlot operations with greater than 1,000 head capacity (USDA-NAHMS, 1999). Intact males express more aggressive and sexual behaviors than castrated males, which can lead to decreases in meat quality and an increased incidence of injury to both handlers and animals (Coetzee et al., 2010). As a result, feedlot operators demand that male calves being placed on feed be castrated. Although feedlots castrate male calves, feeders prefer to purchase steers over bulls due to performance reductions and risks associated with castrating heavy-weight, post-pubertal calves (Bretschneider 2005; Knight et al., 2000; Worrell et al., 1987

Addis et al. (1973), Zweiacher et al. (1979), and Berry et al. (2001) each performed a series of experiments comparing calves castrated prior to and at placement in a feedlot. Each investigator reported that calves purchased as steers exhibited greater ($P<0.05$) gains over the trial periods than calves castrated upon arrival. Addis et al. (1973) reported purchased steers had a 9.4% greater overall gain than bulls castrated on arrival during an 82-day test period. Castrates gained 0.80 kg more than bulls castrated by banding and 1.00 kg more than bulls castrated by the emasculator on arrival (Zweiacher et al., 1979). Berry et al. (2001) also showed bulls banded on arrival at the feedlot exhibited a 19% decrease in average daily gain compared to purchased steers. In addition, purchased steers had increased ($P<0.03$) dry matter intakes and reduced ($P<0.05$) morbidity compared to surgical and non-surgical castrates (Berry et al., 2001; Zweiacher et al., 1979).

Similar findings were reported in a large-scale study evaluating weight gain and health of bull calves castrated upon arrival at a stocker facility (Ratcliff et al., 2005). Bulls castrated on arrival gained 0.12 kg per head per day less ($P<0.01$) during the receiving period than purchased steers. Although castrated bulls had similar gains to steers during the extended stocker phase, steers exhibited higher average daily gains over the entire trial period due to lost performance by bulls during the receiving period. In addition, bulls castrated on arrival had an 8% higher ($P=0.08$) morbidity rate compared to calves purchased as steers.

Aside from aggressive behavior exhibited by intact males and lost performance seen in late castrates, consumer preferences largely drive the need for castrated beef calves within the United States. Intact males are superior to their castrated contemporaries in their ability to efficiently grow and deposit lean muscle tissue (Bailey et al., 1966; Champagne et al., 1969; Klosterman et al., 1954). Unfortunately, bulls lack the ability to produce an acceptable carcass for the American consumer (Field, 1971; Forrest, 1975; Reagan et al., 1971; Seideman et al., 1982).

Bull carcasses consistently produce lower quality grade carcasses than those produced by steers. Champagne et al. (1969) determined that bull carcasses displayed significantly less marbling ($P<0.01$), and subsequently had lower carcass quality grades than steers in a group of Hereford male calves. These results agree with other findings reported by Gortsema et al. (1974), Jacobs et al. (1977), and Landon et al. (1978) where crossbred steers of both English and Continental breed types produced higher quality grade carcasses than bulls of the same breed type and weight.

Additionally, bull carcasses tend to produce tougher and darker beef than beef produced by steers (Seideman et al., 1982). Field (1971) reviewed seven studies that evaluated tenderness in bull and steer carcasses. All seven studies concluded that meat from bulls had higher Warner-Bratzler shear force values than meat from steers, indicating bull meat is tougher. Hunsley (1971) determined that differences in shear force values between bulls and steers widen as age at harvest increases.

Differences in carcass characteristics are substantiated by studies that compare bull meat to steer meat in taste panels and consumer acceptance surveys. In a study conducted by Jacobs et al. (1977), researchers found that 60% of consumer respondents in a blind survey from three retail outlets preferred the overall palatability of beef from steers to beef from bulls. Over 45% of these same consumers responded that cuts purchased and prepared from the round of bulls were inferior to previous purchases of beef. In a trained sensory panel test conducted by Reagan et al. (1971), panelists found significant differences in flavor, tenderness, and overall acceptability in two different comparisons of steaks from steers and bulls. Forrest (1975) reported that a trained taste panel ranked rib roasts harvested from steers as more ($P<0.05$) desirable than those harvested from bulls in tenderness, juiciness, flavor, and overall palatability.

It has also been suggested that quality grade and palatability differences exist between steers castrated prior to weaning and those castrated after weaning and closer to puberty. Prigge (1976) reported that calves castrated at weights exceeding 250 kg produced carcasses similar to that of bulls in fat composition and quality. Heaton et al. (2006) reported differences in tenderness, juiciness, flavor, and overall palatability with a consumer panel that ate beef on a regular basis. These consumer panelists ranked

steaks from steers castrated before 90 days of age higher ($P<0.04$) in all of the above palatability attributes than steaks from steers castrated after 225 days of age.

There are clear disadvantages to utilizing intact males within the United States beef industry. Aggressive behavior, reduced carcass quality, and poor consumer acceptance of bull meat all drive market demand for castrated calves. Additionally, lost performance associated with the added stress of castrating heavy-weight, post-pubertal calves in the stocker and feedlot segments illustrate a need for cow-calf producers to implement the practice before marketing calves at weaning.

Method and Timing of Castration

According to Lents et al. (2006), over 17 million calves under the age of one year are castrated annually in the United States. USDA-NAHMS data from 2007 would support this, reporting that the majority of these calves are castrated prior to sale on their ranch of origin. Although it seems castration is a common practice, the method and age at which calves are castrated is highly variable. Reports suggest age at castration can range from 1 day of age to over 123 days of age, with nearly 20% of cow-calf producers opting to castrate after 123 days of age (USDA-NAHMS, 2007). Approximately half of the cow-calf producers used surgical methods to castrate calves, while the remaining half utilized non-surgical methods (USDA-NAHMS, 2007). Factors ranging from producer philosophy, perceived calf stress, operational resources and size may determine the methodology and timing at which castration is implemented.

Surgical methods

Surgical castration encompasses a variety of techniques that ultimately incise the scrotum to expose the testicles, after which the testicles are removed. Scrotal incisions can be made with either a knife blade or a scalpel, and should be placed high enough

on the scrotum to allow for proper drainage. Correct incision placement can help prevent fluid build-up and subsequent infection during the healing process. When using a knife blade or scalpel, adequate drainage can be achieved by pushing the testicles into the upper portion of the scrotum or body cavity before removing the bottom half of the scrotum. When castrating with the Newberry Knife, the same procedure should be followed before incising the sides of the scrotum. This ensures the anterior and posterior flaps created by the incision properly expose the testicles and allow for drainage.

Once the scrotum has been incised, the spermatic cord must be severed completely to remove the testicles. Severing the spermatic cord can be accomplished through the use of traction, scraping with a blade, crushing, or twisting the spermatic cords. Traction is performed by holding the exposed testicles and using downward force to pull the testicles until the spermatic cord breaks. Scraping the spermatic cord facilitates the separation of tissues and vessels during the removal process. The emasculator tool can be used to remove the cord while crushing or crimping associated blood vessels, which may reduce hemorrhaging in larger, more sexually mature cattle (Lane et al., 2010). Twisting is performed when using the Henderson Castration Tool™, which can also effectively severe the spermatic cord and reduce significant blood loss in older bulls (Jensen, 2006).

Surgical castration is highly effective. Following the procedure, producers can be assured both testicles were removed unlike some non-surgical methods. However, surgical castration can be stressful and result in post-castration hemorrhage and infection if not executed properly (Coetzee et al., 2010). This risk may increase when

surgical castration is performed in heavy-weight, post-pubertal males (Coetzee et al., 2010; Lane et al., 2010).

Non-surgical methods

Non-surgical castration is generally referred to as bloodless castration since these methods destroy and/or remove the testicles without subsequent blood loss and hemorrhaging. There are two primary non-surgical methods, banding and the emasculatome.

Banding, by either the elastrator, Callicrate Bander™, or similar device, applies an elastic band around the bull's scrotum, above the testes. These bands impede blood flow through the spermatic cord, eventually creating a necrotic state that causes the testicles and scrotum to slough off within a period of weeks. The elastrator is only recommended for use in calves less than one month of age (Lane et al., 2010). The Callicrate Bander™ works in a similar fashion to the elastrator except that it employs a much larger elastic band, which is tightened by a ratchet mechanism and secured with a metal grommet. This tool can be used in older, heavier-weight cattle (Jenson, 2006).

Operators should exercise caution when applying the bands with either method. Failed castration and complications can result if the elastic band is misplaced or not tightened correctly. The risk of prolonged wound formation at the site of band placement seems to increase as age at castration increases (Fisher et al., 2001; Knight et al., 2000). Additionally, all calves should be vaccinated with a tetnus antitoxin to avoid anaerobic infection that may result from the procedure.

The Burdizzo emasculatome is another bloodless method used by some cattleman. The emasculatome works by crushing the spermatic cords and prohibiting blood flow to the testicle. The loss of blood flow and reduction of nervous function

allows the testicles to atrophy and become non-functional. Prior to the screwworm eradication, the use of emasculatomes by cow-calf producers was common since the procedure did not require incising the scrotum and creating a wound that would attract the insect (Capucille et al., 2002). Today, emasculatomes are used by only 3.5 percent of cow-calf operations in the United States (USDA-NAHMS, 2007).

Many producers perceive non-surgical methods as less stressful and labor intensive than surgical methods. Although some data may support this philosophy (Fisher et al., 1996; King et al., 1991; Robertson et al., 1994), other reports suggest that there is minimal difference, if any, in the stress response associated with non-surgical techniques (Berry et al., 2001; Fisher et al., 2001; Warnock, 2010).

Warnock (2010) evaluated castration method on calf performance and stress response in a feedlot setting. Male calves were assigned to one of five treatments; control calves surgically castrated prior to weaning at an average age of 52 days, intact bulls, bulls castrated by a Callicrate Bander™ upon arrival (d 0), bulls castrated by the Henderson Castration Tool™ upon arrival (d 0), and bulls castrated surgically upon arrival (d 0). During the first two weeks of the arrival period, control calves gained 0.7 kg per head per day, while bulls castrated surgically, with the Henderson Castration Tool™, and with the Callicrate Bander™ gained 0.2, 0.2, and 0.1 kg per head per day, respectively. Since stress has the ability to reduce performance, these results indicate short-term stress elicited by castration will occur regardless of method used. Although differences were initially observed during the two-week arrival period, gain response for the entire 84-day trial period was similar among all treatment groups, indicating calves recovered from late castration, regardless of method used.

Warnock (2010) also evaluated the acute phase response to castration method. Acute phase proteins, like ceruloplasmin and haptoglobin, have been utilized to quantify the stress response associated with a particular management practice over that of performance alone (Arthington et al., 2003). Intact bulls and bulls castrated either surgically, by the Henderson Castration Tool™, or by the Callicrate Bander™ exhibited similar ceruloplasmin concentrations post-castration, which were all higher ($P<0.10$) than ceruloplasmin levels exhibited by control steers during this measurement period. Similarly, haptoglobin levels among the castration methods were similar following castration, but numerically higher than control steers.

Acute phase responses between castration methods differed between days ($P=0.02$). Banded bulls exhibited a delayed stress response compared to the stress response exhibited by surgically castrated bulls. Plasma ceruloplasmin concentrations in banded calves were elevated over that of controls ($P<0.10$) beginning on day 15. Henderson castrates exhibited elevated ($P<0.05$) ceruloplasmin concentrations beginning on day 2, but the stress response was mediated by day 15 since ceruloplasmin concentrations between Henderson castrates and controls were similar after this time. Differences in performance and inflammatory response between castrates and control steers post-castration indicate all methods of castration are stressful. However, the amount and duration of stress elicited by specific methods of castration are less clear, and may be dependent on the time at which castration is implemented.

Timing of castration

Industry recommendations generally advocate for castration to occur as close to birth as possible (Bretschneider, 2005). The general belief is that castration in young,

sexually immature calves elicits less of a stress response and reduces the risk of castration-associated blood loss and infection (King et al., 1991; Lyons-Johnson, 1998; Stafford and Mellor, 2005). At the same time, many producers are concerned that castrating too early will reduce growth rates in male calves from birth to weaning (Lehmkuhler, 2003). Some evidence exists that bulls gain slightly faster than castrates during the nursing phase (Klosterman et al., 1954; Marlowe and Gaines, 1958). However, other researchers purpose those differences are due primarily to selection (Brinks et al., 1961; Cundiff et al., 1966; Koch and Clark, 1955).

This belief was supported when Tanner et al. (1970) castrated a random sample of male calves born over a three-year period and found that intact calves did not have a significant weight advantage at weaning to steers. Bulls gained only 0.01, 0.06, and 0.0 kg/d more ($P>0.05$) than steers pre-weaning during the first, second, and third years of the trial, respectively. These gains resulted in a 3.0 kg advantage ($P>0.05$) in 205-day weaning weight for bulls compared to steers over the three-year period. Similarly, Brinks et al. (1961) and Flower et al. (1963) reported bulls only exhibited a 1.5 and 2.3 kg heavier ($P>0.05$) 205-day weaning weight than steers randomly selected for castration, respectively.

Most literature suggests that castrating close to birth has minimal to no effect on ultimate weaning weight. Bailey et al. (1966) compared the pre-weaning growth rate of steers surgically castrated at approximately 3 months of age to calves left intact in two separate studies. Differences in pre-weaning growth rate and weaning weight were not significant among the two treatment groups in either study. Data were pooled for both studies since calves were treated in a similar fashion during the pre-weaning period of

both experiments. Upon weaning at approximately seven months of age, bulls, on average, weighed 183.5 kg while steers, on average, weighed approximately 181.5 kg.

These results agree with those of Glimp et al. (1971), King et al. (1991), and Looper et al. (2005). Glimp et al. (1971) assigned Hereford and Angus calves to a variety of treatments, including castration at birth or weaning, short-scrotum castration at birth or weaning, or left intact. Average daily gain during the pre-weaning period and adjusted weaning weight were not different among any of the treatments. Calves castrated at birth by either a rubber band or short-scrotum method gained 0.73 and 0.78 kg/day, respectively. Calves remaining intact after weaning and calves castrated at weaning either surgically or by the short-scrotum method gained 0.73, 0.72, and 0.75 kg/day, respectively. Looper et al. (2005) also reported that steers surgically castrated at birth or at weaning had similar adjusted 205-day weaning weights. Calves castrated at weaning exhibited a 7 kg heavier ($P>0.10$) adjusted 205-day weaning weight than calves castrated at birth.

In contrast, Micol et al. (2009) reported that steers castrated at 10 months of age had greater live weight gains from birth to weaning than steers castrated at 2 months of age (1.06 vs. 1.01 kg/day). However, steers castrated at 2 months of age gained faster than the 10-month castrates during the growing (0.75 vs. 0.61 kg/day) and finishing (0.74 vs. 0.66 kg/day) phases of the trial, resulting in no weight gain differences over the entire trial period. Similarly, Knight et al. (2000) reported a lower ($P<0.01$) pre-weaning growth rate in calves castrated at birth compared to calves castrated at 6 and 12 months of age. Calves castrated at birth gained 1.08 kg/day pre-weaning, while calves

castrated at 6 and 12 months of age both gained 1.15 kg/day during this time. These differences did not result in significant liveweight differences beyond 6 months of age.

Differences in pre-weaning growth and weaning weight among early and late castrates may further diminish if producers administer anabolic implants at the time of castration. Heaton et al. (2006) reported no difference in pre-weaning average daily gain among calves castrated at three different ages and given an implant. Bagley et al. (1989) also studied timing of castration and implant status on calf growth over a two-year period. Calves castrated at birth had similar average daily gains and weaning weights compared to calves castrated at 4 months of age. Calves administered an anabolic implant at the time of castration weighed on average 8.2 kg heavier ($P<0.01$) at weaning than those not given a growth implant at castration.

Lents et al. (2006) conducted two different studies comparing body weight and gain in calves given an estrogenic implant and castrated prior to or at weaning. In the first experiment, calves castrated surgically and non-surgically between 2 and 3 months of age and administered a growth implant had similar weaning weights compared to calves left intact until weaning. Fifty days post-weaning, calves castrated surgically and non-surgically between 2 and 3 months had greater ($P<0.05$) average daily gains than those castrated at weaning. Calves banded at weaning gained 0.43 kg/day 50 days post-weaning, while calves castrated surgically and banded gained 0.48 and 0.49 kg/day, respectively. In the second experiment, calves were banded at birth, with or without an implant, or left intact and castrated 30 days prior to weaning with an implant. No significant differences in weaning weight were detected among either treatment group banded at birth. However, all calves castrated at birth had heavier ($P<0.01$)

weaning weights and greater average daily gains than the intact group during the 30-day period prior to weaning. Bulls castrated at 6 to 7 months of age only gained 24.1 kg during the 30-day period following castration and prior to weaning. Calves banded at birth, either receiving an implant or not receiving an implant, gained 31.3 and 35.1 kg during this same period.

Marston et al. (2003) reported similar findings to that of Lents et al. (2006). Calves castrated at 90 days of age and implanted had similar weaning weights to bulls left intact until weaning. Although calves castrated at 90 days of age without an implant weighed less at weaning than implanted steers and intact bulls, both early castrate groups had greater ($P<0.01$) average daily gains during a 28-day post-weaning period than bulls castrated at weaning. Calves castrated at weaning gained 1.16 kg/day during the 28-day post-weaning period, while calves castrated at 90 days of age and either implanted or not implanted gained 1.72 and 1.52 kg/day. Results of both studies by Lents et al. (2006) and Marston et al. (2003) indicate any weight advantage intact bulls may have over their castrated contemporaries could disappear if castration is delayed until shortly before or at weaning.

Other studies indicate that delaying castration beyond weaning can also erase any weight advantage intact bulls have over their castrated contemporaries. Burciaga-Robles et al. (2006) reported that calves purchased as bulls tended to arrive at a feedlot environment at heavier weights (249 kg) than calves purchased as steers (238 kg). At the conclusion of a 44-day receiving period, castrated bulls and purchased steers had similar bodyweights (307.1 kg vs. 310.0 kg). Any weight advantage the bulls had over the purchased steers was negated during the trial period because steers exhibited

higher (P<0.0001) average daily gains and better (P<0.0001) overall health. Purchased steers also had reduced morbidities and mortalities, and only required on average $2.65 in medical costs per head compared to $12.30 per head for castrated bulls.

Newsome et al. (2010) and Ratcliffe et al. (2005) analyzed calf performance and castration status data over multiple years using large numbers of calves and found similar results to those of Burciaga-Robles et al. (2006). Calves purchased as steers had greater average daily gains during the receiving periods than those purchased as bulls and late-castrated. Purchased steers also had lower morbidity rates and decreased treatments per animals during the trial periods. Such increases in post-castration weight loss and morbidity seen in older, heavier cattle may be due in part to the increased stress associated with castrating older calves. As stress increases, routine behaviors, like grazing and feed intake, as well as immune function may decrease (Blecha, 2000), inhibiting calf performance following castration.

King et al. (1991) measured peak cortisol concentrations in calves of two different ages (78 days or 167 days) that were left intact, surgically castrated, or castrated using a burdizzo. They determined castration of 78-day old calves did not elicit a significant stress response since peak cortisol concentrations were similar between the intact calves and early castrate treatments at all time points measured. However, a rise (P<0.05) in peak cortisol concentrations three hours post-castration between intact males and late castrates was reported. Calves castrated surgically or by the burdizzo method at 167 days of age exhibited peak cortisol concentrations of 44.2 $\pm$ 4.2 and 38.6 $\pm$ 8.3 μg/L three hours post-castration, respectively. In contrast, bull calves exhibited a peak cortisol concentration of only 24.1 $\pm$ 8.5 μg/L three hours post-castration. This

suggests late castration may elicit a greater stress response in calves, regardless of method used.

In a review of 19 castration studies, Bretschneider (2005) concluded that stress response to castration, measured by peak plasma cortisol concentrations, was significantly higher in calves greater than 6 months of age. Stafford and Mellor (2005) also illustrated the duration of stress following castration lengthens as age at castration increases. Results measuring stress response by plasma concentrations of acute phase proteins support these conclusions. Acute phase proteins are proteins produced by the liver in response to stress and injury (Baumann and Gauldie, 1994). In a United States Department of Agriculture (USDA) study reported by Lyons-Johnson (1998) calves castrated at birth and at 33 weeks of age had significantly lower haptoglobin (an acute phase protein) levels than those castrated at weaning at 36 weeks of age.

Producers should try to minimize castration-associated stress for two reasons. There are clear economic advantages to reducing stress post-castration since stressed animals eat less, gain less, and tend to require more medical treatment. Equally important, an increased concern over animal welfare and animal husbandry practices has arisen among the public. As a result, current literature on both castration method and timing require expansion. There is a clear need to increase producer awareness and knowledge so producers can find ways to mitigate and reduce the stress associated with castration and other calf management practices whenever possible.

Preconditioning

Purpose

Within the beef industry, preconditioning refers to the process of weaning and preparing calves for a future phase of production (Savell, 2008). Preconditioning can

vary widely in both length of time and management applied before calves are marketed and shipped to the stocker or feedlot segments. Programs may consist of castration, dehorning, vaccination, parasite control, or a combination of such procedures. In addition, the timing at which these practices are implemented can vary from producer to producer, with some procedures occurring before weaning and others occurring on the day of weaning.

During preconditioning, calves may be supplemented while in a dry-lot or on pasture, either at the ranch of origin or at a custom preconditioning yard. Supplementation, although not always economical, can improve the nutritional status of fresh weaned calves and train them to eat from a feed bunk as they acclimate from a milk-based diet to a pasture and/or grain-based diet. Preconditioning also serves to minimize the stress of weaning and reduce the incidence of respiratory disease commonly observed in naïve, abruptly weaned calves sold and transported through traditional marketing channels (Lalman and Smith, 2002).

The concept of preconditioning calves is not new. Industry leaders, researchers and veterinarians met in the late 1960s to discuss preconditioning as a means to reduce the economic impact of bovine respiratory disease (BRD) and mismanagement in newly received feeder calves (Gill, 1967; Schipper et al., 1989). Despite the perceived benefits of preconditioning, program results have been highly variable and often conflicting (Cole, 1985). To further compound this problem, the beef industry is geographically widespread and highly diversified in operation type and management (USDA-NAHMS, 2007), creating a lack of uniformity in preconditioning programs across the country. This has made producers slow to adopt preconditioning as an annual practice because they

are reluctant to assume the risk and cost associated with holding calves for a period of time beyond weaning.

At the same time, there is a growing demand for preconditioned calves in the feedlot and stocker segments. Incidence of BRD has not decreased over the years (USDA-NAHMS, 1999) despite advances in vaccines and antibiotics available for prevention and treatment of the disease (Fulton, 2009). Additionally, survey data would suggest only half of calves placed in feedlots have received vaccinations to prevent respiratory disease prior to arrival (USDA-NAHMS, 1999). It is estimated that nearly 15% of calves placed in the feedlot will develop BRD, making it the most common disease condition in United States feedlots (USDA-APHIS, 2001).

Treatment costs, death loss, and reductions in animal performance associated with BRD and mismanagement in feeder cattle continue to produce significant economic losses in the beef industry today (Fulton, 2009). In a study conducted by Fulton et al. (2002), feedlot calves treated once for respiratory disease returned approximately $40.00 less per head than calves requiring no treatment while on feed. In calves treated at least three times for respiratory disease while in the feedlot, returns were nearly $300 less than calves not requiring treatment. Stocker cattle returns are also negatively impacted by morbidity, with recent data indicating a decrease in net returns of up to 21.3% from sickness alone (Pinchak et al., 2004).

Data from the Texas A&M Ranch to Rail program report similar differences between healthy and sick calves, with healthy calves returning $93/head more than sick calves (McNeill, 1999). However, calves classified as healthy in these studies were not necessarily preconditioned. Nevertheless, both recent and classical literature would

suggest health status of newly received feeder calves is related to previous management and the practice of preconditioning.

Effect of preconditioning on calf health

United States feedlot managers expect preconditioned calves to have approximately 75% fewer sick animals and 65% fewer dead animals than calves not preconditioned prior to placement in the feedlot (Avent, 2002). Research comparing the health of preconditioned calves and their non-preconditioned counterparts would support this belief. In a three-year study conducted by Pate and Crockett (1978), calves preconditioned and fed for at least three weeks prior to shipment had fewer ($P<0.05$) calves treated for sickness at the feedlot than their contemporaries shipped directly from the ranch of origin to the feedlot. Additionally, weaned calves shipped directly to the feedlot had a 2.3% death loss, while preconditioned calves did not experience any death loss at the feedlot.

In a review conducted by Cole (1985), data from eight large-scale, controlled trials established that preconditioning reduced feedlot morbidity and mortality by 23% and 49%, respectively. Schipper et al. (1989) reported that preconditioned calves sold through certified sales in Canada had only one-half the number of feedlot treatments non-preconditioned calves had over an eight-year period. Roeber et al. (2001) reported significant differences in feedlot morbidity rates between two groups of preconditioned calves and calves of unknown origin and management procured from the auction market. Preconditioned calves had morbidity rates of 34.7% and 36.7%, while calves of unknown origin and management had morbidity rates of 77.3%.

Step et al. (2008) reported similar results to the previous authors between preconditioned calves that were weaned and retained on the ranch with those that were

either weaned and sold directly to a feedlot or purchased at an auction market and of unknown origin. Calves that were weaned and retained on the ranch for 45 days had lower (P<0.001) rates of respiratory disease and required fewer (P<0.05) treatments than calves shipped directly to the feedlot or purchased from the auction market. Auction market calves were reported to have nearly 42% morbidity while calves weaned and held on the ranch for 45 days only had 5.9% morbidity. Mortality rates also differed between calf origin and weaning management, with auction market calves reporting a 3.1% death loss and ranch weaned calves reporting no death loss during the 42-day receiving period. Equally important, auction market calves ($13.54/head) and ranch calves shipped directly to the feedlot ($13.24/head) had greater (P<0.001) health costs than ranch calves weaned and preconditioned for 45 days ($8.30/head).

Preconditioning also seems to improve health status as calves are transitioned from the cow-calf segment to the stocker segment. Data reported by Lofgreen (1988) indicate that weaning and preconditioning calves for three weeks can reduce morbidity rates when calves are received at stockering facilities. Preconditioned calves were reported to have one-third less BRD related sickness compared to non-preconditioned controls. Coffey and Childs (2002) also reported differences in the incidence and treatment rate of respiratory disease in preconditioned and non-preconditioned stocker cattle. Calves that were verified to have been weaned for 45 days, previously castrated, dehorned, and vaccinated required no treatment for respiratory disease during the entire stockering phase of the trial. However, approximately 9% of the non-preconditioned calves required treatment for respiratory disease during the grazing phase.

In contrast, studies exist that report no difference or even higher rates of feedlot morbidity in preconditioned calves (Swann et al., 1986; Vickers and Pritchard, 1986; Waggoner et al., 2005). Woods et al. (1973) reported that preconditioned calves exhibited reduced ($P<0.01$) rates of respiratory disease in only the last year of a three-year feeder calf study. The number of preconditioned calves treated for respiratory disease that year was 50% less than the number of non-preconditioned calves. The vaccination protocol utilized among preconditioned calves in the last year of the study included three additional immunizations against respiratory disease, which were not used in the previous two years of the study. This may explain the difference in mortality rate for the two treatment groups during that year. In the remaining two years of the study, preconditioned calves exhibited similar morbidity rates to the non-preconditioned calves.

Wieringa et al. (1976) also reported similarities in respiratory disease rate between calves preconditioned for 20 days and control calves weaned and shipped directly to the feedlot. The comparable sickness between preconditioned and non-preconditioned calves in this study may be attributed to the short preconditioning periods as well as the direct shipment of control calves from the ranch of origin to the feedlot. Under normal marketing conditions, non-preconditioned calves are weaned and taken to an auction barn where they are comingled with unfamiliar cattle and handled numerous times before eventual shipment to the feedlot (USDA-NAHMS, 2007; Thrift and Thrift, 2011). According to Abidoye et al. (2006), comingling and the number of sources within a feedlot pen can impact calf health and performance.

In the aforementioned study (Wieringa et al., 1976), a random subset of control and preconditioned calves were placed together in a feedlot pen shortly after arrival to determine if commingling influenced health status of the treatment groups. Following commingling, control calves exhibited an increase (P=0.04) in the incidence of respiratory disease compared to preconditioned calves placed in the same pen. Commingled control calves exhibited a 23.5% morbidity rate, while preconditioned calves in the same pen had only a 5% morbidity rate. This indicates non-comingled control calves remaining separate from their preconditioned contemporaries and shipped directly to the feedlot may not have been challenged enough to exhibit higher morbidity rates in this study.

Although some literature may suggest otherwise, it would seem that preconditioning can influence calf morbidity and mortality rates in subsequent segments of the beef industry. Preconditioning does not eliminate morbidity and mortality within beef production, but it does reduce the rate and severity of sickness. The success of preconditioning programs may be reliant on the efficacy of vaccination protocols (Irsik, 2005; Knight et al., 1972), the amount of time spent within marketing channels as well as the disease and stress level calves are exposed to as they move between production segments (Cole, 1985; Meyer et al., 1970). Because preconditioning programs typically require producers to pre-wean, castrate, dehorn and vaccinate prior to marketing, calf stress may be reduced and immunity may be improved during the initial receiving phases when most calves tend to be at greatest risk of becoming sick (Avent, 2002; Lalman and Smith, 2002; Bailey and Stenquist, 1992). Reductions in calf morbidity and

mortality can not only impact profitability through reduced medicine costs and labor, but through improved calf performance in the stocker and feedlot segments.

Effect of preconditioning on calf performance

Health status of cattle upon entry to a stocker or finishing facility can significantly impact subsequent performance measures, such as average daily gain, feed intake, feed efficiency, and net return (Fulton, 2002; Gardner et al., 1998). In the Texas A&M Ranch to Rail program, calves identified as healthy consistently exhibited greater average daily gains and a 14% lower cost of gain while on feed than those identified as sick (McNeill, 1999). Because preconditioned calves are perceived by many in the industry to be healthier than fresh weaned calves lacking previous management, many feeders and buyers expect preconditioned calves to outperform their non-preconditioned contemporaries (Avent, 2002).

Literature measuring calf performance in subsequent production segments indicate that preconditioned calves start on feed sooner and have higher average daily gains during the receiving phase than their non-preconditioned contemporaries. Cole (1985) concluded that preconditioning calves prior to shipment results in higher average daily gains and greater feed intake during the first 30 to 45 days in the feedlot. Preconditioned calves gained, on average, 1.08 kg/day during the feedlot receiving period compared to non-preconditioned controls who only gained 0.88 kg/day (Cole, 1985). In two separate studies conducted by Bolte et al. (2008; 2009), preconditioned calves weaned in the summer and fall exhibited higher ($P<0.02$) dry matter feed intakes during the first 30 days in the feedlot compared to non-preconditioned controls. Additionally, dry matter intake during the receiving period increased linearly ($P=0.02$) as

the preconditioning period lengthened from 15 days to 60 days in the summer-weaned group (Bolte et al., 2008).

Lofgreen (1988) reported differences in average daily gain and feed intake at receiving between preconditioned calves and un-weaned controls. Feed intake at receiving was increased from 5.39 kg/day in controls to 6.19 kg/day in preconditioned calves, while average daily gain for controls was 0.25 kg/day less than calves preconditioned for 21 days prior to shipping. Preconditioning also resulted in improved feed conversion rates during the receiving period. Calves shipped directly to the feedlot at weaning required 3.69 kg of feed to produce one kg of gain, while preconditioned calves only required 3.05 kg of feed to produce on kg of gain.

Seeger et al. (2008) evaluated the performance of calves of unknown health history purchased at an auction market to preconditioned calves sold through certified sales. The preconditioned calves were separated into two treatment groups based on the health program they were administered. However, all preconditioned calves were weaned for 45 days, treated for parasites, and vaccinated against respiratory disease before sale and arrival at the feedlot. Calves in both preconditioning treatment groups significantly outperformed the calves of unknown health history during the 28-day feedlot receiving phase of the trial. Calves of unknown health history only gained 1.60 kg/day from arrival to the second processing, while preconditioned calves gained 1.80 kg/day and 1.76 kg/day. Dry matter intake during receiving also was affected by treatment ($P<0.05$), with preconditioned calves consuming 7.35 kg/day and 7.60/per day and auction market calves consuming 6.29 kg/day. These differences in performance

between weaning and health programs resulted in fewer ($P<0.05$) days on feed for preconditioning groups.

Improvements in calf performance during the receiving phase are generally attributed to the preconditioned calf's previous exposure to concentrate feeds and reduced stress upon arrival from the pre-weaning process. Most preconditioning programs provide supplementation to calves following weaning, providing a relatively easy transition from nursing to finishing where they are fed a similar diet. Enhanced nutritional status and adaption to high-energy concentrates prior to shipping facilitates calf growth early in the finishing period. In some cases, the trend for higher rates of gain and other measures of performance are not be limited to this short receiving interval.

In a large-scale study comparing feedlot performance of single-sourced preconditioned and non-preconditioned calves, Cravey (1996) reported significant differences in average daily gain, days on feed, and feed conversion measures during the cumulative feeding period. Preconditioning improved average daily gain by 0.09 kg/day and dry matter feed conversion nearly 9%, reducing the feeding period by 40 days for preconditioned calves. In a similar large-scale study evaluating feedlot performance of preconditioned and non-preconditioned calves, average daily gain was improved 10% and dry matter feed conversion improved from 2.93 kg of feed per kg of gain to 2.72 kg of feed per kg of gain by preconditioning (Cravey, 1996). In both studies, preconditioned calves exhibited heavier harvest weights while requiring less feed and fewer days on feed than their non-preconditioned contemporaries.

These results agree with those reported by other authors evaluating cumulative feedlot performance in preconditioned calves. Pate and Crocket (1978) reported an

11% increase in rate of gain over the entire feeding period for calves preconditioned on the ranch for 24 days. Macek et. al. (2011) reported significantly faster feedlot gains, fewer days to harvest, and heavier harvest weights in calves preconditioned for at least 45 days prior to arrival at the feedlot. Seeger et al. (2008) reported calves preconditioned for 45 days gained 1.56 kg/day and 1.55 kg/day over the entire feeding period, while calves of unknown health history gained 1.50 kg/day from arrival to harvest.

In contrast, Pritchard and Mendez (1990) reported no difference in cumulative average daily gain for preconditioned and non-preconditioned calves. Preconditioned calves also exhibited poorer feed conversions, requiring 6.44 kg of feed per kg of gain while non-preconditioned calves only required 6.24 kg of feed per kg of gain. Similarly, Bolte et al. (2009), Lofgreen (1988), and Cole (1985) reported no differences in rate of gain and feed conversion ratios across the entire feeding period among preconditioned and non-preconditioned controls. Although preconditioned calves in all of these studies out-performed their non-preconditioned contemporaries during receiving, the authors failed to find significant performance differences across the growing and finishing phases of feedlot production. This may be attributed to compensatory gain in non-preconditioned calves as they overcome the stress of weaning and adapt to a high-concentrate diet following receiving.

The impact of preconditioning calves on subsequent performance is somewhat variable, and may be dependent upon calf type, calf condition, year effects, and preconditioning method. It seems preconditioned calves hold a performance advantage to fresh weaned calves of unknown health history following their arrival at stockering

and finishing facilities. However, their ability to outperform their non-preconditioned contemporaries throughout the entire feeding period is less clear. Regardless, improvements in gain, feed conversion, and intake during receiving all contribute to lower days on feed and reduced costs of gain. With more desirable measures of growth and reduced mortality rates, preconditioning may also influence the subsequent carcass quality and value of calves.

Effect of preconditioning on carcass attributes

Carcass quality and consistency in beef production have become a focus within the industry in recent years. Increases in the number of cattle sold on a carcass merit basis and through USDA certified brands have established a clear need for producers and feeders to manage cattle in a way that will improve quality and palatability attributes in fed cattle (Smith et al., 2005). Numerous factors have been shown to impact the subsequent carcass composition of beef calves, including previous management, disease, and stress level (Gardner et al., 1999; Mitlohner et al., 2002).

Management practices such as castration and dehorning have been shown to positively influence USDA quality grade and palatability (Field, 1971; Jacobs et al., 1977). Research comparing castrated males to intact males show steers produce more USDA Choice carcasses and meat consumers find to be more palatable than that produced by bulls (Champagne et al., 1969). Castration and dehorning have also been shown to consistently reduce the incidence of quality defects in fed cattle such as bruising and dark cutters (Field, 1971; Seideman et al., 1982). Additionally, evidence exists that when castration and dehorning are implemented prior to weaning, less stress is imposed on the calf, morbidity is decreased, and fewer carcass quality defects result (Burciaga-Robles et al., 2006; King et al., 1991).

The practice of vaccination is also associated with improved carcass quality since it can enhance the health status of recently weaned calves and is a critical component in the effort to prevent respiratory disease (Knight et al., 1972; Macek et al., 2011; Snowder et al., 2006). Literature documenting the relationship between calf health and subsequent carcass quality clearly shows that healthy cattle outperform cattle requiring treatment. Harvested cattle with a history of respiratory disease consistently produce lower quality carcasses and tougher meat (Gardner et al., 1999; McNeill, 1999; Roeber et al., 2001), which can significantly reduce their carcass value (Gardner et al., 1998). Many preconditioning programs stipulate calves must be castrated, dehorned, and vaccinated prior to sale, making preconditioned calves appealing to buyers who understand the connection between pre-finishing management, disease, stress level, and carcass attributes.

Although literature comparing carcass composition and quality among healthy and sick cattle abounds, carcass data comparing preconditioned calves to their non-preconditioned contemporaries is somewhat limited. Research available on the subject does indicate preconditioned calves tend to produce carcasses with more positive attributes that influence profitability, such as degree of marbling, USDA quality grade, and hot carcass weight. Seeger et al. (2008) reported that two treatment groups of preconditioned calves produced approximately 22% and 26% USDA Choice or Prime carcasses, while calves of unknown health history only produced 17% USDA Choice or Prime carcasses; a 35% improvement from preconditioning. All treatment groups had similar dressing percentages, hot carcass weights, and produced the same percentage of USDA Yield Grade 1 and 2 carcasses.

Abidoye and Lawrence (2006) evaluated the performance of cattle that were preconditioned on the ranch of origin to cattle sourced from multiple ranches, commingled and backgrounded prior to entering the feedlot. Preconditioned cattle were castrated, dehorned, immunized, and weaned no less than 28 days prior to arrival at the feedlot. The authors reported that preconditioned cattle had a greater percentage of calves grading USDA Choice or Prime compared to calves that were comingled and backgrounded prior to feedlot entry. Approximately 40% more single-source, preconditioned cattle graded USDA Prime than backgrounded cattle, while 128 backgrounded cattle and only 27 single-source, preconditioned cattle graded USDA Standard.

In a study conducted by Waggoner et al. (2005), calves were allocated to four preconditioning periods to evaluate the duration of time spent between weaning and feedlot entry on performance and carcass characteristics. Calves were preconditioned for 0 to 20 days, 21 to 40 days, 41 to 60 days, or greater than 61 days before arriving at the feedlot. Calves preconditioned for at least 21 days had heavier ($P=0.06$) hot carcass weights than calves preconditioned for 0 to 20 days, and marbling score increased linearly ($P<0.01$) as preconditioning duration increased. Measures of back fat and calculated yield grade also increased as preconditioning duration lengthened; however, all treatment periods produced USDA Yield Grade 2 carcasses. Calves preconditioned for less than 21days produced the lowest value carcasses among the treatment groups, earning only $111.77/45.4 kg compared to $114.91/45.4 kg earned by calves preconditioned for 41 to 60 days. Additionally, net income for calves preconditioned for

less than 21 days was -$41.66/head, while net income for calves preconditioned for 41 to 60 days was $2.23/head.

Macek et al. (2011) also reported heavier (P<0.02) hot carcass weights for calves weaned and preconditioned for 45 and 15 days compared to calves weaned for 0 days and shipped directly to the feedlot. However, Macek et al. (2011) did not report differences in marbling score, USDA yield grade or twelfth-rib back fat like the previous authors. Pate and Crockett (1978) reported preconditioned calves and their non-preconditioned contemporaries produced carcasses with similar dressing percentages and of the same quality grade. Similarly, Roeber et al. (2001) did not report differences in hot carcass weight, marbling score, and carcass value between preconditioned calves and calves of unknown origin and management procured from an auction market. Calves from both the certified preconditioned program and the auction market produced carcasses with marbling scores between Small 00 and Small 27, qualifying both groups for USDA Choice carcasses.

Literature evaluating preconditioning and its effect on subsequent carcass composition is both limited and variable. It would seem that because preconditioned calves have undergone management practices designed specifically to reduce stress and improve health that these calves would produce higher quality carcasses on a consistent basis. Industry perceptions seem to support this idea. According to Avent (2002) feedlot operators expect preconditioned cattle to produce nearly 30% more USDA Choice carcasses than non-preconditioned calves. However, current literature is only indicative of such an association, illustrating a need for further research to support such perceptions.

Effect of preconditioning on calf stress

Calves can be subjected to a variety of stressors throughout their life, with many of these stressors occurring at or around the time of weaning. Although practices such as castration, dehorning, weaning, and handling are all considered standard management processes, each of these events can be stressful (Carroll and Forsberg, 2007). Castration and dehorning are considered to be physical stressors since they can cause temporary pain to cattle undergoing these procedures (Grandin, 1997). Stressors like handling, restraint, and transport are classified as psychological since a pain response is not necessarily invoked, but a fear response is (Grandin, 1997). Weaning can challenge calves from both a physical and a psychological standpoint as they are often forced to rapidly transition away from a milk-based diet, are permanently separated from their dam, transported off the ranch of origin and comingled with unfamiliar cattle in unfamiliar environments (Arthington et al., 2003; Grandin, 1997; Kim et al., 2011).

These concepts are important because stress can negatively impact the ability of calves to resist disease and exhibit favorable performance gains post-weaning. In animals, stress activates both the sympathetic nervous system and the hypothalamic-pituitary-adrenal (HPA) axis in what is commonly referred to as a neuroendocrine response (Breazile, 1988; Murata, 2007). As a result, catecholamines and glucocorticoids are released, which then act on a variety of target organs and tissues in an attempt to help the animal regain homeostasis (Carrol and Forsberg, 2007; Murata, 2007). Although such a response is designed to help protect animals undergoing stressful situations, these reactions may actually impair immune function and increase the likelihood of disease in animals that experience stress over extended periods of time (Aich et al., 2009; Blecha, 2000; Breazile, 1988). Additionally, stress may alter appetite

and the nutritional requirements of animals, which if not met, could further suppress an animal's immune system and their ability to overcome sickness (Carroll and Forsberg, 2007; Hutcheson and Cole, 1986).

Many of the fresh-weaned calves that arrive at stockering and finishing facilities in the United States are in such a stress-induced state (Carroll and Forsberg, 1997). The practices of weaning, castration, comingling, and long-haul transport all occur within in a short period of time for many calves in the beef industry. As calves become stressed from these management and marketing practices, normal activities such as eating or drinking may cease and immune function may become impaired as they attempt to cope and reestablish homeostasis. This results in a weakened immune system and poor nutritional status, making fresh-weaned calves highly susceptible to respiratory illness and death after arrival.

As a result, the concept of preconditioning evolved around alleviating calf stress as a means to improve calf health and performance. The practice of preconditioning provides calves with a period of time to overcome the physical and psychological stresses associated with weaning and calfhood management before they are transported and comingled in subsequent industry segments. Additionally, when combined with supplementation and an effective vaccination program, preconditioning can ease the stress associated with rapid diet change and inadequate feed consumption while enhancing the immune system at a time when calves are at the highest risk of becoming morbid. Many within the industry recognize the benefits associated with preconditioning and its ability to mitigate stress (Avent, 2002; Lalman and Smith, 2002), which has prompted researchers to both quantify and compare the

stress response of preconditioned calves to more traditional methods of weaning and marketing.

One way to measure stress at weaning is through behavioral changes that occur when the maternal bond is disrupted and calves adapt to a new diet (Herzog, 2007). Price et al. (2003) used behavior as an indicator of weaning stress during a three-year study evaluating five weaning strategies. Treatments included non-weaned controls on pasture, fenceline separation from dams while on pasture, non-preconditioned calves under total separation from dams while on pasture, preconditioned calves under total separation from dams in a drylot, and non-preconditioned calves under total separation from dams in a drylot. Preconditioned calves received alfalfa hay in the drylot for 10 days prior to weaning. Although non-weaned controls and fenceline weaned calves were reported to be under less stress than calves under total separation, preconditioned calves under total separation spent more time eating, walked the fenceline less, and laid down more than non-preconditioned calves under total separation. Additionally, preconditioned calves under total separation vocalized less than non-preconditioned calves under total separation. Preconditioned calves were reported to have an average of 371 vocalizations per hour per 10-calf group over the three-year study. Non-preconditioned calves under total separation were reported to have an average of over 518 vocalizations per hour per 10-calf group and nearly 435 vocalizations per hour per 10-calf group for calves on drylot and pasture, respectively.

Observing behavioral changes can be useful in determining if an animal is stressed following implementation of a management practice like weaning. Unfortunately, there are distinct shortcomings in using behavior as a sole means of

quantitative measurement in stress studies. Some practices or events do not necessarily elicit a behavioral change even if the animal is stressed, nor is a particular behavior exclusive to a specific type of stressor (Herzog, 2007). As a result, many researchers prefer to use physiological parameters, such as stress response chemicals and hormones, as markers of stress in animals.

Traditionally, the glucocorticoids cortisol and corticosteroid have been used to measure stress responses in cattle and other livestock undergoing specific management practices. Wieringa et al. (1976) evaluated the effect of preconditioning on plasma corticosteroid levels in Hereford calves being weaned and shipped to the feedlot. Preconditioned calves were weaned three weeks before all calves were transported directly to the feedlot. Preconditioned calves exhibited lower ($P<0.05$) plasma corticosteroid levels both prior to transport and during transport to the feedlot compared to freshly weaned control calves. Control calves had plasma corticosteroid levels of 4.18 μg/100 mL on the day prior to transport, while preconditioned calves had plasma corticosteroid levels of 3.25 μg/100 mL prior to transport.

Differences in corticosteroid levels prior to transport may be attributed to both the adjustment period of preconditioning and handling differences between treatment groups when blood samples were collected. Control calves had to be brought from the pasture to the working pens and sorted from their dams prior to bleeding unlike preconditioned calves that experienced similar conditions three weeks prior and were already at the pens for sample collection. This may be an important factor for producers to consider when deciding to wean and precondition calves. For producers not opting to precondition, the stresses associated with maternal separation, dietary change, and

added handling and processing on the day of weaning may not be separated from the stress directly associated with transport in freshly weaned calves like they can be preconditioned calves.

In contrast, Herzog (2007) evaluated measures of stress during weaning and reported similar serum cortisol levels between abruptly weaned calves, preconditioned calves, and non-weaned control calves. Serum cortisol concentrations for each treatment group averaged 60 nmol/L prior to weaning on day 0, which acted as a baseline control measure. The cortisol concentrations reported for day 1, 2, and 3 following weaning did not rise above this baseline average for either of the treatment groups. Additionally, cortisol concentrations within each treatment did not increase from day 0 to day 3 following weaning when collections ceased. It should be noted that cortisol concentrations were taken only once per day in the morning, which could indicate why the reported cortisol concentrations failed to denote weaning-related stress or differences in stress level between weaning treatments.

Although cortisol is a useful measure of adrenal response during short-term stress, caution must be exercised when using and interpreting cortisol measurements in the literature. Cortisol secretion from the adrenal gland is highly dependent on sampling time and method, circadian rhythms, reproductive state, sex, and genetics (Grandin, 1997). The release of adrenocorticotropic hormone (ACTH), which acts on the adrenal gland to promote secretion of glucocorticoids, also changes over time and can take as long as 20 minutes to peak, making single measurements of serum cortisol unreliable (Grandin, 1997). As a result, researchers have begun to report changes in the immune

system as a means to measure stress more accurately, including increases in positive acute phase protein (APP) profiles.

Acute phase proteins are produced by the liver during the acute phase response (APR) when an animal experiences stress. Originally, the APR was thought to be elicited by the release of pro-inflammatory cytokines specifically as a result of an injury or infection in the animal (Baumann and Gauldie, 1994; Carrol and Forsberg, 2007). These pro-inflammatory cytokines will then travel to the liver and regulate the release of APPs from hepatocytes (Petersen et al., 2004). The APR facilitates the healing process and allows animals to reestablish homeostasis during stressful periods (Lomborg et al., 2008).

Recently, however, the APR is thought to be elicited by psychological stressors in addition to physical stressors, like injury or infection (Murata, 2007). Although the exact mechanism underlying this stress-induced APR in not entirely clear, Murata (2007) hypothesizes that the activation of the HPA axis and subsequent release of glucocorticoids induce production of APPs within the liver. This hypothesis is supported by both in vitro lab experiments (Higuchi et al., 1994) and applied animal research studies in which food animal species were exposed to various psychological stressors and subsequently exhibited changes in APP production (Arthington et al., 2003; Gymnich et al., 2003; Kim et al., 2011).

The production of APPs can be measured through blood serum concentrations, which will either substantially increase above baseline levels in response to stress, as in the case of positive APPs, or decrease below baseline levels in the case of negative APPs (Carrol and Forsberg, 2007; Petersen et al., 2004). Serum concentrations of

APPs allow researchers to quantify the stress associated with a particular practice, much like serum concentrations of glucocorticoids or catecholamines. The primary advantage to utilizing APPs over that of more traditional measures of stress, like cortisol, are their longer half-lives and latency to peak, which provides researchers with a broader sampling window to collect blood serum from animals (Slocombe and Colditz, 2005). Ceruloplasmin and haptoglobin are two positive APPs currently used to measure and evaluate stress in food animal species.

Arthington et al. (2008) evaluated stress in steers allocated to four different weaning programs prior to shipment using ceruloplasmin and haptoglobin. Weaning treatments included control calves weaned on the day of transport, calves provided ad libitum access to creep feed prior to weaning and shipment, calves preconditioned for at least 45 days prior to shipment, and early-weaned calves removed from their dam at 70 to 90 days of age. Preconditioned calves were reported to have a reduced ($P=0.08$) increase in plasma haptoglobin concentrations compared to control and creep-fed calves weaned and shipped on the same day. Haptoglobin concentrations increased from day 0 to day 1 for all treatments. However, preconditioned calves exhibited an increase of 1.50 units during this time period, while fresh-weaned controls and creep-fed calves exhibited increases of 2.15 and 2.63 units of, respectively. Additionally, preconditioned calves generally had lower ceruloplasmin concentrations than creep-fed calves throughout the trial, while early-weaned steers also had lower ($P<0.10$) ceruloplasmin levels on days 8, 15, 22, and 29 following shipment compared to fresh-weaned control calves.

Campistol (2010) also measured the acute phase response in calves during a 42-day preconditioning trial. Calves were initially allotted to one of two pre-weaning treatments; supplemented and unsupplemented. Supplemented calves were given a high-fiber supplement one week prior to weaning, while unsupplemented calves did not receive any supplementation prior to weaning. At weaning (day 7), each pre-weaning treatment was subsequently split into two post-weaning treatments based on weaning strategy. Calves were either weaned using total separation from dams for the entire preconditioning period or weaned using fenceline separation for 14 days before being moved to total separation for the remainder of the preconditioning period. Regardless of pre-weaning treatment or weaning strategy, all calves received supplement from day 7 to day 21 of the trial period.

Campistol (2010) reported that all calves exhibited a post-weaning increase ($P<0.01$) in haptoglobin, regardless of pre- or post-weaning treatment. Haptoglobin levels across all treatments were returned to pre-weaning levels by day 14 of the preconditioning period, suggesting the practice of weaning is a long-term stressor in beef calves. Although no pre-weaning or post-weaning treatment differences were reported for haptoglobin response, ceruloplasmin levels were less ($P=0.02$) at weaning (day 7) for unsupplemented calves compared to supplemented calves. Additionally, calves in this unsupplemented pre-weaning treatment group who were under total separation during the entire preconditioning period exhibited lower ($P=0.04$) ceruloplasmin levels on day 21 than calves in this same pre-weaning treatment group that were under fenceline separation for a portion of the preconditioning period.

Both studies conducted by Arthington et al. (2003) and Campistol (2010) suggest providing calves with a pre-weaning supplementation may not help mitigate the stressors associated with weaning, which include maternal separation, social re-organization, and cessation of nursing. Additionally, a two-part weaning strategy consisting of fenceline separation followed by transport to another location for total maternal separation may lengthen the period calves are under weaning-related stress. Unfortunately, the study conducted by Campistol (2010) lacked both a non-weaned control group and a fresh-weaned treatment group that could be used to compare stress response in preconditioned calves to more traditional methods of weaning and marketing.

Although calves were not preconditioned, Vendramini and Arthington (2007) evaluated post-transport and feedlot receiving stress of early-weaned calves offered a yeast fermentation product. Calves were weaned at an average age of 66 days weighing approximately 84 kg each. Following weaning, calves grazed ryegrass and stargrass pastures for a total of 224 days before simulating transport to a feedlot. Treatments during the grazing period included a control group offered concentrate supplement only and a treatment group offered the same concentrate supplement with a yeast fermentation product. The authors reported similar performance responses during the grazing period for both treatment groups. At the conclusion of the grazing period, half of each grazing supplemented group was loaded onto a trailer and transported for 24-hours before being returned to the research facility.

Following the transport simulation, all calves were placed in a drylot for 30 days and offered one of two diets in a 2 x 2 factorial design. Half of the calves transported

received the concentrate supplement offered in the grazing period alone, while the remaining half received the concentrate supplement with added yeast fermentation product. Similarly, calves not subjected to the transport simulation were allocated to either a supplemented control or supplement with additive treatment. Although transportation reduced ($P<0.01$) calf body weight in the first 24 hours of the feedlot receiving period, calf performance for the remaining 30-day receiving period was not influenced by either transport or yeast supplementation. Likewise, haptoglobin and ceruloplasmin concentrations were similar between all treatments, indicating transportation and yeast supplementation did not influence calf stress levels during this trial.

Haptoglobin and ceruloplasmin concentrations were influenced by sampling day, regardless of treatment. Increases ($P<0.05$) were observed in haptoglobin from day 5 through day 9, while ceruloplasmin increased ($P<0.05$) from day 9 through day 16 of the receiving period. Since non-transported calves exhibited similar increases in acute phase concentrations, increases in stress cannot be attributed solely to transportation in this study. Additionally, calves had been weaned for over 200 days before simulated transport and transition to a feedlot-like environment. This also suggests weaning may not have been the sole stressor eliciting the inflammatory response in this group of early-weaned calves.

As a result, the transition from a grazing environment to a drylot environment typical of many feedlots may have resulted in an increase in calf stress as calves. This is important and may indicate why preconditioning studies report inconsistent results in calf stress and subsequently performance. Although preconditioning may help separate

weaning and transport stress, this early weaning trial indicates weaning for an extended period of time may not completely prevent stress as calves experience transitions in environment and large increases in concentrate level in their overall diet.

Numerous studies have successfully established that weaning, transport, castration, and restraint all increase stress markers in calves (Zavy et al., 1992). At the same time, it is apparent little has been done to determine how preconditioning influences indicators of stress in weaned calves, either through changes in behavior or physiological parameters. Additionally, literature available on preconditioning and its ability to mitigate stress in feeder calves is somewhat vague and utilizes a variety of methods that may not accurately assess stress. Further research in this area is warranted to determine if the success of preconditioning is due in part to the alleviation of stress at weaning prior to shipment and comingling.

Effect of preconditioning on calf value

Feeder calf value is influenced by a variety of factors, including weight, sex, condition, lot size, uniformity, health, and previous management (Avent, 2002). Under normal market conditions feeder calf prices will increase as calf weight decreases, and lot size and uniformity increase (Avent, 2002). Buyers also tend to pay more for castrated steers than heifers, with significant discounts occurring for intact males and calves with horns (Troxel and Barham, 2007). Additionally, calves that are perceived to be healthy or in a condition that would facilitate compensatory gain are priced more favorably than calves perceived as sick, stressed, or “fleshy” in condition (Avent, 2002).

Preconditioning calves can influence each of these factors, subsequently influencing the price producers are offered for calves in a given production year. Preconditioning provides producers with an extended period of time to implement

management practices, such as castration, vaccination, and dehorning, which can help producers avoid unnecessary discounts at the market. The preconditioning period also provides calves with an extended period of time to overcome the stress of weaning, adapt to a dry diet, and gain weight through supplementation. In combination with proper management, this can significantly improve health, condition, future performance, and uniformity among a producer's calf crop.

These improvements in health and performance are the primary reason stockers and feeders are willing to pay premiums for preconditioned calves. As the number of animals pulled and treated for disease declines, medicine cost and associated costs like increased labor, lost performance and reduced end-product quality also decrease (Duff & Galyean, 2006), justifying premiums offered for preconditioned cattle. According to Avent (2002), feedlot managers perceive that preconditioned calves are worth a premium of $0.116/kg over that of similar, non-preconditioned calves. Recent market data support this, reporting actual premiums up to $0.174/kg for preconditioned calves sold through verified programs (King and Seeger, 2005). For calves weighing approximately 227 kilograms, this premium would equate to nearly $40/head.

Substantial premiums, however, are not always observed in the marketplace. Avent (2002) reported premiums for preconditioned calves sold in Joplin, Missouri and at Superior Livestock only ranged from $0.043/kg to $0.074/kg, which are well below the premium feeders reported they were willing to pay in the same study. Donnell et al. (2007) reported calves sold through Noble Foundation cooperators in Oklahoma received premiums averaging only $0.094/kg. Similarly, Lalman and Smith (2002) reported premiums as low as $0.061/kg.

Although counter-intuitive, preconditioning premiums also seem to decrease during periods of high feeder calf market prices (Dhuyvetter et al., 2005). As calf prices increase, calves, regardless of previous management, become more valuable than they would otherwise be in a down market. As a result, death loss and reductions in performance due to stress, sickness, or lack of previous calfhood management become more expensive in high markets. This should increase the incentive for feedlots and stockers to pay more for preconditioned calves than their non-preconditioned counterparts as cow-calf producers assume some of the risk associated with morbidity and mortality during the preconditioning period (Bailey and Stenquist, 1992). However, this is not always the case. In 2005, Dhuyvetter et al. reported an inverse relationship between feeder calf futures price and preconditioning premiums calves earned during special calf sales over a 6-year period.

As a result, participation in preconditioning programs often decline during periods of high feeder calf prices (Lalman and Smith, 2002), due in part to lower premiums. In addition, cow-calf producers lack the incentive to assume the risk and additional costs associated with preconditioning when feeder calf prices are high and the market is unwilling to distinguish between preconditioned and non-preconditioned calves. Increased risk for cow-calf operators and the discrepancies that exist between the perceived or expected value of preconditioned calves and the price paid in the marketplace may explain why cow-calf producers choose not to precondition calves beyond weaning (Dhuyvetter et al., 2005).

The primary reason these discrepancies continue to exist in the marketplace is that feeder calf buyers still bear some risk when purchasing preconditioned calves

(Avent, 2002; Dhuyvetter et al., 2005). Currently, there are a variety of preconditioning programs that exist within the industry, resulting in a lack of uniformity from one protocol to the next. Additionally, discerning previous management within the traditional marketing arena is often difficult and flawed. Buyers are typically uncertain about the characteristics of feeder calves sold through auctions, which forces buyers to price calves based on the average quality within that particular market place and time (Bulut and Lawrence, 2006). Communication within the market can also breakdown and feeders cannot be assured cow-calf producers followed a specific protocol for minimum weaning period or vaccine handling and administration. The information asymmetry created when sellers fail to verify calf quality or previous management increases the risk associated with purchasing feeder calves, which ultimately results in order buyers pricing preconditioned calves below their expected value.

As a result, producers have begun to market preconditioned calves through third-party certified sales. Certified sales help to correct asymmetry within the marketplace by offering buyers and feeders some assurances when purchasing preconditioned feeder calves (Bulut and Lawrence, 2006). Calves enrolled in these marketing programs are required to undergo a specific weaning and preconditioning protocol, of which a third-party certifies. Over time, many of these programs establish a positive reputation within the industry (Avent, 2002), allowing feeders and order buyers to price preconditioned calves enrolled in these certified programs at a premium that reflects their true value within the marketplace.

Bulut and Lawrence (2006) examined this concept by assessing the value of third-party certification for preconditioned calves sold through Iowa auction markets.

Compared to base calves lacking a third-party weaning and vaccination certification claim, preconditioned calves with a certified vaccination claim and certified weaning claim of at least 30 days received a $0.135/kg premium, or for a 227 kg calf, a premium exceeding $30/head. At the same time, calves with partially certified preconditioning claims received premiums above the base price, but significantly less than those earned by third-party certified calves for vaccinations and weaning. Calves with a minimum 30-day weaning certification, but no vaccination certification received a $0.075/kg premium. Calves with a certified vaccination claim, but no certified weaning claim received a similar premium of $0.069/kg, which is nearly half of the premium completely certified calves received in the same market.

The authors also assessed whether the premiums associated with third-party certification cover the cost of participation in third-party preconditioning programs. Bulut and Lawrence (2006) estimated the cost of third-party certification would not exceed $0.022/kg for calves averaging 227 kg. According to recent market data (Bulut and Lawrence, 2006; Donnell et al., 2006; King and Seeger, 2005), the premiums earned through third-party certification sufficiently cover this cost. Additionally, market data reported by Bulut and Lawrence (2006) indicate that buyers do not necessarily distinguish between partial and uncertified preconditioning claims, resulting in a significant value loss regardless of the effort producers have made to improve calf quality. This suggests participation in third-party programs are a worthwhile investment for producers opting to precondition calves.

This concept is further supported by market data from Kentucky's Certified Preconditioned Health (CPH-45) program. Laurent (2011) reported net estimated

returns for producers enrolled in the CPH-45 sales averaged $59.36/head at two market locations over an 18-year period, with negative returns occurring in only two of the 18 years. In four of the years, estimated net returns exceeded $80/head for producers opting to hold calves and market at least 45 days after weaning. Specifically, in 2005, returns were estimated at over $100/head for calves held and sold in the December market weighing approximately 45.45 kg more than if they were weaned and immediately sold in the October market when calf supply was greater.

Similarly, Donnell et al. (2007) reported net returns for multiple preconditioning programs, including the Noble Foundation and Oklahoma State University cooperator sale. Cooperators participating in the Noble Foundation sales during 2004 and 2005 earned estimated management premiums of $0.094/kg, resulting in a net return of $57.31/head when producers marketed heavier calves approximately 52 days after weaning. Dhuyvetter et al. (2005) reported preconditioned calves sold through special calf sales were priced significantly higher than non-preconditioned calves sold through traditional auction market sales. On average, preconditioned calves sold for $0.102/kg more than their non-preconditioned contemporaries sold from fall 1999 to winter 2004. Producers that preconditioned added an estimated 30 kg of additional body weight, that when sold in the November-December market resulted in an estimated net return of over $14/head.

One of the benefits to preconditioning explains this trend. When supplementation is offered during the preconditioning period, cattle can both regain weight lost due to the stress of weaning and gain weight over that of their original weaning weight. Although heavier-weight calves tend to be priced lower in the marketplace, this is often offset by

the seasonality of market prices and premiums associated with preconditioning (Avent, 2002; Dhuyvetter et al., 2005). Producers that opt to precondition will typically sell their calves at least one month later than they would have if they opted to sell calves directly at weaning. For producers with spring calving seasons, which is the majority of cow-calf producers in the United States (McBride and Mathews, 2011), this means marketing preconditioned calves in the November-December market. Feeder calf prices during this period are typically more favorable than the September-October market fresh-weaned calves are sold in (Dhuyvetter et al., 2005). Preconditioning allows producers to capitalize on more favorable feeder calf prices with heavier-weight calves due to seasonality and changes in feeder calf supply and demand.

Preconditioning has several benefits, of which feeder calf buyers and feeders recognize. Improvements in health, implementation of castration, dehorning, and vaccination, as well as the opportunity to mitigate weaning associated stressors prior to transport make preconditioned calves desirable to operators in subsequent industry segments. As a result, buyers have become increasingly willing to offer premiums for preconditioned calves, especially if producers can offer feeders and stockers assurances related to previous management and vaccination protocols. However, information asymmetry and market conditions may not always result in premiums or premiums sufficient enough to cover the risk and associated costs of preconditioning. This forces cow-calf producers to evaluate preconditioning on an annual basis as cost of production, products available, and market dynamics fluctuate.

Factors Influencing Preconditioning Economics and Profitability

Several factors must be taken into consideration when making the decision to precondition, including current market prices, forage availability, on-farm infrastructure,

and feed costs. According to recent data, approximately half of calves sold from cow-calf operations in the United States are sold at weaning, while the remaining half are held on the ranch of origin for preconditioning (USDA-NAHMS, 2007). However, these proportions change from year to year as market factors, weather, and preconditioning costs change. In 2009, nearly 60% of cow-calf operations in the United States decided not to precondition calves and instead sold calves at weaning (McBride and Mathews, 2011). This was due in part to relatively low feeder calf prices, increasing feed and fertilizer prices, and a weak and uncertain 2009 consumer economy (USDA-ERS, 2011).

The likelihood a specific cow-calf operation will precondition in a given year can also be dependent on the operation's geographic location within the country. In 2009, 70% of cow-calf farms located in the Southeastern region of the United States chose not to precondition compared to only 41% of operations in the Northern Plains (McBride and Mathews, 2011). Geographic proximity to subsequent segments of the industry, feed and forage availability within a particular locale, and environmental constraints on production may make holding and supplementing calves beyond weaning less feasible for some cow-calf producers than others.

In addition, an inverse relationship seems to exist between herd size and likelihood of preconditioning. In 2009, nearly two-thirds of farms with less than 50 head of cows opted not to precondition, while nearly two-thirds of farms with greater than 500 cows opted to precondition (McBride and Mathews, 2011). Larger operations are more likely to have a defined calving season, practice better pasture management and record keeping, as well as vaccinate and utilize technologies like implants and ionophores

(McBride and Mathews, 2011; USDA-NAHMS, 2007). Access to better quality forage and beef technologies facilitate calf performance during preconditioning, while shorter calving intervals provide producers with a larger, more uniform calf crop to market following the holding period.

Of these factors, cost is probably the greatest single factor driving the decision to precondition. Cow-calf producers can incur large costs while preconditioning calves, including feed, labor, vaccinations, and at times medicine and death loss. Although most programs average slightly over $1/head/day (Donnell et al., 2007), estimates range between $35/head and $75/head for some programs (Avent, 2002; Lalman and Smith, 2002; Ward and Lalman, 2003). Vast differences in program costs can be dependent upon the preconditioning system utilized, length of time calves were preconditioned, feed costs, and rate of gain (Donnell et al., 2007).

Preconditioning system

Preconditioning can be implemented on either a pasture-based system or a drylot-based system, each with their own advantages and disadvantages. According to Mathis et al. (2009), pasture-based systems seem to reduce stress in freshly weaned calves. In this system, the post-weaning environment is similar to the pre-weaning environment, resulting in less of a dietary change as calves continue to have pasture access for grazing. Although calves in a pasture-based system seem to benefit from this familiar environment, drylot systems tend to produce greater gains post-weaning due to the provision of supplementation (Mathis et al., 2009). Supplementation offered in drylot systems can be forage-based; however, it is often a high-energy concentrate ration, which can also increase the cost of preconditioning.

Although few studies have sought to compare these preconditioning systems in a controlled experimental setting, these generalizations have recently been supported by work at New Mexico State University. Mathis et al. (2008) randomly assigned calves of similar weaning weights to either a pasture-based or drylot-based system to compare calf performance and profitability over a three-year period. Pastured calves remained on native New Mexico range and were supplemented with a 32% crude protein range cube three times per week, while drylot calves received a corn-wheat middlings-based pellet and alfalfa hay each day. During the 42-day preconditioning period, calves under intensive drylot management exhibited greater ($P<0.01$) ADG, resulting in heavier ($P=0.03$) body weights at the conclusion of the preconditioning period.

Although drylot calves gained more and weighed more at the conclusion of the preconditioning period, net income per head was $45 greater ($P<0.01$) for calves managed on a pasture-based system than a drylot system. Feed costs were five times greater ($P<0.01$) in the drylot system; increasing total cost per head to over $60.00 for the drylot system verses only $12/head in the pasture system. Interestingly, pasture calves exhibited greater ($P<0.01$) ADG from day 0 to the midpoint of the preconditioning period, suggesting the pasture-based system was less stressful as calves had less of an environmental and nutritional adjustment to make immediately following weaning.

In a follow-up study, Mathis et al. (2009) evaluated pasture-based preconditioning using a high-input and a low-input method. Calves allocated to a high-input pasture system received ad libitum access to a self-fed corn-wheat middlings-based pellet, while low-input calves received a 32% crude protein range cube three times per week. Again, the high-input system, although pasture-based, resulted in greater ($P<0.01$) post-

weaning gains than the low-input system. Low-input calves gained 0.50 kg/head/day on average, while high-input calves gained 0.82 kg/head/day on average. High-input calves also exhibited heavier (P<0.01) body weights at the conclusion of the preconditioning period, despite similar weaning and trial interim body weights.

As a result of greater gains and heavier final body weights, high-input calves in this trial had a $20/head greater (P<0.01) final value than low-input calves. However, greater (P<0.01) feed costs in the high-input system resulted in a $20.54/head net income advantage for low-input calves. These results are in agreement with the previous study conducted by Mathis et al. (2008), indicating a lower cost approach may be more profitable post-weaning despite greater gains and more marketable calf weight.

Similar results were reported by St. Louis et al. (2003), who evaluated performance and profitability in nearly 200 purchased heifer calves on drylot or winter annual pasture in Mississippi. Calves were assigned to one of three treatments; calves on drylot receiving 4.54 kg/head/day of a mixed grain diet, calves on drylot receiving 2.27 kg/head/day of a mixed grain diet, or calves on ryegrass pasture receiving no supplementation. At the conclusion of the 21-day preconditioning period, net returns were greatest for ryegrass calves, at $46.38/head, compared to $3.21/head and $18.25/head for drylot calves receiving a high rate of supplement or a low rate of supplement, respectively. Total preconditioning cost for purchased calves on ryegrass was less than $30/head, while feed costs alone amounted to nearly $30/head in the high-supplemented drylot group.

In contrast to results previously reported by Mathis et al. (2007) and Mathis et al. (2009), ryegrass calves exhibited greater (P<0.05) ADG than either drylot treatment

group. Ryegrass calves gained 1.33 kg/day, while the drylot calves gained 0.84 kg/day and 0.89 kg/day for high-supplemented and low-supplemented treatments, respectively. The higher rate of gain for pastured calves may be due to forage quality differences between the New Mexico trials using native range and the current study using a winter annual. In addition, Mathis et al. (2009) reported declines in forage quality throughout the trial period, while no forage quality decline was reported by St. Louis et al. (2003).

St. Louis et al. (2003) also reported that ryegrass calves exhibited no sickness or death loss, while both drylot treatments each reported 3.03% morbidity during the preconditioning period. Similarly, Boyles et al. (2007) reported that calves preconditioned on pasture for 30 days had nearly 2.5 times less ($P<0.05$) feedlot morbidity than calves preconditioned on drylot. Mathis et al. (2008) did not report differences in feedlot morbidity between pastured and drylot preconditioned calves, but did report the drylot preconditioning treatment had more ($P=0.02$) calves die during finishing than the pastured preconditioning treatment. Drylot preconditioned calves exhibited a 7.6% death loss compared to a 0% death loss for pasture preconditioned calves.

Although the preconditioning morbidity rates reported by St. Louis et al. (2003) are relatively low, especially for purchased calves, the morbidity and mortality rates reported by St. Louis et al. (2003), Mathis et al. (2009), and Boyles et al. (2007) all indicate pasture-based systems impose less stress on weaned calves. Drylot systems force calves to rapidly transition to a dry, unfamiliar diet, which they must eat out of bunks, which they are also not accustomed to. The drylot environment also facilitates dust and mud accumulation that may reduce mobility and performance in rainy weather, or irritate

the calf's respiratory tract and increasing the risk of morbidity during dry weather. Although data presented would suggest pasture-based systems are more profitable due to lower feed costs, this may not always be the case. In markets when feed and hay prices are relatively low and premiums for preconditioned calves are such that the value of gain is greater than the cost of gain, drylot-based programs may be profitable as well. The decision to precondition as well as the method utilized should be made each year using forecasts for calf, feed, and fertilizer market prices.

Preconditioning time period

Preconditioning programs vary in length, with most programs lasting between 14 and 45 days, and some lasting 60 days or longer (Dhuyvetter, 2003). Recent data suggest when the period from weaning to feedlot arrival is lengthened beyond 45 days feedlot morbidity and health costs are reduced (Mathis, 2009). Literature would also suggest that it typically takes at least two weeks for calves to regain weight lost during the weaning process (Cole and McCollum, 2007; Alkire and Thrift, 2005), making it difficult for producers to recoup expenses through added weight gain when preconditioning periods are only two to three weeks in length. At the same time, the risk and costs associated with preconditioning tend to increase as the interval from weaning to feedlot entry is lengthened. This makes many cow-calf producers hesitant to implement programs for long lengths of time, especially when feed cost are expected to be high. Such a discrepancy creates a challenge for cow-calf producers as they attempt to optimize both profitability and calf performance when deciding how long to precondition.

Data comparing returns from various preconditioning periods is limited. Donnell et al. (2007) analyzed cost and return data for Oklahoma's 2004 and 2005 Noble

Foundation preconditioning sales, reporting net margins increased approximately $1/head for each additional day calves remained in a preconditioning program. This is most likely due to increases in gain above and beyond weaning weight that were achieved through the longer preconditioning periods some producers opted to implement. Feed costs and their influence on margins were also analyzed. Feed was the largest expense to cooperating producers, equating to approximately two-thirds of total preconditioning costs in 2004 and 2005. For every $1 increase in feed and mineral costs net margins were reduced by nearly $1.50/head. Although net returns for the different preconditioning periods were not reported separately, returns for longer preconditioning periods may not have been greater than returns for shorter preconditioning periods since feed costs typically increase with each additional day supplement, mineral, and hay is offered.

In a University of Tennessee study reported by Rawls (2010), preconditioning returns for 45-day and 60-day programs were compared using historical data from 1995 through 2008. Gross margins between the calf value at weaning and the calf value after preconditioning were estimated for both spring and fall calving seasons. Additionally, it was assumed calves preconditioned for 45 days gained 0.80 kg/day, while calves preconditioned for 60 days gained more rapidly at 0.91 kg/day. Feed costs were estimated and adjusted each year for calves receiving a preconditioning supplement at 2% of bodyweight. Preconditioned calves were also assumed to have a 1% death loss during the preconditioning period and a $0.088/kg premium at sale.

Under these assumptions, 60-day preconditioning periods were reported to be more profitable than 45-day preconditioning periods for both fall-born and spring-born

calves. This is not surprising since calves in the 60-day programs benefited from a longer feeding period and an assumed higher rate of gain per day than calves in the 45-day programs. Although feed costs would have been greater for the 60-day programs, total costs were spread out over an additional 15 days and 41 pounds of gain. More importantly, net returns for both 45-day and 60-day programs, regardless of calving season, calf sex, weight, or month marketed, ranged from a $25/head profit to a $25/head loss in at least half to three-quarters of the years reported. This suggests preconditioning margins have historically been small regardless of time period implemented.

Similar results were reported by Waggoner et al. (2005) using New Mexico Ranch to Rail data. Calves were grouped into four treatments based on preconditioning period, including 0 to 20 days, 21 to 40 days, 41 to 60 days and greater than 61 days. Although net returns were calculated for the feeding and finishing period only, net income increased (P=0.09) as preconditioning period increased. Calves preconditioned for 0 to 20 days had a net income of -$41.66/head, while calves preconditioned for 40 to 60 days and greater than 61 days had a net income of $2.23/head and $4.00/head, respectively. Cost of gain was also highest for calves preconditioned for 0 to 20 days, while calves preconditioned for 41 to 60 days spent the fewest days on feed and had the lowest total feed cost. Although this study did not specifically evaluate preconditioning returns, these results are relevant to cow-calf producers retaining ownership through the feedlot segment. Producers opting to retain ownership may capture much more value through the preconditioning process than producers who opt to sell at the end of the preconditioning period when returns are marginal.

Literature comparing the profit margins of short- and long-term preconditioning periods is limited and warrants further research. The length of a particular program influences both calf performance and costs, which ultimately influences the cow-calf producer's return on investment. Longer preconditioning periods provide calves with more time to overcome the stress of weaning, adapt to a dry diet, regain weight lost in the weaning process, and gain additional pounds for the producer to market. On the other hand, longer preconditioning periods also require more resources, specifically in the form of feed, labor, and infrastructure, which could reduce profitability.

Nutritional supplementation and rate of gain

Costs associated with nutrition constitute the greatest single proportion of total preconditioning costs (Cole, 1985; Donnell et al., 2007; Lalman and Smith, 2002). As previously outlined, pasture-based programs tend to have much lower associated nutritional costs than drylot-based programs. At the same time, forage quality and/or quantity may be not be sufficient to meet nutritional requirements or facilitate gains to cover the costs of preconditioning in pasture-based programs (Cole and McCollum, 2007; Lusby, 2006; Thrift and Thrift, 2011). Therefore, provision of supplemental feeds may be justified to increase post-weaning gains over that of grazing alone

Several stocker calf trials illustrate this concept. Paisley et al. (1998) evaluated post-weaning gains of stocker calves grazing winter wheat pasture, either receiving supplementation or not receiving supplementation. Supplement, consisting of ground milo, wheat middlings, and an ionophore, was provided every other day in pellet form. Unsupplemented calves received free-choice access to a high-calcium mineral supplement throughout the trial period. Calves receiving alternate-day energy supplementation achieved significantly higher gains than those not receiving

supplementation. Over the 127-day trial period, calves receiving supplementation gained 1.33kg/day compared to 1.15kg/day for unsupplemented calves, resulting in heavier final body weights.

Biggerstaff et al. (1991) also reported increases ($P<0.05$) in average daily gain when fresh-weaned calves received a molasses-soybean meal supplement in addition to pasture grazing. Calves grazed bahiagrass pastures from September to November, which would be the traditional time period for weaning and preconditioning in most cow-calf herds (McBride and Mathews, 2011). Throughout the three-year backgrounding trial, supplementation improved average daily gain by 0.21 kg over that of unsupplemented calves. At the same time, calf gains across treatments tended to decline during the second month of the trial each year. This was followed by an increase in molasses consumption in treatment groups where supplement was provided. Decreased calf performance and increased consumption of supplement were most likely due to the seasonal declines in forage quantity of bahiagrass pastures during the trial period.

Similarly, Coffey et al. (2006) evaluated the effect of supplementation and forage source on the performance of steers in a three-year fall backgrounding trial. Steers were allowed to graze stockpiled bermudagrass forage or were provided bermudagrass hay as a forage source, while supplemented steers received a 14% crude protein supplement at the rate of 1.82 kg/day. No forage source by supplementation interaction was reported. Although final weight and cumulative average daily gain were similar between the two forage treatments, supplemented steers consistently outperformed unsupplemented steers in each year of the study. On average, supplemented calves

gained 0.34 kg more ($P<0.05$) per day than the unsupplemented calves over the approximate 80-day trial periods.

It is important to note that in each of the trial years, stockpiled forage quantity and quality generally declined from the start of the trial to the conclusion of the trial. Additionally, both forage sources only met maintenance requirements for the steers in the last two-thirds of the trial periods. Reliance on pasture as the sole source of calf nutrition may be a challenge for producers weaning and preconditioning calves in the fall when forage quantity and quality traditionally decline. In such cases, if the costs associated with supplementation to achieve higher rates of gain are less than the value associated with that gain, supplementation in pasture-based systems may prove more economical than grazing alone.

When providing supplement, producers should recognize that fresh-weaned calves have a distinct need for feed that is both high in quality and palatability (Hersom et al., 2011; Lofgreen, 1988; Lusby, 2006). Following weaning, calves are stressed, which may alter their nutritional status and reduce appetite (Carroll and Forsberg, 2007; Hutcheson and Cole, 1986). In addition, fresh-weaned calves spend much of the first few days post-weaning bawling and walking the fenceline rather than consuming feed (Lalman and Smith, 2002; Price et. al., 2003). As a result, preconditioning diets require a higher concentration of nutrients to meet the weaned calf's dietary nutritional requirements and need to be palatable to entice consumption of unfamiliar feeds (Cole and McCollum, 2007).

There are a variety of feeds producers can choose from when preconditioning. Corn, wheat, barley, and milo are acceptable feedstuffs because they are energy dense

and have the potential to meet calf nutrient requirements despite limited feed intake (Addis et al., 1973; Gadberry et al., 2009). Provision of high energy supplementation has been shown to increase calf performance post-weaning (Gill et al., 1980) but producers should exercise caution when using high energy supplements because they may also increase morbidity rates in stressed calves (Gill et al., 1980). Supplements high in protein, particularly natural sources of protein, may also work well in many preconditioning programs since growing cattle require high quality, readily available protein sources to facilitate growth and muscle deposition (Hersom et al., 2011).

Co-product feeds like molasses, citrus pulp, soybean hulls, and dried distillers grains may also be used in growing and preconditioning programs. Co-products tend to be affordable alternatives to more traditional sources of energy and protein like corn and soybeans, especially when cow-calf producers are located in close proximity to manufacturing sources. Several studies have evaluated the use of co-products in preconditioning and stocker programs. Most studies would suggest that co-products can improve calf performance and profitability in post-weaning scenarios over that of grazing alone.

Alkire and Thrift (2005) evaluated citrus pulp as both an affordable and palatable source of energy during a 42-day pasture preconditioning trial. Citrus pulp is a co-product feed readily available to producers located near citrus processing facilities. Although citrus pulp is an excellent source of energy, crude protein concentrations are low. In order to evaluate citrus pulp as an economical alternative to traditional commodity supplements, the authors utilized urea and undegradable intake protein (UIP) as additional sources of protein. Treatments included an unsupplemented control

group and three citrus pulp supplemented groups each receiving 2.27 kg of supplement/head/day. Supplemented treatment groups were citrus pulp with no additional protein source, citrus pulp with 0.22 kg added UIP, and citrus pulp with urea.

Regardless of supplement treatment, supplemented calves exhibited greater ($P<0.01$) ADGs throughout the trial period compared to unsupplemented calves grazing bahiagrass-bermudagrass pasture alone. Calves receiving citrus pulp with added UIP gained the most over the 42-day preconditioning period compared to the remaining citrus pulp treatments. Citrus pulp with added UIP produced 42-day gains of 0.43 kg/head/day, citrus pulp alone produced 42-day gains of 0.33 kg/head/day, and citrus pulp with urea produced 42-day gains of 0.24 kg/head/day. Profitability of supplementation verses grazing alone was also evaluated by the authors, indicating supplementation of citrus pulp with added UIP was the most profitable treatment while grazing alone was the least profitable treatment. Assuming preconditioning resulted in a premium at the time of sale, provision of citrus pulp with added UIP would result in a $30.41/head profit compared to an $18.95/head profit for unsupplemented control calves.

Savell et al. (2007a) compared the use of soybean hulls to soybean meal in a preconditioning program. Calves grazing bahiagrass-berumdagrass pastures were supplemented with either soybean hulls or soybean meal for a 42-day preconditioning period. Both supplements are a co-product of the soybean oil industry and provide adequate crude protein for growing calves. Soybean hulls are also a good source of energy and provide a high level of digestible fiber. Treatments of soybean hulls and

soybean meal were designed to be isonitrogenous, providing 0.27 kg of crude protein/head/day.

Calves receiving soybean hulls exhibited greater ($P<0.0001$) post-weaning gains compared to calves receiving soybean meal. Provision of soybean hulls resulted in a 15.82 kg/head body weight gain for the entire preconditioning period compared to only a 10.14 kg/head body weight gain for soybean meal supplemented calves. Differences in gain may be attributed to differences in energy intake between the treatment groups. In order to keep treatments isonitrogenous, soybean hulls were fed at a higher rate than soybean meal, resulting in a greater amount of total digestible nutrients (TDN) being provided in the soybean hull treatment group. Profitability estimates indicate that feeding soybean hulls can also be more profitable than feeding soybean meal during preconditioning. Assuming preconditioned calves received a premium at the time of sale, calves preconditioned with soybean hulls earned a $7.21/head profit, while those preconditioned on soybean meal lost $0.41/head compared to being sold at weaning.

Austin and Thrift (2007) evaluated the use of molasses, another by-product energy supplement, in a pasture-based preconditioning program. Molasses, an affordable by-product of the sugar industry, is an excellent source of energy commonly used to increase weight gain in grazing cattle. Molasses is typically fortified with nitrogen or protein-containing products to increase crude protein content, especially when utilized in growing programs (Hersom et al., 2011). In the current study, calves were allotted to one of four treatments; unsupplemented control, 16% crude protein fortified molasses slurry, 16% crude protein fortified molasses slurry with an added bypass methionine source, and 32% crude protein fortified molasses slurry. The bypass methionine source

treatment was incorporated into the study as an alternative to the traditional slurry non-protein nitrogen source urea. All treatments grazed bahiagrass pasture, with liquid molasses supplied ad libitum through lick tanks.

Molasses supplementation increased ($P<0.05$) average daily gain over that of unsupplemented controls during the 42-day preconditioning period. Unsupplemented calves lost weight throughout the trial period, exhibiting an average daily gain of -0.06 kg/head/day. Calves supplemented with 16% molasses slurry gained 0.05 kg/head/day with no differences in daily weight gain exhibited between any of the molasses supplementation treatments. Although supplemented calves gained slightly more than unsupplemented controls, weight gains throughout the trial period for all treatments were insufficient to cover the costs of preconditioning when preconditioning failed to bring a management premium for calves. Poor calf performance in the supplemented treatments may be a result of the nitrogen and protein sources used in the trial. Natural protein sources are often better utilized by growing cattle than synthetic or non-protein nitrogen sources (Hersom et al., 2011), which were used exclusively in this study. Results of this study and others (Savell et al., 2007b; Thomas et al., 2009; Thrift et al., 2003) illustrate preconditioning profitability is dependent on a variety of factors, including supplementation source, rate of gain, feed costs, and the ability of producers to capture added value through the marketing process.

It has been demonstrated that the provision of supplementation can increase preconditioning gains over that of grazing alone. The act of supplementation, however, does not definitively produce gains that make supplementation profitable in all cases. In an effort to achieve profitable rates of gain in grazing cattle, many producers opt to

utilize feed additive technologies, like ionophores and subtherapeutic antibiotics, in conjunction with supplementation. Both ionophores and antibiotics work by manipulating the microbial population within the rumen and intestinal tract, reducing digestive disorders, improving digestion and absorption of feedstuffs, and ultimately promoting growth in cattle (Holdsworth and Parker, 2003).

Ionophores are classified as an antibiotic because of their bacteriostatic properties. Originally used in the poultry industry to control coccidiosis, this class of compounds includes the ionophores monensin, lasalocid, and laidlomycin proprionate (Bergen and Bates, 1984; Callaway et al., 2003; Schelling, 1984). The specific mode of action by which ionophores work to improve calf performance is related to their ability to modify the flow of ions within the lipid bilayer of bacterial cell walls (Holdsworth and Parker, 2003; Bergen and Bates, 1984). This can disrupt the bacterial organism's ability to regulate metabolic functions as intracellular ATP is lost through degradation in the cell's proton gradient (Bergen and Bates, 1984; Callaway et al., 2003). Some ionophores also have the ability to disrupt the sodium ion gradient of specific bacterial cells, which can increase intracellular ion concentration and cause bacteria to swell and burst (Bergan and Bates, 1984). As a result, ionophores can selectively inhibit bacteria, specifically gram-positive bacteria within the digestive tract of ruminants (Fernando et al., 2005), subsequently influencing calf performance.

Research documenting improvements in calf performance through the inclusion of ionophores in feedlot diets is extensive. When used in conjunction with high starch diets, ionophores reduce feed intake while maintaining gain, ultimately improving feed efficiency during the finishing period (Horton and Palmer, 1981; Laudert, 1997). When

used in grazing cattle, ionophores have been shown to elicit a gain response in some studies (Horton et al., 1992; Paisely et al., 1998; Worrell et al., 1990), while in others gain was not influenced or reduced (Montgomery et al., 2000). Differences in performance responses may be dependent on several factors, including forage quality, forage quantity, environmental conditions as well as ionophore supplementation rate and frequency (Bretschneider et al., 2008; Horton et al., 1992).

Inconsistencies in grazing cattle responses were reported by Biggerstaff et al. (1991) in a three-year fall backgrounding trial. Monensin was added to a soybean meal supplement at the rate of 200 mg/head/day in the last two years of the trial. Heifers grazing bahiagrass pastures in the second year of the trial and receiving a soybean meal-monensin supplement gained 0.11 kg more per head per day over that of heifers receiving a soybean meal supplement without monensin. Monensin supplemented heifers gained 0.82 kg/head/day over the 47-day trial, while non-monensin supplemented heifers gained 0.70 kg/head/day.

In contrast, gain response to the addition of monensin in the last year of the trial was reversed. Heifers receiving the soybean meal-monensin supplement lost weight over the 55-day trial period while heifers receiving the soybean meal supplement without monensin gained weight. Monensin supplemented heifers gained -0.07 kg/head/day while non-monensin supplemented heifers gained 0.10 kg/head/day. Supplement consumption between treatments in both years of the trial were similar as was residual forage remaining in pastures at the conclusion of each year. Additionally, gains of unsupplemented controls were negative in the third year of the trial when monensin response was poor, while gains of unsupplemented calves in the second year

were similar to gains of calves supplemented without monensin. This indicates differences forage quality between trial years may have been responsible for inconsistencies in response to monensin.

Kunkle and Bates (1989) measured the performance response of grazing Brangus steers and heifers to lysocellin supplementation following weaning. Steer and heifer calves were blocked into a heavy and light weight block. Treatments included soybean meal supplemented at 0.45 kg/head/day with three levels of ionophore included in the diet at 0, 50, 100, or 200 mg/head/day. An unsupplemented control was also included where calves grazed bahiagrass pasture as their sole source of nutrition for the 91-day trial period. Performance response to lysocellin treatment between steers and heifers as well as between light- and heavy-weight calves was similar throughout the trial period

Inclusion of lysocellin in a soybean meal supplement increased ($P<0.05$) daily gains of grazing calves over that of calves receiving supplement without an ionophore. Shrunk weight gains were 0.16, 0.15, and 0.13 kg/head/day for ionophore inclusion rates of 50, 100, and 200 mg/head/day, respectively. Calves receiving lysocellin in a soybean meal supplement gained twice as much as unsupplemented controls, exhibiting a 0.66 kg/head/day rate of gain compared to a 0.32 kg/head/day rate of gain for unsupplemented calves. Cost of gain, including protein and ionophore supplementation, was less than $0.09/kg. Although this figure would seem to be profitable for the time period, market prices for calves at weaning and following backgrounding were not provided to determine if this cost of gain was less than the value of gain.

Improvements in performance following ionophore supplementation were also reported by Horton et al. (1981). Lasalocid was included at 100 mg/head/day in a supplement offered three times per week during a 140-day winter backgrounding trial. Calves receiving lasalocid supplementation exhibited a 14% improvement in average daily gain, resulting in a 10 kg increase in body weight over that of calves not receiving the ionophore. Similarly, Pitman and Pate (1984) reported a 4.7% and 12.3% increase in gain over that of controls in a yearling stocker calf trial for low and high lasalocid intakes, respectively. Steer calves on trial grazed stargrass pastures for 126 days in the fall with lasalocid provided ad libitum in a mineral mix at the rate of 0, 216, and 324 g/ton of mineral mix.

Ammerman et al. (1979) evaluated the use of monensin in a 126-day backgrounding program where cottonseed hulls served as the major source of dietary roughage. Steers were allotted to one of four treatments; soybean meal without added monensin, soybean meal with 200 mg monensin/head/day, soybean meal-corn mixture without monensin, or soybean meal-corn mixture with 200 mg/head/day. The authors reported neither monensin nor supplemented energy level influenced average daily gain. Although monensin did not affect rate of gain, it did significantly reduce feed intake in both supplement groups, improving feed conversion by an average of 13%.

Improvements in performance are primarily attributed to one of two things; reductions in rumen degradation of dietary protein and modifications in rumen volatile fatty acid production (Bergen and Bates, 1984; Schelling, 1984). Ionophores are reported to have a “protein-sparing” effect, which allows more dietary protein to escape digestion in the rumen and reach the abomasum where it can be more efficiently utilized

by the animal (Russell and Strobel, 1989; Schelling, 1984). Several studies have also demonstrated that ionophores reduce the acetate to propionate ratio within the rumen (Ammerman et al., 1979). Propionate production and utilization by the ruminant is considered to be more efficient than the production and utilization of the other volatile fatty acids (Callaway et al., 2003). As propionate production increases, methane production also decreases (Joyner et al., 1979), leading to increased carbon and energy retention during the fermentation process (Bergen and Bates, 1984; Callaway et al., 2003).

Ionophores can also be used in conjunction with antibiotics in grazing cattle supplements and feedlot diets during the receiving period. Duff et al. (1995) allotted 250 crossbred calves to four treatments following arrival and processing at the feedlot. All calves received ad libitum access to a 70% concentrate diet during the 28-day trial period. Treatments included a control diet without ionophore, monensin added at 20 g/ton and tylosin at 10 g/ton of dietary dry matter, monensin added at 30 g/ton and tylosin at 10 g/ton of dietary dry matter, and lasalocid included at 30 g/ton and oxytetracycline at 8 g/ton of dietary dry matter.

Rate of gain from day 0 – 14, 15 – 28, or 0 – 28 were not influenced by treatment, indicating ionophore type and level did not affect calf performance during receiving. Daily dry matter intake from day 0 – 28 tended to be lower for ionophore treatment groups compared to control calves; however, feed to gain ratios throughout the trial period were similar among all treatment groups. Although reduced feed intake did not negatively affect average daily gains in this study, it does have the potential to influence calf health and performance if intake is reduced to the point where daily nutrient

requirements are not met. Reduced dry matter intake following ionophore supplementation in stressed calves have been reported by other authors and may be due in part to poor palatability (Addis et al., 1973; Balsi et al., 2010a; Pritchard and Thomson, 1992).

The addition of dietary ionophores and feed-grade antibiotics in the receiving ration did reduce the numerical percentage of calves exhibiting coccidial oocysts. Fecal samples obtained on day 0 indicated nearly 75% of calves exhibited some degree of coccidiosis before treatments were initiated. Incidence of coccidial oocysts decreased up to 22.2% across treatments by the conclusion of the trial. Ionophores and antibiotics administered through the feed, like monensin and oxytetracycline, can help producers control diseases like coccidiosis, which may improve health and subsequently performance in high-risk, recently weaned calves.

Duff et al. (2000) examined antibiotic regimes while comparing pre-shipping and arrival medication in feedlot calves during the receiving period. Two studies were conducted using medium-weight steers and light-weight steers and bulls. Medium-weight steers were assigned to either a control treatment not receiving antibiotic medication, a pre-shipping treatment receiving an injectable antibiotic (tilmicosin phosphate) prior to arrival at the feedlot, and an arrival treatment receiving the same injectable antibiotic after arriving at the feedlot. Light-weight bulls were castrated and both steers and castrated bulls were allotted to a control, pre-shipping, or arrival treatment as in experiment one. Light-weight calves in experiment two were then assigned in a 3 x 2 factorial design to either receive feed-grade chlortetracycline or not receive feed-grade chlortetracycline from day 5 through day 28 of the receiving phase.

In experiment one, average daily gain, daily dry matter intake, or feed efficiency were similar for control and treated calves regardless of whether antibiotics were administered prior to shipment or at arrival at the feedlot. Throughout the 35-day receiving period, average daily gains were 1.18, 1.24, and 1.27 kg/head/day for control, pre-shipping, and arrival treatments, respectively. Similarly, pre-shipping or arrival antibiotic treatment with injectable tilmicosin phosphate did not significantly improve rate of gain, intake, or feed efficiency in calves from day 0 – day 28 of the trial period in experiment two.

An interaction between tilmicosin phosphate and chlortetracycline was observed from day 5 – day 10 in light-weight calves during experiment two. Control calves not receiving tilmicosin phosphate either pre-shipping or at arrival made a greater ($P<0.10$) improvement in average daily gain when chlortetracycline was added to the diet on day 5 than calves receiving tilmicosin phosphate before or at arrival. Calves receiving chlortetracycline in the diet gained 0.05 kg/head/day from day 5 – day 10, while control calves not receiving chlortetracycline in the diet lost 0.32 kg/head/day during this interval. Additionally, gain to feed ratio was increased ($P<0.10$) with the addition of chlortetracycline in the diet during day 0 – day 14 of the 28-day receiving period.

Although performance response was inconsistent between trials, morbidity rates in medium-weight and light-weight calves were greater ($P=0.01$) for control calves than the medicated treatment groups in both trials. In experiment one, nearly 72% of control calves had to be treated for BRD, while only 46% of calves receiving antibiotic medication required treatment. In experiment two, 40% of control calves required treatment, while 18.7% of pre-shipment calves and 7.5% of arrival calves required

treatment. Morbidity rates were similar between light-weight calves receiving chlortetracycline in the diet and those not receiving chlortetracycline in the diet. Similarities in BRD morbidity rate between feed-grade antibiotic administration treatment groups may be due to differences in intake of individual animals. Although pen intakes were similar between these treatments during the receiving phase, sick and/or stressed animals susceptible to disease may not have consumed enough chlortetracycline to reduce overall treatment group morbidity.

Brazle (1994) measured the effect of chlortetracycline within a mineral mixture for stocker cattle grazing native grass in Kansas. Steers were provided ad libitum access to mineral mixes with four levels of chlortetracycline; 0, 150, 300, or 450 mg/head/day. Supplementation of chlortetracycline did not elicit a gain response in calves during the 92-day trial period. Control calves provided with mineral but no chlortetracycline gained 1.168 kg/head/day. Calves supplemented with 150, 300, and 450 mg of chlortetracycline/head/day gained 1.172, 1.168, and 1.172 kg/head/day, respectively. Incidences of footrot and eye problems were similar between controls and all treatment levels of added chlortetracycline. Only 2% of controls exhibited footrot and less than 7% of controls exhibited eye problems, indicating overall morbidity in this group of stocker calves was low and may not accurately assess the efficacy of feed-grade chlortetracycline in grazing cattle.

Hubbell et al. (2000) also evaluated the efficacy of chlortetracycline in a three month fall and winter grazing trial. Calves were offered 0.91 kg of corn/head/day to act as a carrier for one of two antibiotic feed additives evaluated in the trial. Treatments included a control with corn and no feed-grade antibiotic, corn with 70 mg/animal/day of

chlortetracycline, and corn with 20 mg/animal/day of bambermycin. Measures of gain reported by the authors indicate supplementation with a feed-grade antibiotic while grazing endophyte-infected fescue does not provide a significant growth advantage over that of corn supplementation alone. Control steers gained 56.36 kg over the entire trial period, while steers fed chlortetracycline gained 67.73 kg and steers fed bambermycin gained 59.55 kg. Prior to treatment assignment, calves were preconditioned for 30 days. Although morbidity rates were not reported, preconditioning may have improved calf health and nutritional status prior to the initiation of the trial, subsequently influencing calf response to the provision of antibiotics.

In contrast, Erwin et al. (1956) reported significant increases in gain when chlortetracycline was added to alfalfa or wheat straw rations in a small-scale study. Yearling steers were allotted to treatment in a 2 x 4 factorial experiment, with roughage source (alfalfa and wheat straw), chlortetracycline, fat, and stilbestrol level as variables. No interactions between chlortetracycline administration and the other variables were reported. When chlortetracycline was added in the diet at 5 mg/0.45 kg for both roughage rations, gain increased by 0.1 kg/head/day and by 0.14 kg/head/day for the alfalfa and wheat straw rations, respectively. Chlortetracycline administration did not influence feed intake or feed efficiency over the 183-day trial period.

Addis et al. (1973) also reported positive performance responses to dietary antibiotic supplementation in three separate trials. The feed-grade antibiotics Aureo S-700 (chlortetracycline-sulfamethazine) and Bacitracin MD were added to a 72% concentrate feedlot receiving ration. Calves allotted to the Aureo S-700 treatment received the antibiotic at the rate of 700 mL daily for the first 28 days following arrival.

Bacitracin MD calves received the antibiotic twice daily for the first days of each 28-day feeding period. Control calves offered the receiving ration without a feed-grade antibiotic ate more during the first two weeks of each trial than calves offered rations with Aureo S-700 and Bacitracin MD.

Although initial gains favored control calves, average daily gain over the entire 56-day trial periods were higher for calves receiving feed-grade antibiotics. In the third trial, control calves exhibited an average daily gain of 1.27 kg/head/day, while Aureo S-700 calves exhibited gains of 1.32 kg/head/day and Bacitracin MD calves exhibited gains of 1.37 kg/head/day. Feed conversion was highest for control calves compared to calves being supplemented with an antibiotic. Improved feed efficiency for antibiotic treated calves resulted in lower costs of gain than control calves despite higher treatment and processing costs for antibiotic fed calves.

Although variable, literature on feed-grade antibiotics and ionophores indicate health and performance of stressed calves can be improved with supplementation. Responses in daily gain, intake, and feed efficiency result in widespread use of these feed additives in the feedlot segment (USDA-APHIS, 2011; USDA-NAHMS, 1999). Their success in receiving and finishing diets have expanded their use in post-weaning scenarios in the stocker, backgrounding, and cow-calf segments (USDA-NAHMS, 2007). At the same time, consumers have become increasingly concerned about subtherapeutic antibiotic usage in food animal production and their role in antibiotic resistance in humans. This has prompted researchers and producers to seek alternatives to feed-grade antibiotics and ionophores in diets of calves at the highest

risk of becoming morbid. Alternatives for use in ruminant diets include probiotics and yeast-based additives.

The use of these products in both monogastric species and pre-ruminants as non-antibiotic feed technologies indicate they have the potential to elicit improvements in health and performance in young, stressed calves. Hulut and Cravener (2011) reported similar feed conversion ratios, body weights, and mortality rates among turkey hens fed a commercial control diet containing either feed-grade antibiotics or a yeast-based additive. Bertrand and Martineau (2009) incorporated a yeast-based additive into the diet of veal calves, reporting performance improvements that extended into the fattening period. Similarly, Kerr et al. (2007) reported the addition of a yeast-based additive to milk replacer significantly improved average daily gain and total weight gain in dairy calves.

Newman et al. (1993) reported significant improvements in average daily gain when a yeast-based additive was added to milk replacer in dairy calves. Mannan oligosaccharide offered through non-acidified milk replacer improved average daily gain by 4.227 kg/day over that of controls receiving an unsupplemented milk replacer. A starter diet was also offered to calves ad libitum in both treatment groups, of which intake was increased by 18% in the mannan oligosaccharide treatment group. Incidence of respiratory disease decreased with mannan oligosaccharide supplementation, possibly improving intake and rate of gain in this treatment group.

Responses to yeast-based additives in ruminant animals have been less consistent in the available literature. Cole et al. (1992) incorporated yeast culture at various levels in the receiving diets of feeder calves and lambs in four different studies.

Yeast culture was added included in the diet at a rate of either 0 or 0.75% in the first and third feeder calf studies, and at a rate of 0, 0.75, 1.125, or 1.5% in the second and fourth feeder calf and lamb studies. Including yeast culture into feeder calf diets for 57 days did not significantly improve performance during receiving in the first and second studies. Morbidity rates were similar between control and yeast-supplemented calves; however, the authors did report an improvement in response to antibiotic treatment in yeast-supplemented calves. In the third study, calves supplemented with yeast culture tended to weigh more and exhibit higher feed intake than controls after an infectious bovine rhinotracheitis virus challenge, indicating the addition of a yeast culture may elicit greater performance responses in sick verses healthy cattle.

Phillips et al. (1985) reported similar inconsistencies in response to yeast culture supplementation in feeder calves. Yeast was included in the diet at 0, 1, or 2% of dry matter in the diet. Light-weight feeder calves were subjected to weaning, fasting, re-feeding, and re-fasting to simulate the stress associated with traditional weaning and marketing channels. Although dry matter intake of both yeast culture treatment groups tended to be higher than controls, gain response to yeast culture supplementation did not exhibit a clear trend throughout the trial period. Intake for control calves in trial two was 4.1 kg/head/day, while average dry matter intake for yeast-supplemented calves was 5.1 kg/head/day. This resulted in a 24% improvement in dry matter intake after yeast culture was added to the diet of stressed calves. Dry matter intakes between yeast treatment groups and controls in the first two weeks of each trial were not extremely depressed despite the fasting conditions simulated in the design of the experiment. This indicates calves may not have been stressed enough to reduce

appetite to the degree observed in other stress calf studies (Lofgreen et al., 1980; Lofgreen et al., 1981), explaining why gain response to yeast culture was inconsistent and not improved over controls in most cases.

Birkelo and Rops (1994; 1995) investigated the effect of yeast culture supplementation in growing calves and yearling steers in the feedlot in two separate trials. Weaned calves were blocked by weight and allotted to either a control or yeast-supplemented treatment (Birkelo and Rops, 1994). Calves on both treatments were limit-fed a high concentrate diet for an average of 99 days. Rate of gain and feed efficiency measures were similar between controls and calves supplemented with a yeast culture product in both heavy-weight and light-weight blocks. Average daily gain in controls was 1.09 kg/head/day while average daily gain in yeast-supplemented calves was 1.05 kg/head/day.

In a follow-up study, Birkelo and Rops (1995) evaluated the use of a yeast culture in the finishing diet of yearling steers fed a high concentrate diet. Again, steers were allotted to either a non-supplemented control or a yeast-supplemented treatment group. No treatment differences were reported for weight gain or feed efficiency during the finishing period. Additionally, hot carcass weight, percent USDA Choice and abscessed livers were not influenced by yeast culture supplementation. The authors concluded inclusion of a yeast product in high concentrate diets for growing calves and yearling steers does not benefit health or performance under such experimental conditions.

One yeast-derived product used in food animal diets includes the mannan oligosaccharide Bio-Mos®. Tassinari et al. (2007) used Bio-Mos® in receiving rations for fresh-weaned calves arriving at the feedlot to evaluate its effect on calf health and

performance in a small-scale study. Throughout the 48-day receiving trial, half of the calves on trial received a control receiving diet without Bio-Mos® supplement and the other half of calves on trial were supplemented with the Bio-Mos® additive. Although dry matter intakes were similar between treatments, weight gain was increased by over 3% with Bio-Mos® supplementation, subsequently improving feed to gain ratios for the Bio-Mos® treatment group. Additionally, measures of the immune system indicated yeast-derived supplementation improved calf immune response to vaccines administered upon arrival. Improvements in rate of gain and feed efficiency may be due to reduced stress levels during the transition period between weaning and finishing as indicated by lower α-globulin, and β-globulin levels in Bio-Mos® calves.

In a separate trial evaluating Bio-Mos® in feedlot receiving diets, inclusion of the yeast product yielded similar improvements in calf performance and health (Alltech Technical Update Bio-Mos-935-RT, 2006). Nine hundred and two crossbred weaned calves were allotted randomly to one of two treatments; receiving diet without Bio-Mos® and receiving diet with Bio-Mos®. The receiving diet consisted of barley silage, barley, a vitamin-mineral premix, and chlortetracycline. The Bio-Mos® treatment group had 20 g of Bio-Mos® added to this receiving diet per head per day for the first 20 days following feedlot placement. Average daily gain was improved 0.24 kg/head/day and feed conversion was improved from 12.47 in controls to 8.53 in Bio-Mos® supplemented calves.

Approximately 50% of the control calves required treatment, while approximately 18% of Bio-Mos® supplemented calves were pulled and treated for sickness during the trial periods. Treatment costs were reduced by nearly half, and mortality rate decreased

over 2% between study treatments following Bio-Mos® administration for 20 days. Improvements in health and performance significantly reduced total feeding costs for calves supplemented with Bio-Mos. Total costs, including feed cost per head (with Bio-Mos®), processing, treatment, and mortality was $62.41/head for Bio-Mos® supplemented calves over an average feeding period of 70 days. Total cost for control calves was $106.46/head over an average feeding period of 92 days. Feed and mortality costs made up the largest proportion of total costs since control calves had lower gains, poorer feed conversions, and higher death rates. It should be noted that a true control diet evaluating Bio-Mos® supplementation as an alternative to feed-grade antibiotics was not included in this trial. Bio-Mos® was used in conjunction with chlortetracycline in the receiving rations, which may influence the efficacy of Bio-Mos® when offered to fresh-weaned calves arriving at the feedlot.

Actigen®, a concentrated form of the yeast-derived additive Bio-Mos®, has been evaluated in a limited number of food animal production trials. Literature available on Actigen® is primarily restricted to its use in the poultry, swine, and dairy industries as a feed additive to mitigate production stress in young animals. It is thought Bio-Mos® and Actigen® improve calf performance by regulating the immune response during stress and eliminating harmful bacteria from the intestine (Alltech, unpublished data; Chandler and Newman, 1994). Aris et al. (2011) used ten Holstein calves fed either a control milk replacer or a milk replacer containing Actigen® (1 g/head/day) to measure inflammatory response associated with *Escherichia coli* infections. Actigen® supplementation for 42 days helped to mitigate the immune response in intestinal tissue by downregulating the expression of pro-inflammatory cytokines.

Close et al. (2011) reviewed 12 different studies and reported reductions in pre-weaning piglet mortality rates and increases in piglet birth weight and weaning weight when sows were fed Actigen® in late gestation. The improvements in piglet weights and health were associated with increased quantity and quality of colostrum produced by the sows in the studies. Brennan et al. (2010) reported increases in goblet cell size and small intestinal mucin secretion following Actigen® supplementation in broiler chicks. Additionally, Brennan et al. (2010) compared the efficacy of Actigen® to the conventional feed-grade antibiotic Bacitracin MD when added to a corn-soybean broiler diet. Actigen® and Bacitracin MD regulated mucin production and immune response in similar fashions within the gut, improving small intestine function over that of the control diet without any feed additive.

Unfortunately data utilizing Actigen® in ruminants, particularly in beef cattle at or around the time of weaning, is currently unavailable. According to literature published on monogastrics and pre-ruminants, Bio-Mos® and Actigen® seem to have some potential for regulating stress and improving performance in food animals. These yeast-derived additives as well as other direct-fed microbial alternatives may be utilized in increasing amounts if government regulation and/or consumer demands restrict antibiotic use in livestock diets. This creates a clear need to determine the efficacy of feed-grade antibiotic alternatives as more consumers become opposed to subtherapeutic antibiotic usage in food animals. Specifically, more research is needed to determine the efficacy and cost effectiveness of antibiotic alternatives in conjunction with calf management practices, like preconditioning, which have the potential to reduce calf stress and improve performance and value in beef calves.

CHAPTER 3
EFFECT OF TIMING OF CASTRATION ON NURSING CALF BODYWEIGHT GAIN AND WEANING WEIGHT

Story in Brief

The objective of this study was to determine if timing of castration in nursing calves affected calf performance, primarily weaning weight. Ninety-two calves were assigned to one of two castration treatments, early (average age at castration 36 $\pm$ 18 days) or late (average age at castration 131 $\pm$ 26 days). Calves were stratified to treatment by birth date, breed (Angus or Brangus), and cow age. All calves were surgically castrated using a Newberry Knife to incise the scrotum and traction to remove the testes. Birth weight was similar ($P \geq 0.83$) between early and late castrates at the onset of the experiment. Actual weaning weight, adjusted 205-d weaning weight, and body weight change throughout the experimental period were all similar ($P \geq 0.51$) between early and late castrate treatments. Brangus calves tended ($P=0.06$) to be heavier at weaning and had heavier ($P=0.01$) adjusted 205-d weaning weights compared to Angus calves. However, there was no breed by castration interaction ($P \geq 0.40$) between early and late castration treatments for any of the measurement points. This study suggests that delaying castration until calves were more advanced in age was not advantageous to increasing weaning weight.

Rationale

Castration is a common management practice within the United States beef industry. Traditionally, steers have held a distinct advantage in the market place over their intact contemporaries because of their ability to fit within modern beef production systems and produce a more desirable carcass for consumers (Bretschneider, 2005). Although intact males will gain more efficiently and produce a higher red meat yield than

steers (Arthaud et al., 1969), their aggressive behavior and reduced carcass quality create a need for bull calves to be castrated prior to weaning.

Although the practice of castration is widely utilized within the industry, the timing and method utilized for castration can vary considerably from operation to operation (USDA-NAHMS, 2007). Factors that may impact timing of castration include producer philosophy, product marketing claims, weather, and availability of resources such as facilities or labor. Some cattlemen believe that delayed castration can improve growth rate in nursing calves. This belief is also endorsed by some product manufacturers who claim that delayed castration can create significant weight gain advantages at weaning compared to calves that were castrated at or near birth. Since producers are paid on a pounds basis and most cattlemen opt to market their calves at weaning, differences in weaning weight can mean differences in profitability.

Despite the perceived benefits of delayed castration, studies have shown that both light-weight and yearling calves castrated post-weaning have significantly reduced feedlot performance and health compared to calves that were purchased as steers (Brazle, 1992; Berry et al., 2001; Knight et al., 1999). Additionally, there is evidence that castration elicits a greater stress response in older calves than in calves that were castrated at or near birth (Stafford and Mellor, 2005). As the principles of animal welfare and the economics of efficiency become increasingly more of a focus within the beef industry, producers may find that the supposed benefits of delayed castration are far outweighed by its drawbacks.

The objective of this study was to determine if age at castration resulted in significant differences in weaning weight and growth rate in nursing calves. In addition,

comparisons between Angus and Brangus calves were made between treatment groups to determine if there was a breed by castration effect.

Materials and Methods

Ninety-two intact Angus and Brangus bull calves were utilized in the study. Calves were born between December 18, 2009 and March 28, 2010. Calves were stratified by birth date, breed (Angus or Brangus), and cow age (first-time heifer or cow), paired, and then randomly assigned to one of two treatment groups, early (n=51) or late (n=42) castration. All calves were surgically castrated using a Newberry Knife to incise the scrotum and traction to remove the testes. Early castrates (n=23 Angus; n=28 Brangus) were 36 days of age on average (range 3 to 73 days of age) at time of castration (March 1, 2010 and April 23, 2010). Late castrates (n=15 Angus; n=26 Brangus) were 131 days of age on average (range 84 to 180 days of age) at time of castration (June 16 and June 17, 2010). At the time of castration, average body weight of the late castrate treatment group was 162 $\pm$ 4.9 kg. All calves were weighed once per month beginning in May until weaning on August 16, 2010. The experiment took place at the University of Florida Boston Farm-Santa Fe River Ranch Beef Research Unit. Cow-calf pairs had ad libitum access to hay with co-product supplement during the winter months (December 2009 through April 2010), and were maintained on bahiagrass (*Paspalum notatum*) pasture throughout the remainder of the trial period.

The experiment was designed as a completely randomized design, with castration treatment, breed, and breed by treatment as the fixed effects, steer within treatment as the random effect and individual calf as the experimental unit. Data were analyzed using the Mixed procedure of SAS v9.2. Means were calculated using the least squares

means, and means were separated using the P-diff option when the overall F-value was <0.10.

Results and Discussion

There was no breed by castration interaction ($P \geq 0.40$) between treatments for any of the measurement points in this study, which suggests the effect of time at castration was not different for the two breeds utilized. At the initiation of the trial, calf birth weights (Table 3-1) were similar (P=0.83) among castration treatments. However, Brangus calves tended (P=0.07) to be heavier at birth than Angus calves. At the conclusion of the trial, mean weaning weight was 206 $\pm$ 5.2 kg. Although weaning weight was similar (P=0.76) between early and late castrated calves, Brangus calves tended (P=0.06) to be 13 kg heavier at weaning than Angus calves. In addition, weight per day of age at weaning and adjusted 205-d weaning weight were similar ($P \geq 0.24$) between treatments. Brangus calves had greater (P=0.01) adjusted 205-d weaning weights compared to the Angus calves.

Calf body weights for the month of May (Figure 3-1), were similar (P=0.98) between the early and late castration treatments. This implies calves castrated at or near birth (early) had overcome any growth delays related to castration by the time body weight measurements were initiated. Castration in younger, sexually immature calves seems to elicit less of a stress response than castration in older, heavier calves (Bretschneider, 2005; Stafford and Mellor, 2005). Lyons-Johnson (1998) reported that calves castrated at birth or 33 weeks of age had reduced serum haptoglobin levels compared to calves castrated at 36 weeks of age. Haptoglobin is an acute phase protein produced in response to stress and/or injury, making it a useful measure of stress in animals undergoing management practices like castration (Baumann and

Gauldie, 1994; Murata, 2007). Stress can decrease health and normal behaviors, like suckling (Blecha, 2000). A decreased stress response to early castration could account for bodyweight similarities among the treatments in May.

Additionally, early castrates did not seem to experience any significant disadvantage in growth due to treatment throughout the trial period. Calf body weight change and mean ADG (Table 3-1) were similar ($P \geq 0.19$) during the trial period. These results indicate delaying castration approximately 100 days will not result in a significant weight advantage at weaning compared to calves castrated at or near birth. At the same time, early castration should not result in lighter weight calves at weaning, which is of significant concern to producers who choose to market at that time.

In a study conducted by Bailey et al. (1966), calves castrated at approximately three months of age had similar pre-weaning growth rates and weaning weights compared to calves left intact until weaning. Bagley et al. (1989) found no differences in pre-weaning average daily gains and weaning weight between calves castrated at birth and calves castrated at 4 months of age. Although time at castration in the current study differs slightly from Bailey et al. (1966) and Bagley et al. (1989), our findings are in agreement.

In contrast, Marlowe and Gaines (1958) reported that castrated males grew 5% slower than bulls during a pre-weaning trial period in a purebred herd. This resulted in a 7.3 kg advantage in adjusted 210-day weaning weight for bulls over steers. Similar results were reported by Klosterman et al. (1954) and Cundiff et al. (1966). These sex differences may be due to selection bias as calves chosen to remain intact tended to be larger, faster growing calves (Cundiff et al., 1966). Producers opting to retain herd sire

replacements generally choose to castrate calves that exhibit less growth potential from both a genotypic and phenotypic standpoint. When selection bias was controlled for, Brinks et al. (1961) and Tanner et al. (1970) reported differences in pre-weaning growth rate and ultimate weaning were not significant between intact calves and castrates.

Differences in pre-weaning growth and weaning weight between early and late castrates may be further reduced if producers administer anabolic implants at the time of castration. Marston et al. (2003) reported Angus crossbred calves receiving an implant and castrated early, at approximately three months of age, gained similarly to calves castrated at weaning, at approximately seven months of age. Both late and early castrates receiving an implant gained 1.15 kg/day during the nursing phase. However, calves castrated early without an implant only gained 1.08 kg/day during the nursing phase.

Lents et al. (2006) reported also calves castrated and implanted between two and three months of age had similar ($P \geq 0.45$) weaning weights compared to calves left intact until weaning. Calves banded and implanted at two to three months of age tended ($P=0.06$) to gain more than intact calves prior to weaning (0.94 kg/day versus 0.90 kg/day, respectively). Heaton et al. (2006) implanted and castrated calves at three different ages; less than 90 days, 225 days (at weaning), and 380 days of age or greater. Average daily gains during the pre-weaning phase of the trial were similar ($P \geq 0.89$) among treatment groups. Although calves were not implanted in the current study, these results suggest a single implant at the time of castration could positively impact rate of gain in nursing calves, and compensate for any castration-associated weight loss that may occur in young calves.

Since both early and late castration procedures were performed prior to weaning and the onset of puberty, results from the current study would seem reasonable. Cattle do not attain puberty, and thus secrete significant amounts of growth-promoting testosterone, prior to weaning at 6 – 9 months of age (Barber and Almquist, 1975; Bretschneider 2005; Lunstra et al., 1978). According to herd data, calves in this study would not have been expected to reach puberty prior to 9 months of age (Austin, 2009), long after calves in the current study were assigned to treatment and castrated.

The concept underlying delayed castration is to leave male calves intact long enough to capture the benefits of endogenously secreted androgens that are known to stimulate growth in animals (Gortsema et al., 1974). However, to capture the full benefit, castration would most likely need to be delayed until calves were post-pubertal. It is only at this point calves would have the ability to secrete enough endogenous testosterone to create significant differences in weight and growth performance (Knight et al., 1999). The comparable pubertal status of the treatment groups in this study likely contributed to the similar weaning weights and growth measures between the early and late castrates.

Table 3-1. The effect of age at castration on calf growth performance

	Treatment[1]			
Item	Early	Late	SE[2]	P-Value
Birth weight, kg	36	37	1.1	0.83
Weaning weight, kg	207	205	5.2	0.76
Weight per day of age, kg	1.1	1.1	0.03	0.24
Adjusted 205-d weaning weight, kg	233	229	4.0	0.51
Body weight change, kg				
May to June	35	34	2.1	0.79
June to July	39	37	1.6	0.40
July to August	45	44	2.0	0.55
May to August	80	78	2.7	0.49
Birth to Weaning	171	169	4.9	0.71
ADG[3], kg/d				
May to June	1.05	1.03	0.06	0.79
June to July	0.94	0.89	0.04	0.39
July to August	0.75	0.72	0.03	0.54
May to August	0.85	0.83	0.03	0.49
Birth to Weaning	0.91	0.87	0.02	0.19

[1] Early Castrated (average age at castration = 36 days) Late Castrated (average age at castration = 131 days)

[2] Standard error (n=92)

[3] Average daily gain

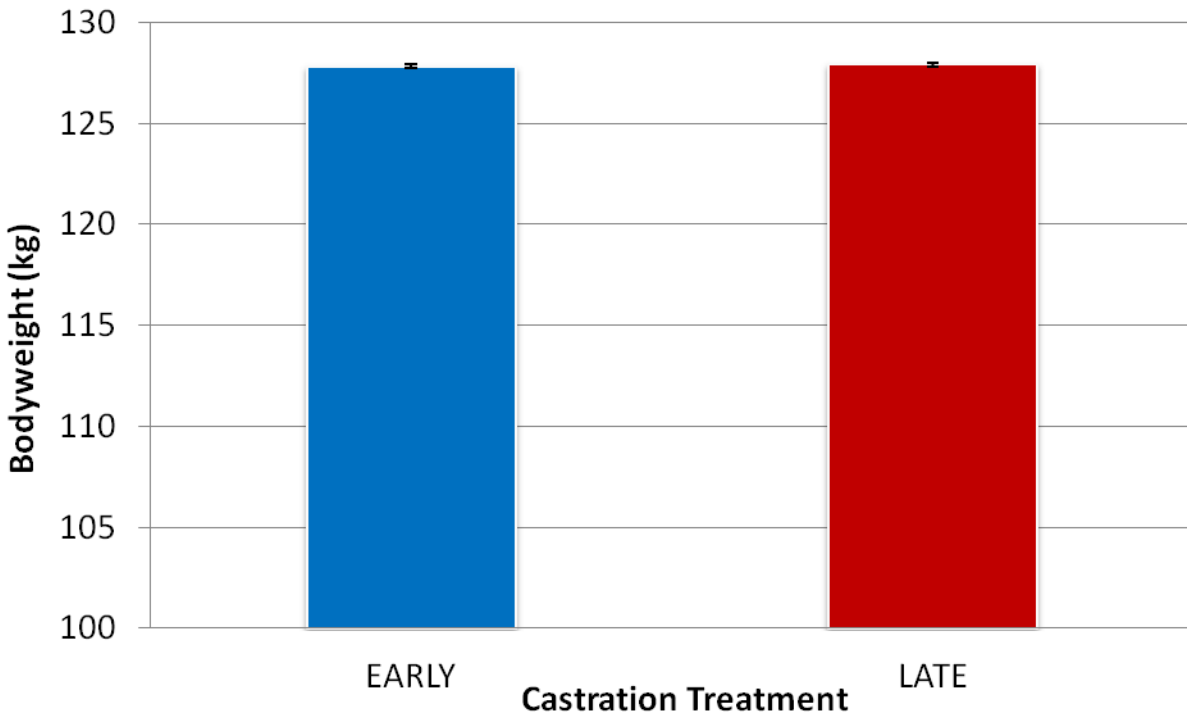

Figure 3-1. Effect of castration timing on calf bodyweight in May. P=0.98.

CHAPTER 4
THE COMPARISON OF FEED ADDITIVES DURING PRECONDITIONING ON GROWTH AND PERFORMANCE OF BEEF CALVES

Story in Brief

The objective of this study was to evaluate the response of weaned calves to different feed additives within a preconditioning supplement. Specifically, alternatives to antibiotics and ionophores were evaluated to determine their effectiveness in improving calf performance and mitigating the stress response observed during the weaning process. Following stratification by bodyweight, sex, previous castration status, and breed, 160 calves were randomly allotted to one of four treatments (n=40 calves/treatment): 1) control calves (CON) were supplemented without additives; 2) Chlortetracycline calves (CTC) were supplemented with added chlortetracycline at 350 g/hd/d; 3) Monensin calves (RUM) were supplemented with added Rumensin at 175 mg/hd/d; and 4) Actigen® calves (ACT) were supplemented with added Actigen® at 10 g/hd/d. Calf bodyweight was similar (P=0.16) among treatments at the beginning of the trial period. Over the 52-day preconditioning period, ACT resulted in the greatest gain response. Chlortetracycline calves exhibited similar (P=0.35) gains to ACT, which were both greater ($P \leq 0.005$) than gains exhibited by RUM. Control calves were similar ($P \geq 0.13$) to both medicated treatments, but did not gain more (P=0.02) than ACT. Plasma concentrations of haptoglobin and ceruloplasmin were similar ($P \geq 0.70$) among treatments; however, a day effect ($P \leq 0.0001$) was observed in both acute phase proteins measured. Our results indicate Actigen® may improve calf performance as effectively as chlortetracycline during a preconditioning period of this length, but neither additive was effective at mediating stress post-weaning.

Rationale

In recent years the demand for preconditioned calves by the feedlot segment has increased the willingness of beef cattle producers to implement preconditioning programs. There are a variety of programs producers can choose to implement, which may include pre-weaning vaccination, castration, dehorning, or a combination of such procedures (Pritchard and Mendez, 1990). In addition, the period during which calves are preconditioned may vary in length, with some calves being weaned and preconditioned for up to 45 or 60 days prior to marketing (Dhuyvetter, 2003).

One of the key factors associated with preconditioning is the nutrition of the freshly weaned calf (Cole, 1985). Nutritional aspects of preconditioning not only consider nutritional needs of the weaned-stressed calf, but also include the acclimation of calves to dry feed, feed bunks, and water troughs (Savell, 2008). One of the greatest costs associated with preconditioning programs is the cost of feed inputs (Cole, 1985). The provision of supplemental feeds can increase the cost of preconditioning over grazing alone, but the additional gains associated with supplementation may prove more economical than grazing alone. Supplementation can be a favorable management practice to increase the nutritional profile of the weaned calf and reduce the stress associated with the weaning process.

Another reason for preconditioning calves is to reduce the incidence of morbidity in calves observed subsequent to weaning and prior to feedlot finishing. The preconditioning period allows calves to overcome the physiological and psychological stresses associated with weaning that may suppress immune function and increase calf susceptibility to disease (Lalman and Smith, 2002). Establishing a good immune response before entering the feedlot has been shown to reduce the incidence of

morbidity by 6% and mortality by 0.7% in the feedlot (McNeill, 2001; Cole, 1985). Preconditioning status is one of the major factors associated with premium calf prices (King et al., 2006) primarily due to the improved health status of the calves.

The use of feed additives in the preconditioning diet is one means to positively affect the health status of fresh-weaned calves during preconditioning. Traditionally, preconditioning diets may contain an antibiotic, ionophore, or both. The use of these feed technologies have previously been demonstrated to increase calf performance through suppression of sub-clinical disease and improvement in rumen fermentation (Holdsworth and Parker, 2003). However, there has been an increase in demand for calves that can qualify for “natural” and “never-ever” production programs (Smith, 2005). The use of antibiotics and ionophores is precluded from natural programs, even during the preconditioning period. The opportunity to incorporate alternative feed technologies into preconditioning diets that replace antibiotics and/or ionophores may offer producers more flexibility when marketing weaned calves.

The objective of this study was to evaluate the response of weaned calves to different feed additives within a preconditioning supplement. Specifically, Actigen ® an alternative to antibiotics and ionophores, which are prohibited from use in naturally-raised and organic programs, was evaluated to determine its effectiveness in improving calf performance and mitigating the stress response observed during the weaning process.

Materials and Methods

The experiment was conducted at the University of Florida Santa Fe Beef Research Unit in North Central Florida from August 2010 until October 2010. All

procedures during this experiment were approved by the University of Florida's Institutional Animal Care and Use Committee (IACUC).

Animals and Treatments

Cow-calf pairs were gathered off pasture on the morning of August 16, 2010. Steers (n=80) and heifers (n=80) of Angus and Brangus breeds were separated from their dams and placed into one of four dry-lot treatment pens (n=40 calves/pen) at the start of the experiment (day 0). Calves remained on the ranch of origin for the duration of the experiment. Calves were born between December 2009 and April 2010. All calves received similar pre-weaning management, which included vaccination at approximately 4 to 6 months of age, identification, as well as surgical castration and dehorning when necessary.

All calves on trial were supplemented with a formulated wheat middlings-cottonseed meal-based pellet (19% CP, 76% TDN). Supplement pellets were formulated and manufactured by Lakeland Nutrition Group (Eaton Park, FL, USA). Prior to the start of the experiment, a full bodyweight (BW) was taken on July 28, 2010 and calves were blocked by BW, breed type, previous castration status, and sex. Calves were then randomly allotted to 1 of 4 treatments (n=40 calves/treatment): 1) control calves (CON) were supplemented with the formulated basal diet without additives; 2) Chlortetracycline calves (CTC) were supplemented with the control diet plus added chlortetracycline at 350 g/head/day; 3) Monensin calves (ION) were supplemented with the control diet plus added Rumensin® (Elanco, Greenfield, IN, USA) at 175 mg/head/day; and 4) Actigen® calves (ACT) were supplemented with the control diet plus added Actigen® (Alltech, Nicholasville, KY, USA) at 10 g/head/day. Supplements were offered daily at a targeted intake of 1.82 kg/head/day. All supplements were

formulated to be isonitrogenous and isoenergetic. Adequate feed bunk space was provided in each dry-lot pen and pasture.

Calves were held in their dry-lot treatment pens (n=40 calves/pen) for 1 week before being transferred to 1 of 32 1.2 ha pastures (n=5 calves/pasture) for a total of 8 pastures/treatment. During the dry-lot phase, calves received ad libitum access to perennial peanut (*Arachis glabrata*) hay. Mean forage available per dry-lot pen was estimated at 1573.33 DM kg/ha. Each pasture was composed of a mixture of bahiagrass (*Paspalum notatum*) and bermudagrass (*Cynodon dactylon*). The pastures were previously grazed and fertilized at 60 lb N/acre prior to the initiation of the experiment. The nutritional value of the forage in the pastures for the duration of the experiment was 15% CP, 33% IVDMD. The mean forage available per pen at the start of the experiment was estimated at 463.75 DM kg/ha. All pens had a feed bunk, waterer, and shade provided. Calves remained in the same pasture from day 7 to day 52 of the experiment. Nutritional composition of preconditioning supplements, peanut hay, and pastures available to calves throughout the trial are presented in Table 4-1.

Feed Sampling

Pasture samples were obtained on day 4 of the experiment, prior to transferring calves to their treatment pastures on day 7 of the experiment. Samples were obtained to estimate forage quantity and quality by hand clipping 3 0.25 m^2 areas and compositing the samples. Pasture samples were dried at 60°C in forced air oven for approximately 96 hours. Dried samples were ground to pass through a 1-mm screen in a Wiley mill (Arthur H. Thomas Company, Philadelphia, PA, USA). Pasture samples were analyzed for CP, organic matter (OM), and in vitro dry matter digestibility (IVDMD). Total nitrogen was determined using macro elemental N analyzer (Elementar, vario

MAX CN, Elementar Americas, Mount Laurel, NJ, USA) and used to determine CP (CP = N x 6.25). In vitro DM digestibility of samples was determined using the ANKOM analyzer (ANKOM, New Jersey, USA). Supplement samples were analyzed by the same procedure outlined above for pasture samples.

Sampling and Analysis

Calf BW was obtained on 2 consecutive days at the initiation (day 0 and day 1) and termination (day 51 and day 52) of the experiment. Day 0 was the day of weaning, with day 1 considered the first day on the supplement. One-half of the calves on trial were utilized for intensive blood collection to measure acute protein plasma (APP) concentrations. Calves were gathered on day 0, 1, 4, 7, 11, and 14 for collection of BW and blood samples for APP analysis. Additionally, hip height measurements were taken on day 0 and day 51 of the trial.

Blood samples were collected via jugular venipuncture into 7.5 mL polypropylene syringes containing 1.6 mg potassium EDTA as an anticoagulant (Monovette, Sarstedt Inc., Newton, NC). Samples were placed on ice immediately after collection and transported to the lab for further processing. Blood samples were centrifuged at 1500 x *g* for 15 min at 5°C to obtain plasma, which was placed in sample vials and stored at -20°C for subsequent analysis of ceruloplasmin and haptoglobin concentrations.

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 = 5.3 %; intra-assay CV variation = 1.9 %).

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-assy variation = 4.35 %; intra-assay CV variation = 2.67 %).

Data were analyzed by the MIXED procedure of SAS 9.2 (SAS Inst. Inc., Cary, NC). The model included the main effects of treatment. All variables quantified by day 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

Animal Performance

Supplement refusal did not occur throughout the trial, indicating supplement intake was adequate and similar between treatments. Starting, intermittent, and ending calf

bodyweights (Table 4-2) were similar (P>0.15) among feed additive treatments. Although, individual bodyweight measurements were not influenced by feed additive supplementation, differences were observed in bodyweight change (BWC) (Figure 4-1) and average daily gain (ADG) (Figure 4-2) during the trial period (P<0.0001). Calves offered supplement with ACT gained more (P≤0.03) total weight over the trial period than RUM and CON calves, and tended (P=0.10) to gain more weight than CTC calves. Additionally, CTC calves tended (P=0.06) to gained more than RUM calves, but not more (P=0.58) than CON calves.

Similar differences were observed for ADG over the entire preconditioning period. Calves receiving supplement with ACT exhibited a greater (P<0.02) cumulative ADG than RUM and CON treatment groups. Calves receiving supplement with CTC also gained at a faster (P<0.01) rate over the 52-day preconditioning period than RUM supplemented calves. Feed additive response between ACT and CTC was similar (P=0.35), with ACT calves gaining 0.48 kg/head/day and CTC calves gaining 0.42 kg/head/day.

Our results indicate Actigen® may improve calf performance as effectively as chlortetracycline during a preconditioning period of this length. Several authors have also reported similar gain responses when either a yeast-derived or antibiotic additive is provided within food animal diets. Hulut and Cravener (2011) reported similar feed conversion ratios, body weights, and mortality rates among turkey hens fed a commercial control diet containing either feed-grade antibiotics or Actigen®.

Birkelo and Rops (1994) investigated the effect of yeast culture supplementation in growing calves in two separate trials. Weaned calves on both a control and yeast

additive treatment were limit-fed a high concentrate diet for an average of 99 days. Rate of gain and feed efficiency measures were similar between controls and calves supplemented with a yeast culture product in both heavy-weight and light-weight blocks. Average daily gain in controls was 1.09 kg/head/day while ADG in yeast-supplemented calves was 1.05 kg/head/day.

Yeast-based additives have also been shown to elicit performance responses over that of food animals not receiving a feed additive. Tassinari et al. (2007) used Bio-Mos®, which Actigen® is derived from, in receiving rations for fresh-weaned calves arriving at the feedlot. Although dry matter intakes were similar between treatments, weight gain was increased by over 3% from Bio-Mos® supplementation, subsequently improving feed to gain ratios for the Bio-Mos® treatment group.

In contrast Vendramini and Arthington (2007) reported no benefit to adding a yeast fermentation product to a concentrate supplement for early-weaned calves grazing pasture. The authors reported similar performance responses during the post-weaning grazing period for both treatment groups. Calf gain during winter grazing of ryegrass pasture was 0.88 and 0.83 kg/head/day for control and yeast-supplemented calves, respectively.

Differences in gain response between Vendramini and Arthington (2007) and the current study could be attributed to pasture quality, season, and calf age. Early-weaned calves were weaned at an average age of 66 days weighing approximately 84 kg each, while calves in the current study were weaned at an average age of 194 days weighing approximately 203 kg each. At only 2 months of age, the rumen and microbial population within the digestive tract of early-weaned calves may not be functioning

enough to respond to a yeast-based additive. Additionally, in the winter calves grazed ryegrass pasture and in the spring grazed stargrass pastures, which are typically higher quality forage species than the bahiagrass and bermudagrass species the calves in the current study grazed in the fall when forage quality of these species would typically decline.

All treatment groups lost weight following weaning (P=0.73), and gains made during the drylot period (Figure 4-3) indicate weight lost as a result of the weaning process was not fully recovered by day 7 in all treatment groups. Calves offered supplement with ACT and RUM lost 0.08 and 0.41 kg/head/day, respectively, under drylot conditions. Alkire and Thrift (2005) and Austin and Thrift (2007) report similar reductions in bodyweight the first week post-weaning.

Data indicates inclusion of ionophores in young, stressed calf diets may reduce feed intake and decrease gain if only fed for brief time periods (Ammerman et al. 1979; Schelling, 1984). Although orts were not collected for any of the treatment pens throughout the trial, RUM calves did exhibit poor performance gains, particularly early in the trial period. The loss in weight for RUM calves could have been due to reduced digestibility as calves adapted to the ionophore.

Ionophores can alter the microflora within the digestive tract, and if calves are not given sufficient time to adapt to ionophore supplementation, digestibility and gain can be reduced initially (Bergen and Bates, 1984; Calloway et al., 2003; Schelling, 1984). Once calves become adapted and the microflora in the rumen and small intestine stabilize digestibility and gain can increase (Bergan and Bates, 1984; Schelling, 1984). Poos et

al. (1979) reported improvements in digestibility and performance following a 21- and 28-day adaption period.

Losses in gain and bodyweight in ACT calves during drylot were not as severe as losses exhibited in the RUM treatment (P=0.005). However, these losses cannot be attributed to reduced supplement intake in either the ACT or RUM treatment groups since supplement consumption met desired levels and weigh-back was never collected during the drylot period. This indicates that feeding ionophores and yeast-derived additives in conjunction with the stress of weaning, adaptation to a dry diet, and a drylot environment may not always elicit positive gains or changes in bodyweight in brief post-weaning scenarios.

In contrast to overall measures of BWC and ADG, drylot gains for calves offered supplement with the feed-grade antibiotic CTC were greater (P<0.0001) than the RUM and ACT additive treatments. Chlortetracycline improved gain nearly 2 kg/head/day over that of RUM, and by nearly 0.75 kg/head/day compared to ACT. Inclusion of CTC in the diet tended to increase (P=0.07) gain over that of CON calf gains. Although overall performance responses were similar between ACT and CTC treatment, it appears offering CTC at a subtherapeutic rate in a preconditioning supplement may be more effective at improving calf performance under drylot conditions immediately following weaning.

Duff et al. (2000) reported improvements in drylot gain during the initial weigh periods of a feedlot receiving trial. Calves receiving chlortetracycline in the diet gained 0.05 kg/head/day from day 5 – day 10, while control calves not receiving chlortetracycline in the diet lost 0.32 kg/head/day during this interval. Additionally, gain

to feed ratio was increased with the addition of chlortetracycline in the diet during day 0 – day 14 of the 28-day receiving period.

Results of Duff et al. (2000) and the current study conflict with those reported by Addis et al. (1973). Calves offered supplement with a chlortetracycline-sulfamthazine antibiotic had reduced gains in the initial week of a feedlot receiving study compared to calves receiving the high-concentrate supplement without an antibiotic. Compared to control calves, antibiotic supplemented calves gained 0.75 kg/head/day while control calves gained 0.91 kg/head/day. This is likely due to reduced feed intake of calves receiving the feed-grade antibiotic. Controls calves consumed approximately 5% more per day in dry matter than calves receiving the chlortetracycline-sulfamthazine additive. Calves exhibiting reduced feed intake post-weaning will often fail to consume enough feed to meet their daily nutrient requirements. This can prevent calves from regaining weight rapidly and decelerates gain early in post-weaning management systems.

In the current experiment, at the conclusion of the second week, ADG and BWC were positive for all treatments (Figure 4-4), and calves continued to gain steadily for the remainder of the preconditioning period (Figure 4-5). This agrees with Cole and McCollum (2007) who suggest it can take calves between two and three weeks to recover and gain bodyweight post-weaning. Our results indicate calves had adapted to the supplement offered and overcome the stress of weaning by the day 14 of the trial.

Calves were transitioned to pasture on day 7, which may have also aided in calf weight gain during this measurement interval. Alkire and Thrift (2005) and Austin and Thrift (2007) reported positive calf gains following transition from a drylot to a pasture during preconditioning. Drylot preconditioning environments are considered to be more

stressful during the post-weaning period than pasture environments (Mathis et al. 2008). Placement on pasture during the second week of the current study may have reduced stress while offering calves a more familiar nutrition source than hay offered during the drylot period, eliciting positive gains.

Performance response to preconditioning and feed additive supplementation during the pasture period (Figure 4-6) indicates ACT calves gained more ($P<0.01$) weight than CON and RUM calves. Bodyweight change in response to ACT supplementation increased 25.45 kg/head on average during the pasture period, while CON calves gained 15.09 kg/head and RUM calves gained 14.74 kg/head on average. Actigen® supplementation also tended ($P=0.07$) to increase bodyweight during this measurement period over that of CTC supplementation.

Data examining the use of Actigen® in growing cattle under grazing conditions is currently unavailable, and the use of similar yeast-based additives in grazing calves is limited in scope. Results reported by Verdramini and Arthington (2007) suggest yeast-supplementation during grazing is equally as effective as supplementation without a feed additive. In this study, calves were grazing high-quality ryegrass and stargrass following early weaning, while calves in the current study were older and grazing low-quality pastures during the fall of the year when forage quantity and quality traditionally decline.

Our results indicate ACT may elicit a greater response than supplement alone in a grazing system when pasture quality is low and calves are older. Pasture quality and ionophore supplementation rate may have also allowed ACT supplemented calves to outperform RUM calves since other authors have suggested ionophore response is

dependent on these factors (Bretschneider et al., 2008; Horton et al., 1992). Additionally, our results indicate ACT may work as effectively as CTC and other subtherapeutic antibiotics in pasture-based preconditioning programs.

Animal Stress

Treatment differences in plasma concentration of haptoglobin and ceruloplasmin were not observed throughout the sampling period. However, measures of both APPs indicate all calves experienced stress as a result of the weaning process. Both plasma haptoglobin (Figure 4-7) and ceruloplasmin (4-8) concentrations significantly increased from weaning to day 4 ($P<0.0001$) regardless of treatment. Both Arthington et al. (2008) and Campistol (2010) reported similar post-weaning increases in plasma concentrations of haptoglobin and ceruloplasmin across treatment groups. Our results suggest weaning is a stressful management practice for beef calves since plasma concentrations of haptoglobin are often detectable only in cattle undergoing stress (Arthington et al., 2003; Makimura and Suzuki, 1982).

Plasma haptoglobin levels at weaning (day 0) for all calves averaged 6.01 units. Plasma haptoglobin levels peaked on day 4, averaging 7.57 units across all treatments. Plasma concentration of ceruloplasmin exhibited a similar trend post-weaning, peaking on day 7 and then steadily declining through day 14 of the preconditioning period. Although haptoglobin levels trended downward between day 4 and day 14, the inflammatory response to weaning was not fully mitigated when blood serum collections ceased on day 14. Day 14 haptoglobin levels remained elevated ($P<0.0001$) from day 0 levels, but were not different ($P>0.59$) than levels on day 7 or day 11. Vendramini and Arthington (2007) reported similar differences in peak sampling day and plasma concentration declines between haptoglobin and ceruloplasmin.

No treatment by day interaction was observed for haptoglobin concentrations during the sampling period; however, an interaction (P=0.01) between treatment and day was detected for ceruloplasmin post-weaning (Figure 4-9). Despite the interaction, no clear trend in treatment effect was observed for any of the sampling days used to measure stress. Differences between treatments on day 0 were numerically greatest (P>0.07) between the ACT and CTC calves (2.61 mg/100 mL ± 1.41). Actigen® and CTC continued to exhibit the largest numerical (P>0.16) differences between treatments when plasma concentrations peaked on day 7 (1.98 mg/100 mL ± 1.41). By the conclusion of the measurement period, differences in ACT and CTC calves on day 14 were reduced to 0.61 mg/100 mL ± 1.41, which was less than the differences observed between ACT and RUM calves (0.91 mg/100 mL ± 1.41) and ACT and CON calves (0.98 mg/100 mL ± 1.41) on day 14.

The interactions detected may be statistically significant, but do not conclusively provide insight into how these feed additives mitigate stress and influence performance of preconditioned calves. Others have concluded that such interactions are a consequence of the magnitude and time of increase in acute phase concentrations post-weaning rather than individual treatment differences within sampling day (Arthington et al., 2003). The lack of a relationship between plasma acute phase protein concentrations and ADG (P>0.23) as well as the lack of morbidity and mortality over the trial period suggests none of the feed additives were more or less effective at mitigating stress over that of supplementation alone when calf health was excellent and post-weaning performance was marginal.

Economic Evaluation

A summary of the costs associated with supplementing calves in this preconditioning trial is given in Table 4-3. Supplement cost differed between treatments, with ACT being the most expensive ($38.87/head) and CON being the least expensive ($35.88). However, incremental costs of all additives used were minimal and not a significant (P=0.19) component of feed cost. Although total preconditioning costs were not included in this economic evaluation, profitability of the different preconditioning treatments was calculated by comparing the calves receiving a supplemental feed additive (ACT, CTC, RUM) to calves not receiving a supplemental feed additive (CON). Profit (or loss) was calculated for each treatment by subtracting the feed cost of gain from the value of gain obtained during the 52-day preconditioning period, and then multiplying by the total weight gained during preconditioning.

Assuming preconditioned calves would sell for the same price as non-preconditioned calves, value of gain obtained during the preconditioning period was calculated to be $1.71/kg/head. In this evaluation, ACT was the only profitable treatment ($3.74/head), with all other treatments resulting in losses following the preconditioning period. Actigen® supplementation was $20.47/head more (P=0.002) profitable than RUM and tended (P=0.09) to be $10.71/head more profitable than CON. At the same time, ACT profitability was similar (P=0.20) to CTC, suggesting it may be both an effective and affordable alternative to antibiotic feed additive supplementation when preconditioning does not result in a management premium at marketing. Rumensin® supplementation was the least profitable additive in this evaluation, resulting in a $16.73/head loss. This loss was approximately $12.50/head more (P=0.05) than the loss associated with including CTC in the preconditioning supplement.

When assuming a premium of $0.11/kg at the time of sale, which would not be uncommon if calves were marketed through a certified sale, the value of gain was calculated to be $2.81/kg/head. In this evaluation, all treatments except RUM resulted in a profit. Supplementation with ACT and CTC resulted in a $31.14/head and $16.53/head profit, respectively. Control calves not receiving a supplemental feed additive produced a profit of $11.62/head, while RUM supplementation resulted in a loss of $3.66/head.

Again, profitability outcomes for ACT and CTC were similar (P=0.16), while ACT was approximately $35/head more (P=0.002) profitable than RUM. This indicates ACT would be equally or more cost effective than feed grade antibiotics and ionophores in a preconditioning program of this length. Actigen® also tended (P=0.06) to be more profitable than CON, producing approximately $20/head more profit than supplementation alone. Chlortetracycline supplementation tended (P=0.06) to be more profitable than supplementation with RUM. Control calves were intermediate (P>0.14) in profitability to calves supplemented with the traditional antibiotic additives RUM and CTC, indicating producers may not necessarily benefit from the inclusion of these additives at preconditioning when calves are kept on the ranch of origin and calf health is excellent.

Based on the assumptions outlined above, cattle supplemented with Actigen® received the largest economic returns; with Rumensin® supplementation receiving the lowest, regardless of if a premium was offered. Although the addition of low levels of feed additive technologies resulted in variable economic returns within this

preconditioning program, ultimately, it seems that Actigen® is a suitable alternative to antibiotics when the goal is to improve weight gain in a cost effective manner.

Table 4-1. Nutritive value of preconditioning supplement, pasture, and peanut hay (PHAY) offered to calves throughout the experiment.

Item	Control	Actigen®	Chlortetracycline	Rumensin®	Pasture[1]	PHAY
DM, %	94.27	94.29	94.58	94.73	19.94	91.50
CP[2], %	17.84	19.22	18.98	19.82	14.86	9.74
IVDMD, %	58.44	57.59	60.00	60.71	33.24	36.95
OM, %	90.81	91.18	91.34	91.78	93.39	92.48

[1] Mixture of bahiagrass and bermudagrass forage collected at the initiation of the experiment.

[2] CP, IVDMD, and OM are expressed on a dry matter basis

Table 4-2. The effect of supplemental feed additive treatment on calf growth during preconditioning

	Treatment[1]					
Item	CON	ACT	CTC	RUM	SE[2]	P-Value
Starting weight (day 0)[3], kg	204.4	203.9	198.5	205.9	2.34	0.16
Ending weight (day 52)[4], kg	221.3	228.8	217.3	217.7	3.96	0.17
Body weight change, kg						
Day 0 to day 7[5]	1.818[a]	-0.540[b]	2.443[a]	-2.869[c]	0.63	<0.001
Day 0 to day 14	5.057[a]	6.165[a]	3.963[a]	0.881[b]	1.07	0.01
Day 7 to day 14	3.239[a]	6.705[b]	1.520[a]	3.750[a]	1.00	0.01
Day 7 to day 52[6]	15.09[a]	25.45[b]	16.45[a]	14.74[a]	2.67	0.03
Day 14 to day 52	11.85[a]	18.75[b]	14.93[ab]	10.99[a]	2.28	0.09
Day 0 to day 52	17.05[ac]	25.11[b]	19.03[ab]	11.99[c]	2.53	0.01
ADG[7], kg/d						
Day 0 to day 7	0.260[a]	-0.077[b]	0.467[a]	-0.410[c]	0.08	<0.001
Day 0 to day 14	0.361[a]	0.440[a]	0.283[a]	0.063[b]	0.08	0.01
Day 7 to day 14	0.463[a]	0.958[b]	0.217[a]	0.536[a]	0.14	0.01
Day 7 to day 52	0.335[a]	0.566[b]	0.411[a]	0.328[a]	0.06	0.02
Day 14 to day 52	0.312[a]	0.493[b]	0.432[ab]	0.289[ab]	0.06	0.05
Day 0 to day 52	0.325[ac]	0.479[b]	0.419[ab]	0.228[c]	0.10	0.002

[ab] LS means within a row with different superscripts are different P<0.05.
[1] CON (control, supplement without feed additives) ACT (supplement with Actigen at 10 g/hd/d) CTC (supplement with chlortetracycline at 350 g/hd/d) RUM (supplement with monensin at 175 mg/hd/d)
[2] Standard error (n=32)
[3] Starting weight (day 0) was taken by averaging day 0 and day 1 body weight measurements
[4] Ending weight (day 52) was taken by averaging day 51 and day 52 body weight measurements
[5] Day 0 to day 7 drylot period
[6] Day 7 to day 52 pasture period
[7] Average daily gain

Table 4-3. An economic evaluation of supplemental feed additive treatment during preconditioning

	Treatment[1]					
Item	CON	ACT	CTC	RUM	SE[2]	P-Value
Feed cost of gain, $/kg	2.85	1.61	2.96	4.30	0.85	0.19
Profit (loss) with no premium, $/head	(6.97)[ab]	3.74[a]	(4.25)[a]	(16.73)[b]	4.34	0.02
Profit (loss) with premium[3], $/head	11.62[ab]	31.14[a]	16.53[a]	(3.66)[b]	7.14	0.02

[ab] LS means within a row with different superscripts are different P<0.05.
[1] CON (control, supplement without feed additives) ACT (supplement with Actigen at 10 g/hd/d) CTC (supplement with chlortetracycline at 350 g/hd/d) RUM (supplement with monensin at 175 mg/hd/d)
[2] Standard error (n=32)
[3] Premium of $0.11/kg of calf bodyweight included in profit (loss) calculation

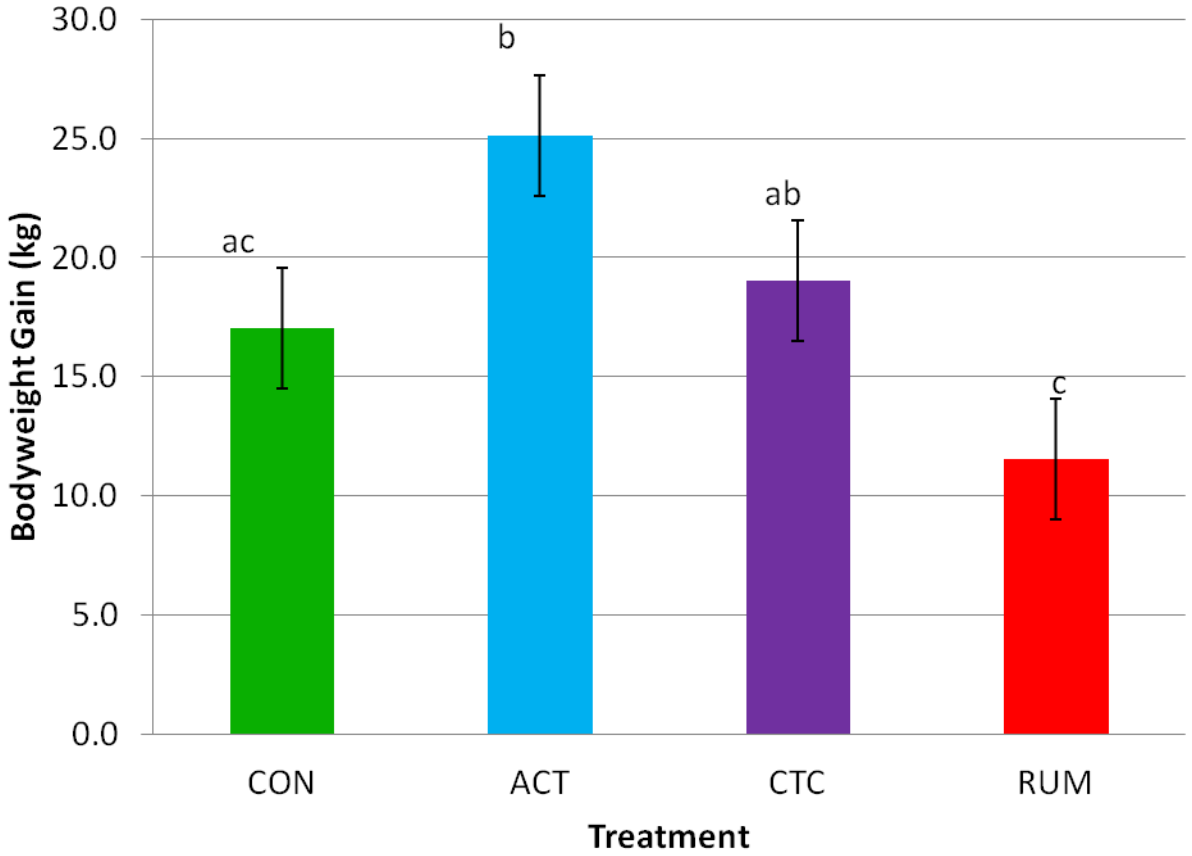

Figure 4-1. Effect of feed additive treatment on bodyweight change during a 52-day preconditioning program. P=0.01.

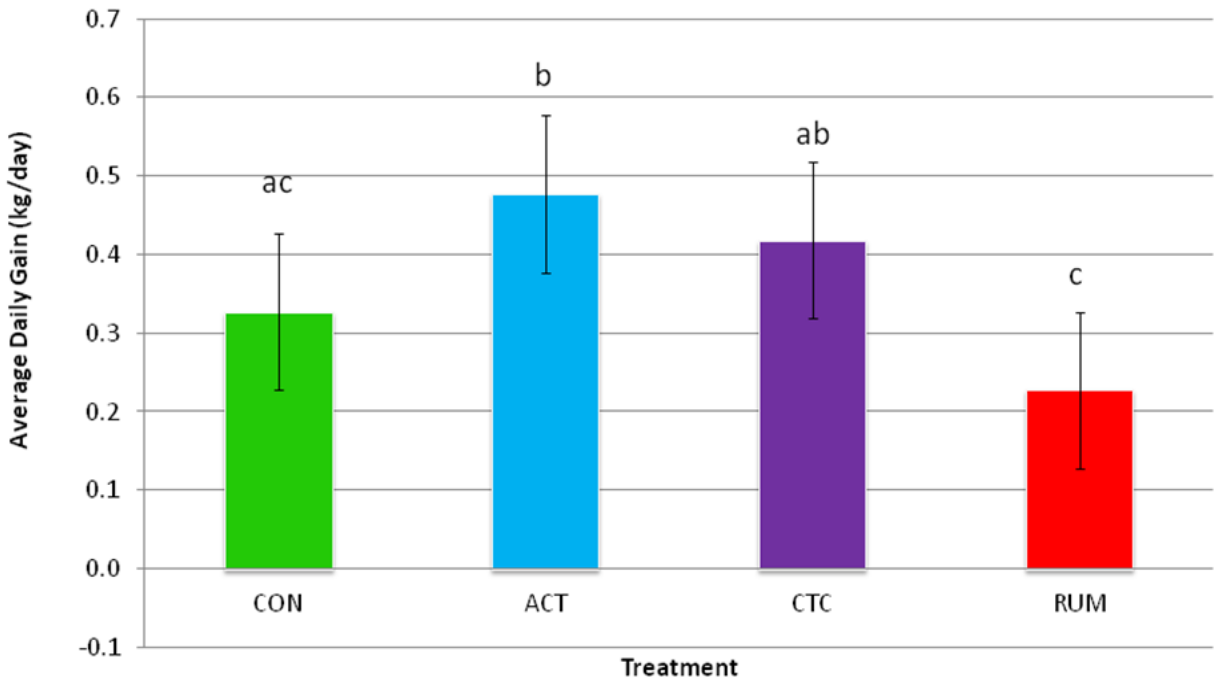

Figure 4-2. Effect of feed additive treatment on average daily gain during a 52-day preconditioning period. P=0.002.

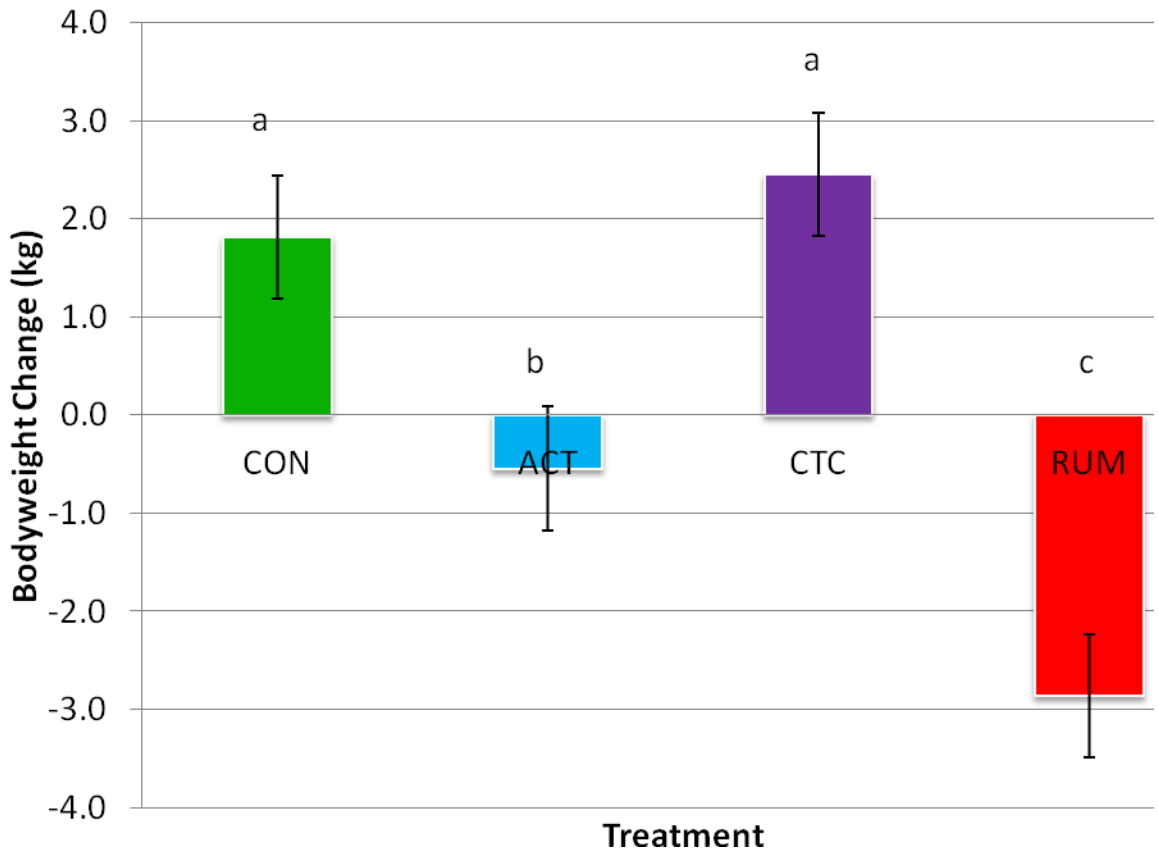

Figure 4-3. Effect of feed additive treatment on bodyweight change during a 7-day drylot period of a preconditioning period. P=0.02.

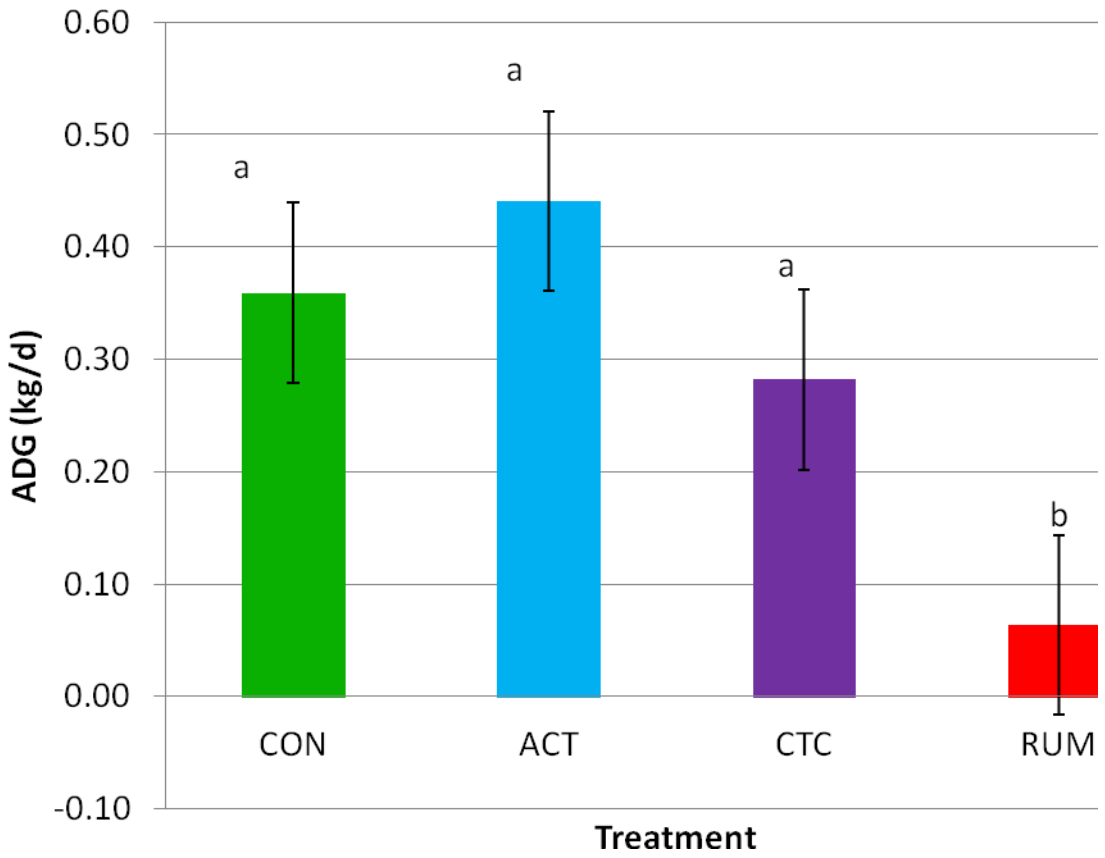

Figure 4-4. Effect of feed additive treatment on 14-day average daily gain during a 52-day preconditioning period. P=0.01.

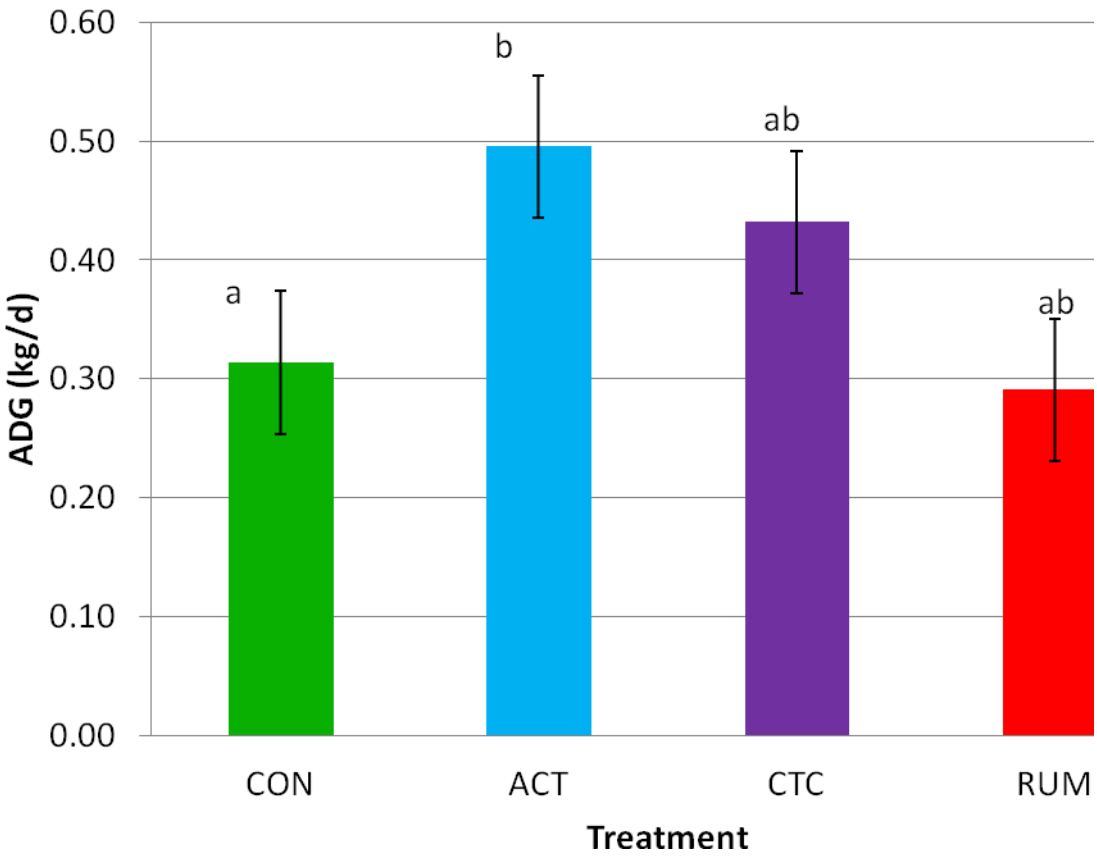

Figure 4-5. Effect of feed additive treatment on average daily gain from day 14 through day 52 of a preconditioning program. P=0.06.

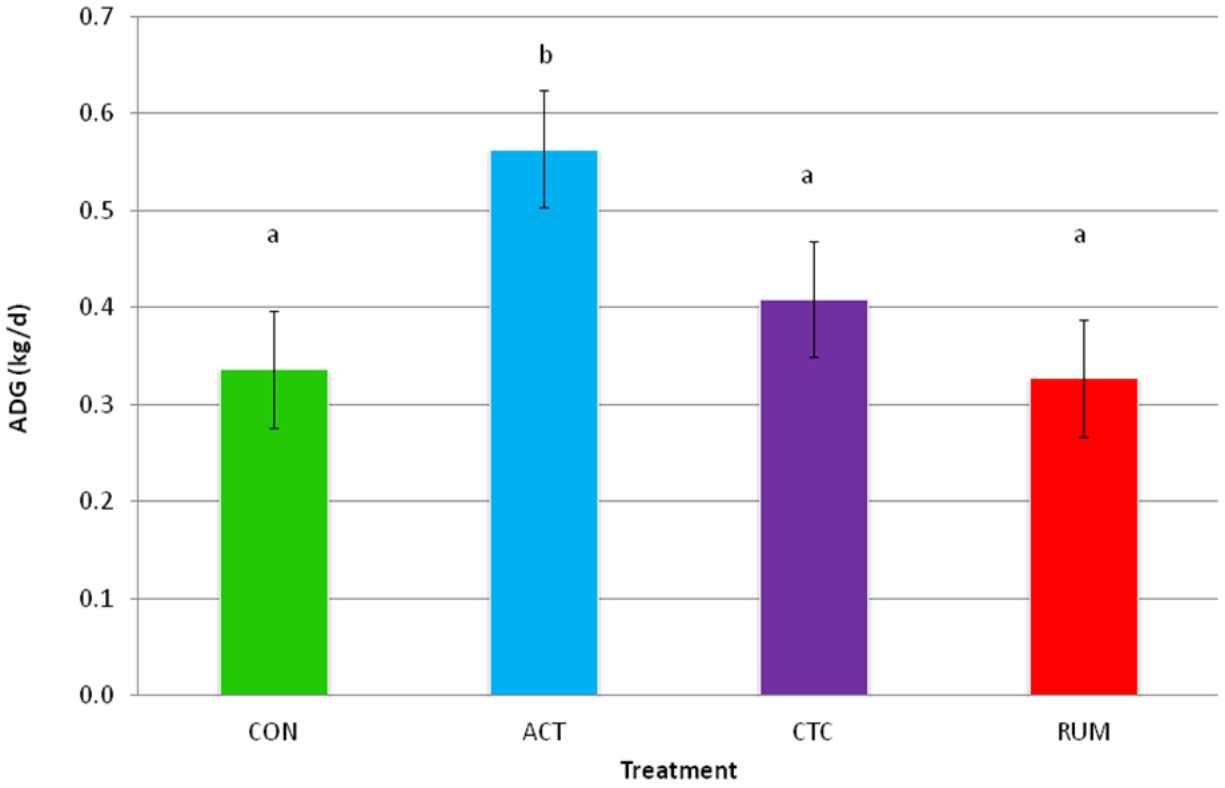

Figure 4-6. Effect of feed additive treatment on average daily gain during the pasture period of a preconditioning program. P=0.02.

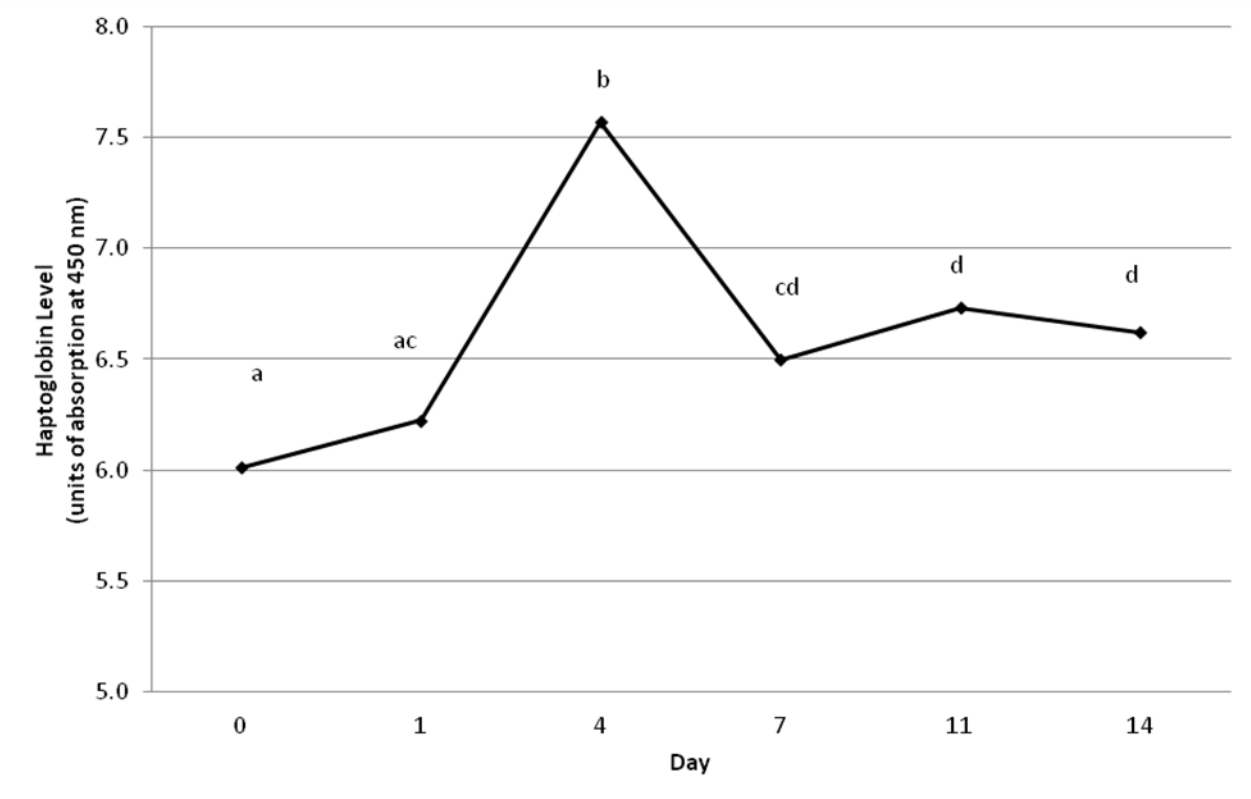

Figure 4-7. Effect of sampling day on plasma concentration of haptoglobin post-weaning. P<0.0001.

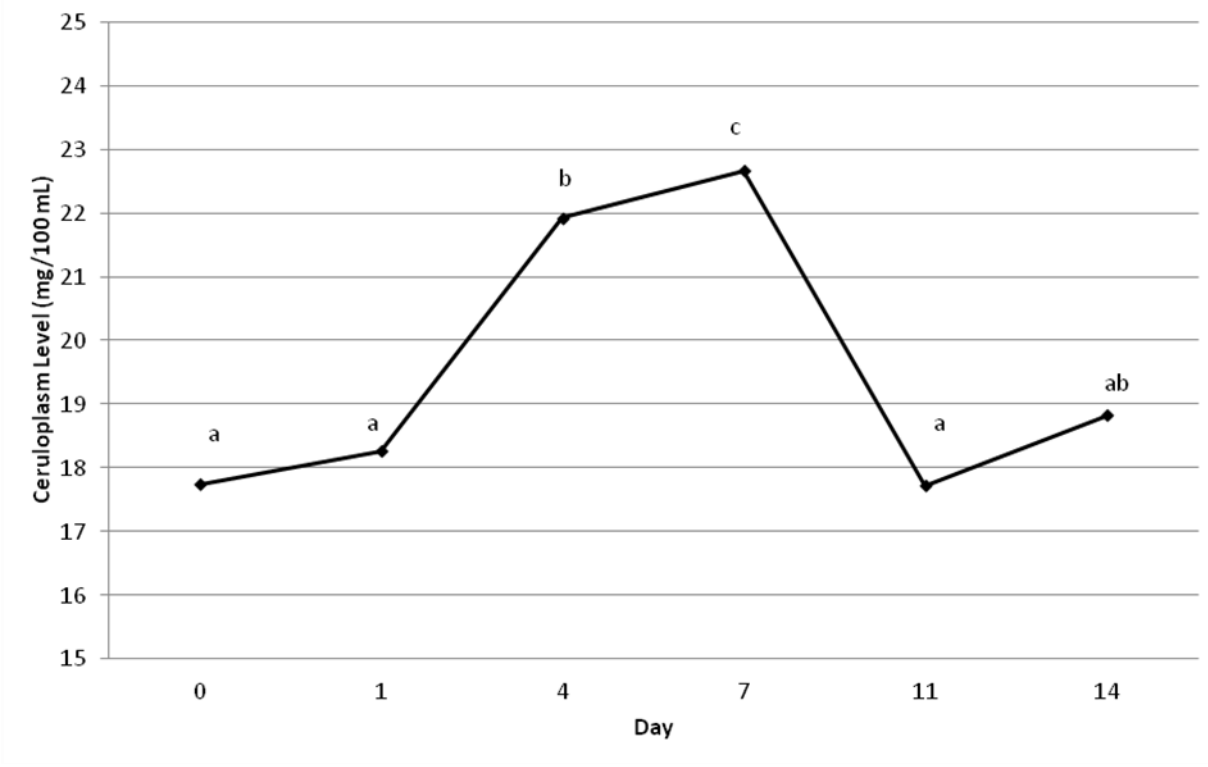

Figure 4-8. Effect of sampling day on plasma concentration of ceruloplasmin post-weaning. P<0.0001.

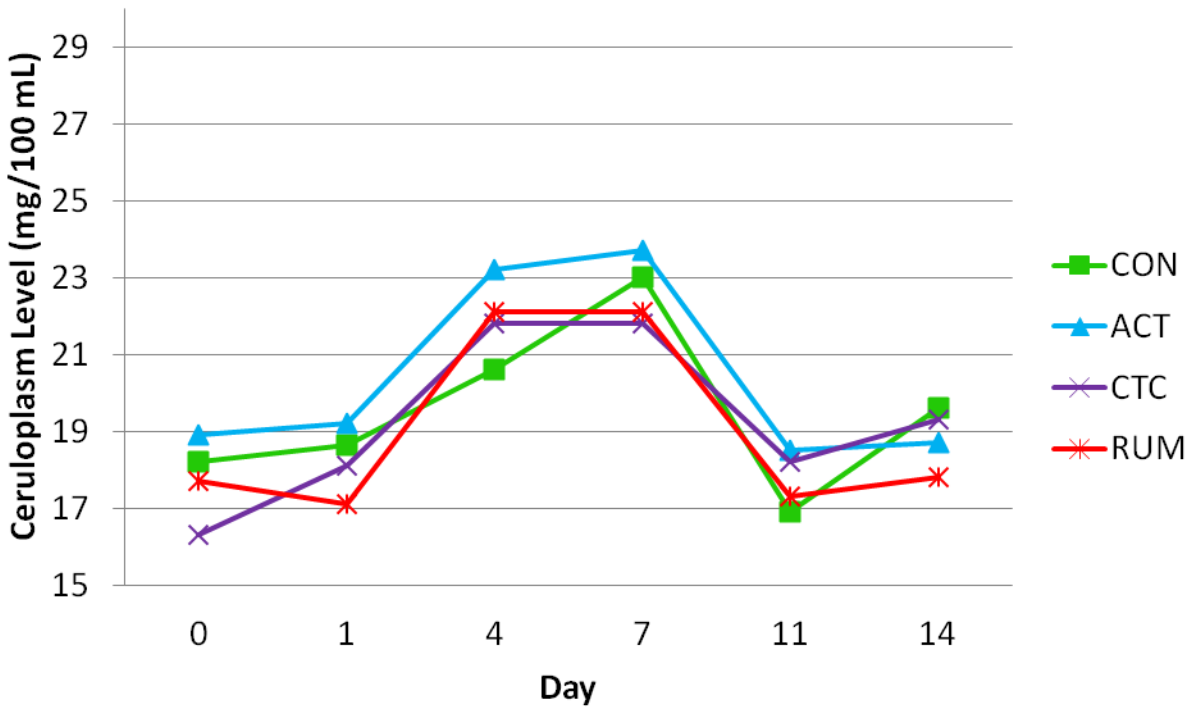

Figure 4-9. Effect of feed additive treatment and sampling day on plasma concentration of ceruloplasmin post-weaning. P=0.01.

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CHAPTER 5
CONCLUSIONS

No differences in early and late castration were observed. Calf performance results from this trial and others indicate that producers have some degree of flexibility in determining when to implement castration. Castration at or near birth will not have a detrimental effect on calf performance or ultimate weaning weight. Equally important, delayed castration will not result in added pounds at weaning.

Additionally, the addition of low levels of feed additives technologies resulted in variable post-weaning gain responses, similar stress responses to weaning, and variable economic returns. These results, however, are not definitive and more work is warranted to determine how factors like season, calf age, forage availability, additive inclusion rate, and preconditioning system influence performance response to Actigen® and other antibiotic alternatives. Equally important, economic analyses evaluating the cost effectiveness of feed additives in preconditioning programs are almost non-existent. There is a clear need to determine not only if performance responses can be elicited through additive provision, but if the responses observed improve calf value enough to cover the additional costs associated with supplementation.

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BIOGRAPHICAL SKETCH

Amie Marie Taylor was born in Alachua, Florida to Marie and Scott Taylor. She was raised on a small farm outside of Gainesville, Florida where she was active in both 4-H and FFA since the age of eight. Amie graduated from Santa Fe High School in 2004, and then from the University of Florida with a dual Bachelor of Science degree in Animal Science and Agriculture Education in the spring of 2009. During her undergraduate program, Amie served as a UF College of Agriculture and Life Sciences Ambassador for three years. Prior to graduation in the spring of 2009, Amie also completed an internship teaching high school Agriscience students at Williston High School in Williston, Florida.

Following graduation, Amie was accepted into a graduate program under the direction of Dr. Todd Thrift and Dr. Matt Hersom. During her graduate program, Amie assisted in teaching 33 sections of undergraduate courses within the Animal Sciences department, including Introduction to Animal Science, Cow-Calf Management, Farm Animal Reproduction and Endocrinology, and Large Animal Practicum. Amie plans on pursuing a career teaching Agriscience at the secondary or post-secondary level.