MANAGEMENT STRATEGIES TO IMPROVE EFFICIENCY OF BEEF CATTLE PRODUCTION

A Thesis

by

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ABSTRACT

A 49-d study was conducted to evaluate preweaning in a feedlot to increase performance and health during postweaning. Eighty-four $^{7}/_{8}$ Angus × $^{1}/_{8}$ Nellore cows with their calves were assigned to one of two treatments: preweaning in a feedlot or on pasture. For 21 d prior to weaning, LOT cow-calf pairs were placed in feedlot pens, while PAS remained on pasture until weaning. All calves remained in the feedlot for 28 d postweaning. Preweaning calves in confinement resulted in greater ($P \leq 0.01$) pre- and postweaning performance. Antibody production response to vaccinations were not affected by preweaning strategy ($P \geq 0.50$).

A 104-d study was conducted to evaluate timing of grain feeding on animal performance, carcass traits, and economic outcome in beef heifers. Twenty-one $^{7}/_{8}$ Angus × $^{1}/_{8}$ Nellore heifers were provided one of two diets 1) fiber-based and 2) corn-based. Heifers were assigned to one of three feeding period treatments: 1) C from month 12 through 15 and F from month 16 through 23 (CFF); 2) F from month 12 through 15, C from month 16 through 19, and F from month 16 through 23 (FCF); 3) F from month 12 through 19 and C from month 20 through 23 (FFC). Treatment × period interactions ($P < 0.01$) were detected for performance measurements. During periods of grain feeding, ADG was greater as was G:F. Ultrasonic measurements did not differ between treatments ($P > 0.05$). Period effects were detected for ultrasonic measurements ($P < 0.01$). Rib fat and rump fat were greater with each period. Ratios of IMF to subcutaneous fat decreased in period 1 from initial and were not different after that time. Significant differences for carcass characteristics were not observed ($P \geq 0.17$). Feed costs and profitability were not significantly different between treatments ($P \geq 0.22$).

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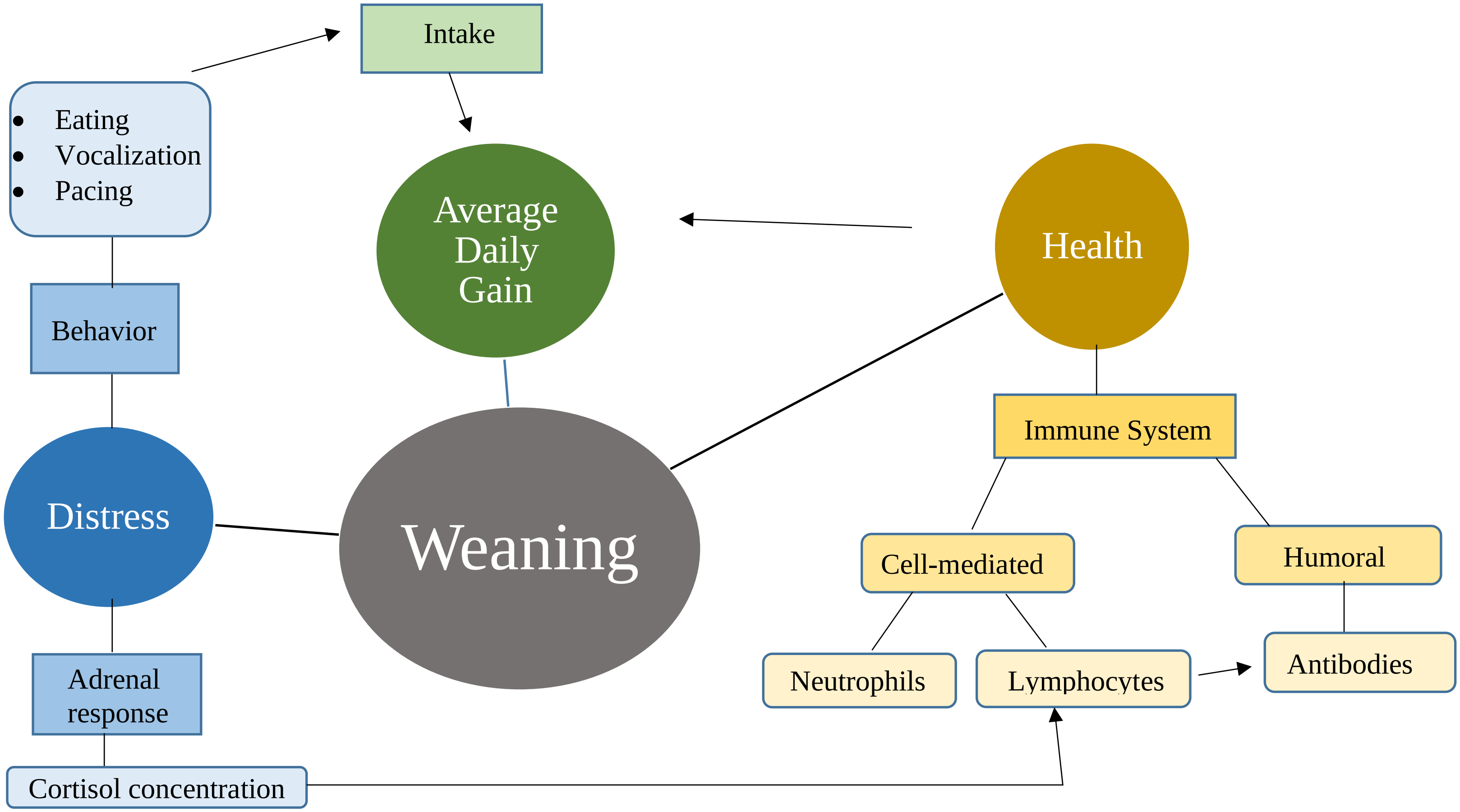
CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Introduction

Weaning is the act of removing calves from their dam's nutrient supply. This process can be accomplished through several strategies. During natural weaning, occurring 7 to 14 mo of age, the dam physically prevents the calf from suckling. Traditional management strategies wean calves abruptly by physically separating calves from their dams to accomplish this dietary change. Abrupt weaning, or traditional weaning (TW), occurs around 7 mo of age and causes a number of stressors associated with the dietary, environmental, and social disruptions. One of the best ways to quantify the effects of the stressors following weaning is through measuring ADG. Average daily gain (ADG) decreased from 30 to 124% in the 7 to 14 d postweaning period (Price et al., 2003; Haley et al., 2005). In the first 48 hours following weaning, weaned calves lost 3.6 kg versus non-weaned calves, who gained 1.8 kg (Fanning et al., 1995). Weight loss and reduced ADG result from decreased intake and increased energy expenditure as a result of shifting behavior from feeding to increased vocalization and pacing. Time spent eating decreased between 60% and 100% for up to four days postweaning, until calves adjusted to a new diet, environment, and loss of their dam (Price et al., 2003; Solano et al., 2007). In some cases weaning causes cell-mediated functions to decrease by 21 to 60% which can increase likelihood of morbidity (Lynch et al., 2010). Accordingly, cow-calf producers and researchers work to develop strategies to ameliorate the effects of weaning (Figure 1) by reducing the number of potential stressors occurring simultaneously.

Figure 1. Weaning outcomes and their relationships.



Two-stage processes to mitigate the negative effects of weaning

Two-stage management protocols attempt to separate the dietary, environmental, and social disruptions in order to mitigate performance losses and negative health outcomes and increase animal well-being. Implementation of two-stage protocols, including: nose-flap, fence-line, creep feeding, and confinement weaning, potentially alleviates commonly observed negative responses to changes in diet, environment, and social structure. Nose-flap weaning is designed to separate obstruction from dams' milk from social and environmental disruptions by utilizing anti-suckling devices prior to physical separation. Fence-line weaning is designed to separate social change from milk obstruction, allowing visual and auditory contact between cow-calf pairs before remote separation. Creep feeding is a preweaning strategy designed to introduce a weaning diet while allowing calves to remain in physical contact with their dam and milk supply. Confinement weaning is a postweaning management strategy designed to introduce a weaning diet, comparable environment, and eating from a feed bunk to enhance long-term acclimation. Responses to two-stage protocols are quantified at the application of the first stage and then again during the second stage. For example, in the case of nose-flaps, responses are quantified after nose-flap insertion and after physical separation, also known as the postweaning period. Responses to creep feeding are quantified during the preweaning and postweaning period. In the case of fence-line weaning, responses are quantified after calves are fence-line separated and after they are remotely separated. Responses to confinement weaning are gathered postweaning and during subsequent feedlot entry. Data from two-stage management practices (Boyles et al., 2007; Enriquez et al., 2010; Krebs et al., 2010) suggest two-stage strategies do not completely prevent the performance losses observed at weaning nor physical separation.

Haley et al. (2005) evaluated short- and long-duration two-stage, nose-flap weaning (3 and 14 d, respectively) compared to traditional weaning (TW). During first stage, a 14-d period, TW calves gained more than nose-flap weaned calves in both the short- and long-duration groups due to obstruction of suckling (0.81 vs. 0.38 and 0.04 kg/d, respectively). At separation (d 0) nose-flaps were removed from short- and long-duration nose-flap calves and all treatments were remotely separated from their dams. For the 8 d following separation from their dams both short- and long-duration groups gained more than TW calves (1.18 and 0.68 vs. 0.37 kg/d). Reduced gain responses of TW calves following separation are similar to that of calves after nose-flaps were inserted due to cessation of milk supply. Separating the disruptions associated with TW does not result in mitigated gain responses. Instead separating these disruptions shifts the period of time when reduced gains are exhibited, which is succeeding the withdrawal from milk.

Similar to the data reported by Haley et al. (2005), other researchers have demonstrated reductions in ADG of 50% to 100% compared to TW calves during the first stage when suckling was obstructed (Enriques et al., 2010; Lippolis et al., 2016). Enriquez et al. (2010) evaluated a 24 d period in which calves were either fitted with nose-flaps or fence-line weaned before remote separation on d 0 compared to TW. Average daily gain of nose-flap weaned calves was 80% less than ADG of TW calves the first 14 d of stage one. However, from d -11 to 0 nose-flap weaned calves resulted in an ADG 50% greater than TW calves who were still with their dams. Greater gains exhibited by nose-flap calves compared to TW, as the weaning date approached, demonstrates the calf receives limited nutritional supply from the dam during late lactation and obstruction from milk is a short-term stressor. Despite the period of adjustment to a forage-only diet prior to separation, nose-flap calves experienced a second reduction of 0.53 kg/day after separation from their dams, which lasted up to 7 d (Enriques et al., 2010), while TW calves' ADG increased by 70% compared to the decrease exhibited 11 days prior to weaning. Greater postweaning gains of TW calves after separation is an unexpected response. However, this suggests complete separation results in fewer stressors than separating the disruptions associated with TW. These studies demonstrate separating timing of dietary, social, and environmental changes does not completely mitigate performance responses as a result of weaning, and TW increases postweaning ADG by 80% compared to nose-flap insertion prior to separation (Enriquez et al., 2010) in contrast to (Price et al., 2003; Haley et al., 2005), likely due in part to length of the period before physical separation.

Like nose-flap weaned calves, fence-line weaned calves are able to remain in visual and auditory contact with their dam. Fence-line weaned calves do not exhibit significantly different ADG compared to TW calves after fence-line separation (0.90 vs. 0.88 kg/d); however, fence-line weaned calves gain 45% more compared to TW calves as weaning date approaches (Enriquez et al., 2010), likely as a result of relying on nutrients from forage-only compared to milk supply from dam. Seven days postweaning TW calves' ADG is 60% greater than fence-line weaned calves (Enriquez et al., 2010). According to Enriquez et al. (2010) this may have occurred as a result of proximity to dam and the perceived potential for nursing preventing calves from progressing. In other studies, fence-line weaning improved postweaning ADG by at least 95% compared to TW (Price et al., 2003; Stookey et al., 1997) as a result of 60% greater feeding activity after fence-line weaning (Price et al., 2003). Separating dietary, environmental, and social changes alter performance responses postweaning, however, in the case of both nose-flap and fence-line weaning, decreased ADG is exhibited after suckling is obstructed. Additionally, nose-flap and fence-line weaning create the potential for a second negative performance response once calves are physically, visually, and auditorily separated from their dams (Enriquez et al., 2010). Based on the gain results of TW compared to nose-flap and fence-line weaning, all calves experience a period of decreased ADG as a result of separation from milk supply.

Another strategy is the introduction of a high-concentrate creep-feed to calves prior to weaning. Creep-feeding has significant results during the preweaning period; however, differences in ADG after weaning are not significant between creep-fed and non-creep fed calves. Creep-feeding as a strategy to acclimate calves to a weaning diet prior to weaning has resulted in 5 to 60% greater ADG during the preweaning period and 7 to 30 kg heavier weights at weaning, however, postweaning gains and intake are not significantly affected (Myers et al., 1999; Aguiar et al., 2015; Sayre et al., 2018). Additionally, non-creep fed calves exhibit 7% greater ADG postweaning compared to creep-fed calves, resulting in comparable weights at 365 d of age (309 vs. 315 kg, respectively; Martin et al., 1981). Creep-feeding increases preweaning growth and has the ability to acclimate calves to a familiar diet postweaning. However, similar to other weaning strategies postweaning performance as a result of creep-feeding is not significantly affected .

Observed reductions in ADG are not exclusively the result of decreased feeding behavior. Reduced ADG is also observed during periods of increased morbidity (Walker et al., 2007), which is often interpreted as a suppression in immunological function. Because immune function consists of humoral (antibody responses) and cell-mediated immunity (white blood cell responses), researchers assess immunocompetence by measuring cell-mediated and humoral functional activity. Stress can increase morbidity by increasing cortisol concentrations, which suppress lymphocyte activity, therefore, cortisol is often evaluated as an indicator of potential immunosuppression. Lymphocytes act directly (T-cells) by killing infectious microorganisms and indirectly (B-cells) by producing antibodies. Lymphocyte and neutrophil counts, indicative of inflammation, increase by 20% two days after weaning compared to non-weaned calves (Lynch et al., 2010). Similarly, Hickey et al. (2003) reported significant increases in lymphocyte and neutrophil count 24 hours postweaning compared to non-weaned calves. Destruction of foreign bodies by neutrophils and immunocompetence of lymphocytes also decreases by 21% and 60% after TW, respectively (Lynch et al., 2010). In addition to increased white blood cell count, Hickey et al. (2003) reported weaned calves have cortisol concentrations 15% greater than non-weaned calves, which can lead to reductions in antibody production. However, cortisol concentrations, white blood cell count and their functional activity return to baseline levels between 2 and 4 d postweaning, suggesting cell-mediated and hormonal responses to weaning are short-term (Hickey et al., 2003; Lynch et al., 2010).

Humoral immunity consists of production of antibodies and can be quantified by measuring antibody responses to vaccination. Titer values, used to measure effective antibody response, increase up to 100% seven days postweaning in response to bovine viral diarrhea (BVD) vaccination (Sayre et al. 2018). Responses to infectious bovine rhinotracheitis (IBR) vaccination increases by 40% 7 days, postweaning (Sayre et al., 2018). High titer values after vaccination demonstrates a functional humoral immune system (Ross, 2003). Based on previous research, degree of humoral and cell-mediated immunity after weaning is altered depending on management practices such as vaccination, nutrition, and two-stage protocols (Krebs et al., 2010; Lynch et al., 2012).

According to Lippolis et al. (2016), nose-flap weaning decreased antibody response to BVD vaccinations by 50% 24 h after separation compared to TW calves. In contrast, other studies reported that titer values for BVD and IBR vaccinations did not significantly differ between TW and nose-flap weaned calves (Sayre et al., 2019; Krebs et al., 2010). Nose-flap weaning did not result in differences in lymphocyte or neutrophil counts after separation compared to TW (Krebs et al., 2010). In contrast to nose-flap weaning, separating dietary disruption from social and environmental disruptions, introduction of a creep-feed during the preweaning period increased humoral and cell-mediated immunity (Lynch et al., 2012; Sayre et al., 2019). Providing creep-feed during preweaning increased antibody responses to BVD and IBR vaccinations after weaning by 60 and 20%, respectively, compared to non-creep fed calves (Sayre et al., 2019). Greater antibody response in creep-fed calves may have occurred due to the high-energy ration providing additional energy for antibody production. Immunocompetence postweaning, quantified as lymphocyte activity, was increased from 20 to 50% with concentrate supplementation during preweaning compared to unsupplemented calves (Lynch et al., 2012). Despite significant changes in lymphocyte count after weaning, and regardless of strategy implemented, numbers and activity return to baseline levels 3 to 7 d following separation (Hickey et al., 2003; Lynch et al., 2010; Lynch et al., 2012; Sayre et al., 2019).

Similar to short-term health responses, stress responses observed after TW persist for 3 to 4 d postweaning (Price et al., 2003; Haley et al., 2005). Stress responses observed after TW include increased frequency of vocalization and pacing with decreased time spent grazing, ruminating, and playing (Enriquez et al., 2011). Compared to behaviors exhibited prior to TW, calves spend 30% more time pacing, 70 to 95% less time eating, and vocalize 1166% more frequently up to 72 hours postweaning (Price et al., 2003; Haley and Stookey, 2005; Solano et al., 2007). Vocalizations are used to evoke attention for maternal care; however, high frequency of calling after weaning is considered a signal of "yearning" for reunion with dam and "frustration" due to obstruction from dietary and social security (Watts and Stookey, 2000; Latham and Mason, 2008). Vocalization unrelated to maternal care provokes cows to ignore calls over time, suggesting calves strictly increase vocalization to solicit maternal care and security (Weary and Hötzel, 2008). While time spent playing ceased after weaning, activities returned to normal 4 d postweaning (Enriquez et al., 2010).

Compared to TW, insertion of nose-flaps prior to physical separation decreased vocalization by 97% and increased time spent eating by 20% 3 d after separation (Haley et al., 2005). Enriquez et al. (2010) reported 3% and 13% increase in vocalization after nose-flap insertion and fence-line weaning, respectively, compared to TW calves. However, a second stress response is evoked after calves are separated. Enriquez et al. (2010) recorded no observations of vocalization the day prior to separation and reported 5% of nose-flap weaned calves vocalized after separation from their dams. After remote separation, fence-line weaned calves had a smaller percentage of observed calf vocalizations compared to TW and nose-flap weaned calves during the postweaning period (3% vs. 23% and 5%, respectively; Enriquez et al., 2010). Additionally, fence-line weaned calves spent 50% more time eating compared to TW (Price et al., 2003). Fence-line weaned calves spent 60 to 70% of their time within close proximity to the fence-line. However, after 3 d this behavior was no longer exhibited (Price et al., 2003; Enriquez et al., 2010). Stress behaviors observed after weaning do not persist more than 5 d postweaning, indicating weaning and separation are short-term stressors (Price et al., 2003; Haley et al., 2005; Enriquez et al., 2010).

In an attempt to alleviate future stressors, such as placement into the feedlot, confinement weaning is used as a strategy to introduce calves to an environment and diet similar to that of a feedlot by placing calves in drylot pens after separation from dam. Bailey et al. (2016) evaluated a 28-d postweaning period in which calves were separated and placed in a drylot or fence-line weaned with and without supplementation before feedlot entry. Fence-line weaned calves were supplemented with the same diet received by the confinement weaned calves. During the 28-day postweaning period calves weaned in confinement gained more than fence-line weaned with or without supplementation (0.31 vs. -0.22 and -0.31 kg/d, respectively; Bailey et al., 2016). Additionally, confinement weaned calves exhibited 15% and 10% greater ADG the first and last 30 days in a feedlot, respectively, compared to fence-line weaned calves without supplementation. However, confinement weaned calves’ ADG was not significantly different than fence-line weaned with supplement during the finishing period (1.12 vs. 1.06 kg/d, respectively; Bailey et al., 2016). Furthermore, intake and G:F increased by 0.10 kg/d and 10% respectively, compared to fence-line weaned calves, but did not significantly differ from fence-line weaning with supplementation (Bailey et al., 2016). Advantages of weaning in confinement may include acclimatization to a feedlot environment, improved diet, as well as eating from a feed bunk. However, if confinement weaning is infeasible, providing supplementation to pasture weaned calves during the postweaning period introduces calves to new diet which may assist in adjustment to future dietary disruptions (Bailey et al., 2016).

Boyles et al. (2007) compared confinement weaned calves (30 d before trucking), fence-line weaned calves (30 d before trucking), and calves weaned at trucking. In contrast to findings by Bailey et al (2016), weaning in confinement resulted in weight loss of 0.6 kg/d during the first week in a feedlot compared to positive gain exhibited by calves fence-line weaned 30 d before trucking and calves weaned at trucking (0.4 and 0.5 kg/d, respectively); however, this decrease was a short-term response (7 d), and confinement weaned calves' intake during the first week was 8% greater than calves weaned at trucking (Boyles et al., 2007). Overall ADG of fence-line weaned calves and those weaned at trucking was 56% greater than confinement weaned calves.

In addition to observed weight losses the first week in a feedlot, Boyles et al. (2007) reported greater percentage of morbidity as a result of confinement weaning compared to weaning calves at trucking or fence-line weaning calves 30 d before trucking (38% vs. 28% or 15%, respectively). Similarly, Bailey et al. (2016) observed greater morbidity of confinement weaned calves during the 28-d postweaning period compared to fence-line weaned with and without supplementation (5.16% vs. 1.97% and 0.65%, respectively); however, during the feedlot receiving period, both fence-line weaned groups had greater morbidity rates than confinement weaned (1.97% and 0.65% vs. 0%, respectively). These results suggest feedlot entry did not present as many new stressors for confinement weaned calves as it did for calves not previously acclimated to a similar diet and environment prior to entry. Additionally, Bailey et al. (2016) suggests that acclimation to the feedlot environment allowed confinement weaned calves to overcome sickness more effectively than other weaning strategies upon receiving.

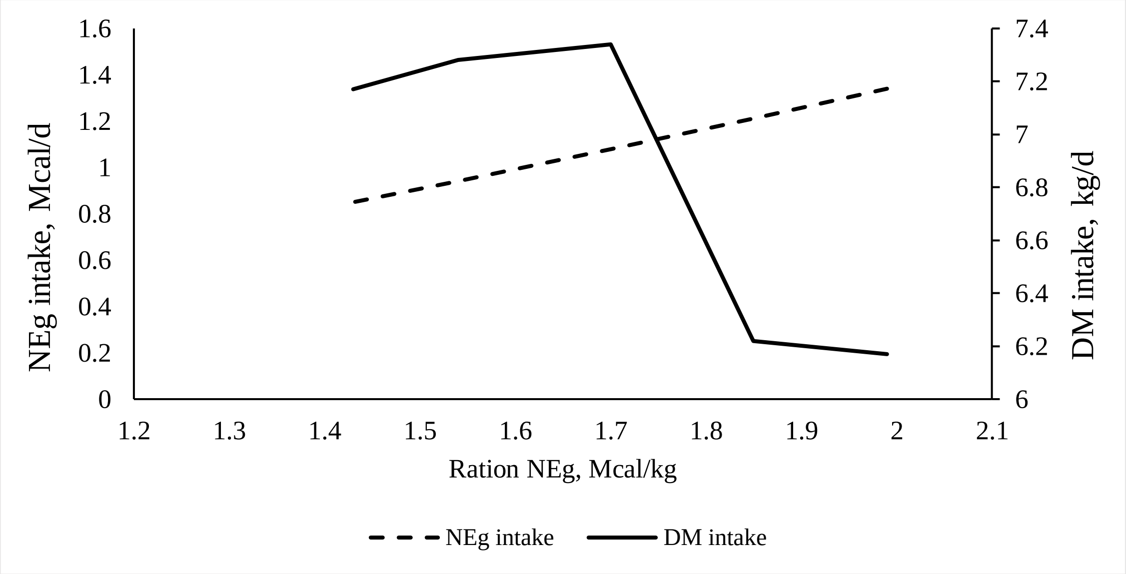
Acclimation to a feedlot environment can include both acclimation to the drylot pen and to consuming feed from a bunk. Walker et al. (2007) observed that weaning calves in confinement for 21 d before returning to pasture, and training animals to eat from the bunk during confinement weaning both increased feeding behavior and immune response to vaccination the first week in a feedlot by 60% and 17%, respectively. Moreover, confinement weaned and yard trained calves' feedlot ADG was 20% and 8% greater ADG than TW calves., respectively. While greater feeding behaviors and increased intake were observed the first week in the feedlot as a result of confinement weaning and training, after 2 days no significant differences were observed between confinement weaned, yard trained, and TW calves (Walker et al. 2007). Based on previous research, the overall performance and health differences between weaning calves in confinement versus pasture vary.

Effects of finishing cattle on grain-based diets

Inclusion of grain in finishing diets increases animal performance (often measured as average daily gain (ADG) and feed efficiency (gain to feed ratio, G:F) and carcass traits (hot carcass weight, HCW; quality grade) by increasing available energy concentration of the diet. Increasing available energy concentration of the diet can indirectly affect profitability by reducing the unit cost of energy and increasing quality grades of carcasses. Finishing diets are typically formulated to provide 2.70 to 3.45 Mcal of ME/kg of DM (Kreihbel et al., 2006). Increased ADG during finishing affects profitability by reducing days on feed and increasing carcass gain (Meissner et al., 1995). Feeding grain-based versus forage-based diets to finishing cattle increases ADG by 20 to 50% (Oltjen et al., 1971; Bennett et al., 1995), and increases feed conversion by 40 to 75% (Oltjen et al., 1971; Berthiaume et al., 2006). Fat deposition increases by 9 to 50% in intramuscular depots and up to 100% in subcutaneous adipose tissue, by feeding grain-based diets (Bowling et al., 1977; Aberle et al., 1981; Strachan et al., 1993). During finishing, fat deposition is energetically more efficient than lean deposition because fat contains more calories per kg than muscle. Additionally, a large proportion of BW gain is water with protein deposition. Therefore, fat deposition can decrease efficiency of gain as proportion of fat increases (Meissner et al., 1995; Krehbiel et al., 2006). Additionally, the presence of excess external fat by providing greater energy concentrations results in lower product yield, reducing profitability (Sharman et al., 2013; Feuz et al., 1993).

Cattle consuming grain-based diets consume more dry matter (DM) and digestible energy per day compared to their forage-fed counterparts. This occurs because as digestible energy concentration in a ration increases, DM intake, once limited by ruminal fill, increases. However, voluntary feed consumption decreases when available energy intake exceeds the animal's maintenance and genetic capacity for growth through chemostatic and/or thermostatic mechanisms (Brokken et al., 1976; Dinius et al., 1976). By decreasing intake as digestible energy in the diet increases, the animal is efficiently meeting its requirements for maintenance and growth (Brokken et al., 1976). Thus, if the relationship between DM intake and increasing available energy is quadratic, increasing available energy in a finishing ration would result in more efficient gains. Dinius et al. (1976) evaluated five diets ranging from 1.43 to 1.99 Mcal NEg/kg that were made by increasing the proportion of corn. Net energy intake available for gain increased while DM intake decreased with increased available energy in the ration (see Figure 2).

Figure 2. Relationship between energy concentration in the diet, dry matter intake, and NEg intake [1].



[1] Reprinted with permission from Dinius, 1976. Copyright by Oxford University Press.

Similar to intake, ADG is affected by digestible energy concentration in grain-based diets as well as composition of growth. Rate of gain increases as available energy in the ration increases (Brokken et al., 1976). Results from Dinius et al. (1976) demonstrate that ADG of steers fed a ration consisting of 1.99 Mcal NEg/kg was 100% greater than steers fed the lowest-energy diet (1.43 Mcal DE/kg), despite a 20% lower intake for 1.99 Mcal NEg/kg. Furthermore, ADG of the highest-energy fed steers tended to be 11 to 32% greater than those fed lower energy rations (Dinius et al., 1976). Greater ADG accompanied with lower DM intake as NE available for gain in the ration increased, demonstrates as energy increases, cattle require less feed to produce a unit of gain.

Accordingly, because grain-based are higher in NEg than roughage based-diets, grain-finished cattle will require less feed to produce a unit of gain. According to Oltjen et al. (1971), grain-finished cattle required 40% less feed to produce a kg of gain compared to cattle finished on an all-forage diet. Meissner et al. (1995) evaluated 5 finishing trials varying in ME concentration, DOF, intake, and ADG. Cattle were grouped by feeding periods of 90 and 140 with average DMI of 7 and 9 kg/d, respectively. Cattle consuming 9 kg versus 7 kg/d gained more per d as a result, and were considered “fast-growing”, whereas cattle gaining less were considered “slow-growing” (Meissner et al., 1995). As energy in the ration increased from 2.5 to 2.75 and 2.5 to 3.0 Mcal of ME/kg DM, so did ADG and G:F of slow-growing cattle; however, as ME increased from 2.75 to 2.87 Mcal/kg, ADG and G:F of fast-growing cattle plateaued and began to decrease with persistent increases in ME. According to researchers, this occurred as a result of greater ME intake contributing to inefficient gains associated with fat deposition (Meissner et al., 1995).

Increased ADG, as a result of greater available energy in the ration, increased hot carcass weight (HCW) 50 to 80% (Fishell et al., 1985; Meissner et al., 1995). Cattle evaluated in the study by Fishell et al. (1985) were fed diets with varying amounts of energy and protein to allow maximum growth rate (1.42 kg/d; high-energy diet), near-maximum protein deposition and minimum fat deposition (0.77 kg/d; medium-energy diet), and restricted protein and fat deposition (0.34 kg/d; low-energy diet). Animals gaining 1.42 kg/d had HCWs 84 and 108 kg heavier than those gaining 0.77 and 0.34 kg/d, respectively (Fishell et al., 1985). Because of greater available energy in grain versus forage, HCW is expected to be greater for grain-finished compared to forage-finished if animals are slaughtered with comparable days on feed. Berthiaume et al. (2006) recorded 13 kg heavier HCW for steers fed a high-grain diet compared to a forage-finishing diet. Similarly, Bennett et al. (1995) reported grain-finished steers had HCW that were 66 kg heavier than pasture-finished steers. Significantly greater HCW of grain-finished versus pasture-finished cattle in the study by Bennett et al. (1995) was potentially affected by energy expenditure of grazing versus confined cattle and number of days on feed. As DOF increases, cattle continue to deposit fat and lean, regardless of ADG, contributing to heavier carcasses (Dinius and Cross, 1978; Strachan et al., 1993; Muir et al., 1998). Cattle finished on grain for 70, 105, and 175 d had similar ADG during the finishing period, however, HCW increased linearly with DOF as expected (Strachan et al., 1993). In contrast to these findings, Strachan et al. (1993) results show HCW did not significantly differ between 0, 21, and 42 d of grain feeding, but increased by 40 kg when grain was fed for 63 d compared to 0 and 21 d. Furthermore, HCW gained per d increased by 64% after grain was fed to steers for 21 d versus 0 d; however, as DOF increased by 21 and 42 more d, HCW gained per d did not differ (Strachan et al., 1993). This is likely due to similar ADG of cattle fed grain for 0, 21, 42, and 63 d, composition of growth (fat versus lean), or composition of fat deposition (external versus internal).

Intramuscular and subcutaneous fat deposition increases in response to dietary energy and rate of gain. While highly marbled carcasses affect profitability associated with greater yield grades and premiums, excess subcutaneous fat lowers carcass yields, decreasing returns (Schoonmaker et al., 2004; Sharman et al., 2013). Feeding grain-based diets increases IMF deposition because fermentation of starch increases production and proportion of propionate, provides glucose for intestinal absorption, and increases blood glucose concentrations (Smith and Crouse, 1984). According to research by Smith and Crouse (1984) glucose provided 50-75% of acetyl units for *in vitro* lipogenesis in intramuscular adipose tissue compared to 1-10% of acetyl units for subcutaneous adipose tissue. Fermentation of fiber results in a greater proportion of acetate, which is preferentially used by subcutaneous adipocytes. Acetate, provided 70-80% acetyl units for lipogenesis in subcutaneous adipose tissue while only10-20% acetyl units to lipogenesis in intramuscular adipose tissue (Smith and Crouse, 1984). Dissimilar results are shown by Bowling et al. (1977), evaluating 30 pairs of carcasses (one forage-finished, one grain-finished) of identical quality grades and skeletal maturity to compare external fat thickness. Carcasses from grain-finished cattle had external fat thickness 2x greater than forage-finished carcasses. Similarly, grain-finished carcasses resulted in 20 to 80% greater fat thickness than forage-finished carcasses (Oltjen et al., 1971; Utley et al., 1975; Bennett et al., 1995). Increasing energy intake above an animal’s maintenance increases subcutaneous fat deposition (Sainz and Paganini, 2004). Greater external fat thickness of grain-fed carcasses may have been a result of differences in available energy between grain and forage diets; however, nutrient composition of diets fed before slaughter was not given in the 1977 study. If forage-finished cattle consumed similar amounts of digestible energy as grain-finished, differences in external fat may not have been detected by Bowling et al. (1977).

Greater rates of gain (1.42 vs. 0.77 and 0.34 kg/d) as a result of dietary energy to manipulate composition of gain, increases marbling score (4.5 vs. 2.0 and 1.6; Fishell et al., 1985). Similarly, conclusions by Aberle et al. (1981) reveal cattle with unrestricted ADG resulted in marbling scores 48% greater than cattle restricted to gain of 0.68 kg/d.

Thus, feeding grain- versus forage-based diets result in greater marbling scores as a result of differences in available energy in rations (Utley et al., 1975; Bennett et al., 1995). In addition to greater external fat thickness, researchers recorded marbling scores 16% greater for grain-finished calf- and yearling-fed carcasses compared to forage-finished calf- and yearling-fed carcasses (Utley et al., 1975). Similarly, Bennett et al. (1995) reported 20% greater marbling scores for carcasses from grain- versus forage-finished cattle. According to Krehbiel et al. (2006), increased RE as a result of increased metabolizable energy intake, is associated with increased proportion of fat in gain and slightly decreased proportion of protein in gain when grain diets are fed. However, some researchers indicate marbling does not differ between grain- and forage-based diets (Oltjen et al., 1971; Muir et al., 1998). Muir et al. (1998) reported no differences in IMF between pasture- and grain-finished cattle in two experiments. However, carcass IMF of cattle (pasture- and grain-finished) in experiment 1 was 60% greater than those in experiment 2 due to the 0.2 Mcal ME/kg difference in rations. According to these researchers, carcasses from cattle finished on pasture or forage can exhibit similar marbling scores to those of grain-fed cattle as long as they achieve growth rates similar to those observed in a feedlot (Muir et al., 1998).

CHAPTER II

PREWEANING IN CONFINEMENT TO PROMOTE POSTWEANING PERFORMANCE AND HEALTH

Overview

A 49-d study was conducted to evaluate an alternative preweaning system in which calves are pre-weaned in a feedlot setting prior to separation to increase postweaning performance and ameliorate immune function during weaning. Eighty-four $^7/_8$ Angus × $^1/_8$ Nellore cows with Angus-sired calves (40 heifers, and 44 steers; initial BW = 217.8 kg $\pm$ 9.2) were assigned to one of two treatments: preweaning in a feedlot (LOT; n = 41) or preweaning on pasture (PAS; n = 43). For 21 d prior to weaning, LOT cow-calf pairs were placed in feedlot pens, while those assigned to PAS remained on pasture. After weaning, calves assigned to the LOT treatment remained in the feedlot , while those assigned to PAS calves were placed into the feedlot. All calves remained in the feedlot for the 28-d postweaning period. Cows in PAS had heavier weights on day of weaning compared to LOT cows ($P < 0.05$).Preweaning calves in confinement resulted in greater ($P \leq 0.01$) ADG during the preweaning period, postweaning period, and overall ADG. Calves preweaned in confinement converted feed more efficiently than PAS calves ($P < 0.05$) following weaning. Calves in LOT gained 13.3 kg more ($P < 0.01$) than PAS calves over the duration of the trial. Feed intake postweaning was not different between LOT and PAS calves ($P = 0.38$). Antibody production response to IBR and BVD vaccinations were not affected by preweaning strategy ($P \geq 0.50$). Preweaning in confinement increased postweaning performance without compromising responsiveness to vaccinations.

Introduction

Weaning is the act of removing calves from their dam's milk supply and is often considered one of the two most stressful events in the calf's life, followed by placement in a feedlot (Boyles et al., 2007). Beef calves are typically weaned at 7 to 8 months of age by abrupt separation of cow-calf pairs. Nutritional and environmental disruptions occurring at weaning in addition to loss of maternal contact results in a period of postweaning stress, which is indicated by endocrine responses (Hickey et al., 2003; Lefcourt and Elasser, 1995) and may be expressed through increased vocalization (Smith et al., 2003; Lambertz et al., 2015), reduced ADG (Price et al., 2003; Haley et al., 2005), weight loss (Fanning et al., 1995; Arthington et al., 2005), decreased feed intake (Price et al., 2003), and suppressed immune function (Hickey et al., 2003; Lefcourt and Elasser, 1995). Performance, behavior, and health responses to related to weaning may persist for five days postweaning (Enriquez et al., 2011) or longer (beyond 10 weeks, Price et al., 2003).

Some calf responses postweaning are inevitable; however, minimizing the effects of weaning disruptions may improve both productivity and animal well-being, motivating research of various strategies to mitigate stress responses of traditional weaning (TW) methods. Disruptions in nutrition leading to performance losses and negative health outcomes can be minimized through nutritional management, such as creep feeding a weaning diet prior to separation. Changes in housing and social contact with dam can be minimized by allowing visual and auditory contact with dam through a fence-line or nose-flap insertion to prevent suckling prior to remote separation. Fence-line weaned calves gained 8.0 kg more and exhibited fewer stress-related behaviors (e.g. vocalization, decreased grazing, walking) during the first 2 weeks postweaning than calves TW (Price et al., 2003). Nose-flap weaned calves gained 44% more, vocalized 96.6% less, and spent 23.0% more time eating compared to TW calves 7 d postweaning (Haley et al., 2005). However, fence-line and nose-flap weaning strategies may not always successfully alleviate weaning impacts and may result in adverse effects (Enriquez et al., 2010).

The objective of this research study was to evaluate an alternative weaning practice in which calves are pre-weaned in a feedlot prior to separation as a means to mitigate effects of weaning by addressing changes in diet through creep feeding and acclimating animals to a similar environment prior to separation. Preweaning calves in a feedlot with their dams' is expected to increase postweaning productivity and immune responses compared to calves that are naïve to feedlot at weaning, and thus must cope with both dietary and maternal separation and housing transition stressors simultaneously.

Materials and methods

Experimental procedures used in this feeding trial were approved by the Agricultural Animal Care and Use Committee of Texas A&M AgriLife Research.

Eighty-four cows $^{7}/_{8}$ Angus × $^{1}/_{8}$ Nellore with Angus-sired calves (40 heifers, 44 steers; initial BW = 217.8 kg ± 9.2) originating from resident populations at the McGregor Research Center, (McGregor, Texas, USA) were used to evaluate the effect of preweaning system on calf health and performance. Calves were born between January and March 2019 (average age = 180 d). Calfhood management included vaccination with a clostridial vaccine (Covexin®8; Merck Animal Health, Madison, NJ, USA), castration and dehorning at < 75 d of age. Calves were vaccinated 21 d prior to weaning a second dose of the same clostridial vaccine and a killed, multivalent respiratory viral vaccine (Triangle®5;

Boehringer Ingelheim Vetmedica, Ft. Dodge, IA, USA) to aid in prevention of clostridial and respiratory diseases, respectively. At weaning calves received a multivalent modified-live viral vaccination (Titanium®5; Elanco Animal Health, Greenfield, IN, USA).

Cow-calf pairs were stratified by calf BW and randomly assigned to 1 of 8 groups. Four groups were assigned to each of two treatments: preweaning in a feedlot (LOT; n = 41) or on pasture (PAS; n = 43). For 21 d prior to weaning, LOT cow-calf pairs were placed in feedlot pens (110 × 360 m), while those assigned to PAS remained on pasture. At weaning (d 0), all cattle were individually weighed, and calves were weaned from their dams. Calves from LOT and PAS were held in a common lot for 7 days for similar exposure before transitioning to designated pens. Calves belonging to the PAS groups were placed in one of four confinement pens interspersed among those containing LOT calves. All dams were returned to pasture. Calves were weighed on days -21, 0, 7, 28, while cows were weighed on days -21 and 0.

Blood samples were collected on days -21, 0, 7, and 28, and antibody titers were analyzed to evaluate antibody response to BVDV2 and IBR1 vaccines. Collected blood samples were sent to Texas A&M Veterinary Medical Diagnostic Laboratory (TVMDL) for assessment of antibody production by viral neutralization. Viral strains used in viral neutralizing tests included Bovine Viral Diarrhea Virus Type II (BVDV2-VN) and Bovine Herpes Virus Type 1 (IBR1-VN). Titer values resulting in <4 were assigned a value of 1 for subsequent data transformation and analysis. Titer values were transformed as the base 2 logarithm for analysis and results are reported on that basis.

Calves assigned to PAS had access to milk from their dams and the same forage and hay sources as cows prior to weaning. Calves assigned to LOT were co-housed with dams prior to weaning, and so had access to dams' milk, but were also provided with access through creep gates to feed bunks containing the same diet provided to cows (Table 1). Feed delivered in the creep feeders was determined with standard bunk management procedures for growing cattle exercised at the McGregor Research Center. If calves consumed all the feed delivered to the bunk for two consecutive days, amount of feed delivered to the bunk increased the third day.

Cows on pasture grazed available forage, and were offered additional hay. Cows assigned to LOT were fed a daily ration to meet energy requirements estimated as 80% of NASEM (2016) maintenance, plus requirements based on days of pregnancy and lactation (Trubenbach et al., 2019). Limit-feeding of cows according to this formulation results in substantial fill adjustment upon transition but has been shown to allow cows to maintain BW over periods of at least 56 d (Trubenbach et al., 2019; Boardman et al., 2020).

Table 1. Ingredient and nutrient composition of the diet fed to cow-calf pairs during preweaning and postweaning periods

Item	% of diet
Ingredient Composition	
Milo stalk	35.0
Dry rolled corn	35.0
Dried distillers grain	27.5
Molasses	6.0
Premix[a]	2.0
Nutrient Composition[b]	
CP,%	13.1
Ca, %	0.66
P, %	0.37
NE_m, Mcal/kg	1.73
NE_g, Mcal/kg	1.11

[a] Contained 19-21% Ca, 0.01% P, 0.20% K, 0.10% Mg, 20% NaCl, 450 ppm Cu, 2800 ppm Zn, 10 ppm Se, 100,000 IU/lb Vit. A, 9,000 IU/lb Vit. D3, 1600 IU/lb Vit. E.

[b] Calculated from nutrient analyses according to NRC (2016) table values.

Statistical Analysis

Data were analyzed using MIXED procedures of SAS (SAS Inst. Inc., Cary, NC). Fixed effects included pen, and treatment. Experimental unit for this project was pen. Significance was declared at ($P \leq 0.05$).

Results and discussion

During the preweaning period (d-21 to 0), LOT calves had 37% greater ($P < 0.01$; Table 2) ADG compared to PAS calves, likely the result of having access to feed. Allowing calves access to supplemental or creep feed may result in 5 to 60% greater preweaning ADG compared to control calves and 7 to 30 kg heavier weaning weights (Myers at al., 1999; Aguiar et al., 2015; Sayre et al., 2018). In contrast to these findings, creep fed calves in the current study did not have significantly different weaning weights compared to PAS calves; however, CON calves tended to have heavier weaning weights (242 vs. 235 kg; $P = 0.31$).

Table 2. Effect of preweaning strategy on pre- and postweaning performance of calves[1]

	Treatments[2]			
Item	LOT	PAS	SEM	*P*-value
No. of Obs	41	42		
ADG, kg/day				
D -21 to 0	1.16	0.82	0.05	< 0.01
D 7 to 28	1.41	0.62	0.06	< 0.001
D 0 to 28	0.89	0.68	0.05	0.03
Overall ADG	1.01	0.74	0.03	≤0.01
Total Weight Gain, kg	49.5	36.2	1.56	< 0.01
Pre-wean intake, kg/day	2.66		0.18	
Post-wean intake, kg/day	6.97	6.74	0.18	0.38
G:F	0.13	0.10	0.008	0.05

[1] LOT = calves in confinement during weaning trial; PAS = calves on pasture during weaning trial

[2] LOT = calves pre-weaned (21 d) in confinement before weaning; PAS = calves pre-weaned (21 d) on pasture before weaned in confinement

Calves subjected to LOT had 30% greater ADG (*P* = 0.03) postweaning, 36% greater overall ADG, and gained 13.3 kg more over the duration of the trial (*P* < 0.01). Results as such were expected as a result of LOT calves consuming the concentrate ration 21 d longer than PAS calves and were acclimated to the diet and environment prior to separation. Similarly, Blanco et al. (2008) reported calves supplemented with a high-concentrate diet during the 60-d preweaning period resulted in 99% greater ADG postweaning. However, other researchers have reported no significant differences in postweaning ADG between creep fed and non-creep fed calves (Myers et al., 1999; Aguiar et al., 2015; Sayre et al., 2018) or reduced postweaning ADG in creep fed calves, resulting in comparable weights at 365 d of age (309 vs. 315 kg, respectively; Martin et al., 1981).

Table 3. Effect of preweaning management on pre- and postweaning cow-calf weights

	Treatments^2			
Item	LOT	PAS	SE	*P*-value
No. of Obs	41	41		
Calves				
Initial BW, kg	217.5	218.1	4.18	0.91
D 0 Weight, kg	242.0	235.3	4.64	0.31
D 7 Weight, kg	237.3	241.4	4.54	0.52
D 28 Weight, kg	266.9	254.4	4.90	0.07
Cows				
Initial BW, kg	513.8	505.6	9.78	0.55
D 0 Weight	438.2	509.9	9.98	0.05

[1] LOT = cow-calf pairs in confinement during weaning trial; PAS = cow-calf pairs on pasture during preweaning

[2] LOT = calves pre-weaned (21 d) in confinement with dam before weaning; PAS = calves pre-weaned (21 d) on pasture with dam before weaned in confinement

Preweaning calves in confinement with their dams has not been extensively researched; however some research has evaluated placing calves in confinement after separation compared to calves remaining on pasture (confinement weaning). Confinement weaning is designed to introduce calves to an environment and diet similar to that of a feedlot to mitigate stressors associated with future disruptions. During a 28-d postweaning period calves weaned in confinement gained more than supplemented and unsupplemented, fence-line weaned calves (0.31 vs. -0.22 and -0.31 kg/d, respectively; Bailey et al., 2016). Additionally, results of Bailey et al. (2016) show confinement weaned calves exhibited 15% and 10% greater ADG the first and last 30 days in a feedlot, respectively, compared to unsupplemented, fence-line weaned calves. According to a study by Walker et al. (2007), calves confinement weaned and trained to eat from bunks before arrival to a feedlot resulted in 5% greater ADG and displayed 40% greater feed activity (attendance at the feed bunk) on d 1 in the feedlot compared to animals unaccustomed to eating from bunks. In contrast, if confinement weaning is infeasible, supplementing grain to pasture weaned calves results in similar feedlot ADG compared to confinement weaned calves (Bailey et al., 2016). Calves previously acquainted with concentrate have greater concentrate and total dry matter intake postweaning and during the feedlot period (Moriel and Arthington, 2013; Arthington et al., 2008). However, in the current study, calves kept in confinement and creep fed during preweaning did not result in significantly different feed intake postweaning compared to PAS calves ($P > 0.38$), and feed conversions postweaning were 30% greater ($P < 0.05$) for LOT calves.

Cows assigned to PAS treatment were 72 kg heavier ($P < 0.05$) at weaning compared to LOT cows. Confined cows were fed the same concentrate diet creep fed to the calves; however, their daily ration was formulated to meet 80% of maintenance energy requirements, plus requirements based on days of pregnancy and lactation. Lighter BW of

LOT cows at weaning is likely due to difference in ruminal fill compared to cows on PAS. Trubenbach et al. (2019) reported intake restriction decreased ruminal DM fill, and Hemphill (2017) observed *ad libitum* forage intake increased ruminal fill by 37 kg compared with ruminal fill during a period of restricted intake.

No differences were observed between treatments in immune response to vaccination based on titer values for IBR and BVD Type II from preweaning to conclusion of trial ($P \geq 0.5$; Table 4.). Calves in the current study were vaccinated on d -21 and received a booster at weaning (d 0). According to a study by Ross (2003), high and low titer values for BVDV are considered >1:128 and <1:64, respectively. In the current study IBR and BVD titer values on d -21 were <1:64 for LOT and PAS groups, representing values at an unvaccinated state. At the end of the trial (d 28) titer values for IBR and BVD were >1:128 for both LOT and PAS groups, but did not differ from each other (P = 0.45). Increased titer values of both treatments indicate immune system of calves responded positively to both vaccinations. However, there were no significant differences between treatments for IBR and BVD titer values nor changes in titer values throughout the trial. In contrast, Sayre et al. (2018) observed a greater antibody response to BVD after weaning in creep fed versus non-creep fed calves, but similarly found no differences in antibody response to IBR between treatments. Providing creep feed during a preweaning period may mitigate reduction in white blood cell activity by reducing nutritional stress which can result in a suppressed immunological response (Lynch et al., 2012).

Table 4. Immunological responses based on antibody titer values of IBR and BVD Type II for two preweaning methods[1]

	Treatments[2]			
Item	LOT	PAS	SEM	*P*-value
IBR Titer[3]				
D -21	0.71	0.98	0.19	0.33
D 28	4.32	4.63	0.30	0.45
D -21 to 0	1.29	0.75	0.49	0.46
D 0 to 7	2.90	2.88	0.31	0.97
D 7 to 28	-0.59	0.02	0.21	0.08
D 0 to 28	2.32	2.91	0.37	0.29
Total Change	3.61	3.65	0.45	0.95
BVD Titer				
D -21	1.12	1.53	0.27	0.27
D 28	8.56	8.67	0.31	0.79
D -21 to 0	1.37	0.07	0.53	0.13
D 0 to 7	1.29	1.23	0.28	0.88
D 7 to 28	4.78	5.84	0.40	0.11
D 0 to 28	6.07	7.07	0.45	0.16
Total Change	7.44	7.14	0.45	0.65

[1] Titer values resulting in < 4 were assigned a value of 1 for data analysis. Before analysis the log of titer values were taken

[2] LOT = calves pre-weaned (21 d) in confinement before weaning; PAS = calves pre-weaned (21 d) on pasture before weaned in confinement

[3] IBR = infectious bovine rhinotracheitis; BVD = Bovine viral diarrhea virus

Disruptions in dietary and environmental familiarity can increase rates of morbidity. Morbidity increases when the immune system is unable to prevent illness, while an uncompromised immune system is able to fight infection and disease through antibody and white blood cell responses. Boyles et al. (2007) reported greater percentage of morbidity the first week in the feedlot as a result of confinement weaning compared to weaning calves at trucking and fence-line weaning 30 d before trucking (38% vs. 28% and 15%, respectively). Similarly, results of Bailey et al. (2016) demonstrate greater morbidity of confinement weaned calves during the 28 d postweaning period compared to supplemented and unsupplemented, fence-line weaned calves (5.16% vs. 1.97% and 0.65%, respectively); however, during the feedlot receiving period, both fence-line weaned groups had greater morbidity rates than confinement weaned (1.97% and 0.65% vs. 0%, respectively). These results suggest confinement weaned calves did not experience as many new stressors during feedlot entry compared to fence-line weaned calves. Additionally, researchers suggest acclimation to a similar environment allows weaned calves to overcome sickness more effectively than unacclimated calves and can reduce illness throughout the finishing period (Walker et al., 2007; Bailey et al., 2016).

Conclusion

Preweaning in confinement resulted in increased ADG prior to weaning and after weaning, suggesting adjusting calves to a similar diet and environment serves to acclimate animals. Neither weaning strategy resulted in sufficient stress to reduce immunological response to vaccination, indicating that stress levels were not sufficiently high to limit immunological function. Results of this study support the hypothesis that preweaning in confinement will increase performance during the pre- and postweaning periods. Replication of this study would be beneficial to follow the animals through receiving period and first week in a feedlot to witness long-term effects of preweaning in confinement on gain, feed conversion, and heath.

CHAPTER III

EFFECT OF TIMING OF GRAIN FEEDING ON ANIMAL PERFORMANCE, CARCASS CHARACTERISTICS, AND PROFITABILITY

Overview

A 104 d study was conducted to evaluate timing of grain feeding during stages of production on animal performance, carcass characteristics, and profitability. Twenty-one $^7/_8$ Angus × $^1/_8$ Nellore heifers (initial BW = 282 kg ± 67.2) were provided one of two diets 1) fiber (F; 65% chopped alfalfa, 35% dried distillers' grains) and 2) corn (C; 40% dry-rolled corn, 25% alfalfa hay, and 35% dried distillers' grains). Heifers were assigned to one of three feeding period treatments for 4 month intervals: 1) C from month 12 through 15 and F from month 16 through 23 (CFF); 2) F from month 12 through 15, C from month 16 through 19, and F from month 16 through 23 (FCF); 3) F from month 12 through 19 and C from month 20 through 23 (FFC). Treatment × period interactions ($P < 0.01$) were detected for ADG, feed intake, feed conversion (G:F), and BW ($P < 0.01$). During periods when cattle were fed grain, ADG was consistently greater as was G:F. Ultrasonic measurements for intramuscular fat (IMF), 12th-rib fat (RBFT), rump fat, IMF:RBFT, and IMF:rump fat did not differ between treatments ($P > 0.05$). Period effects were detected for ultrasonic measurements ($P < 0.01$) with IMF being significantly greater in period 3, the final period, than the other periods. Subcutaneous fat thickness, RBFT and rump fat, was greater as heifers advanced through the feeding periods. The ratios of IMF to subcutaneous fat decreased markedly in period 1 from initial and were not different after that time. Significant differences for carcass characteristics were not observed ($P \geq 0.17$), and all heifers graded Select or Choice. Feed costs and profitability were not significantly different between treatments ($P \geq 0.22$). Timing of grain feeding does not significantly affect animal performance, carcass characteristics, and profitability.

Introduction

Feeding grain-based diets to cattle increases available energy concentration of the diet and results in increased energy intake, ADG, feed efficiency, and fat deposition by . Increased ADG during finishing directly affects profitability by reducing days on feed (DOF) and increasing carcass gain, and indirectly based on its relationship to feed conversion (Meissner et al., 1995). Additionally, grain-based diets result in 10 to 30% greater marbling (intramuscular fat, IMF) compared to forage-based diets, resulting in improvement in quality grade and carcass value (Utley et al., 1975; Bennett et al., 1995; Berthiaume et al., 2006). However, increased IMF deposition is accompanied by increased fat deposition in other regions, including subcutaneous fat (Bowling et al., 1977; Anderson and Gleghorn, 2007; Albrecht et al., 2017). Excessive external fat at slaughter results in decreased profitability as a result of less retail product. Our objective was to evaluate ADG, intake, G:F, fat deposition, and profitability of heifers fed grain-based diets during different periods of growth. We hypothesize finishing heifers earlier in production will affect profitability by increasing feed conversions as they relate to intake and ADG. Additionally, feeding grain-based diets earlier in production will increase carcass value by increasing marbling, thus increasing profitability.

Materials and methods

Experimental procedures used in this trial were approved by the Agricultural Animal Care and Use Committee of Texas A&M AgriLife Research.

Twenty-one $^{7}/_{8}$ Angus × $^{1}/_{8}$ Nellore heifers (initial BW = 282 kg ± 67.2) originating from McGregor Research Center, McGregor, Texas were used to evaluate timing of grain feeding on growth performance, carcass quality, and profitability. Heifers were born between January 15 and February 22 (2018) and weaned at approximately 189 d of age. Heifers were vaccinated with killed viral vaccine during spring management (63 d of age) Covexin®8 and two killed viral vaccines at preweaning (169 d of age) Covexin®8 and Triangle®5, to aid in prevention of clostridial and respiratory diseases, respectively. Twenty-one days later at weaning heifer calves were vaccinated again with a modified-live viral vaccination (Titanium®5).

Heifers were stratified by BW, randomly assigned to one of three treatment groups (n=7), and fed at Texas A&M Research Center, McGregor, Texas. After treatments were assigned, heifers were placed in three pens (n = 7) with GrowSafe Systems® and fed a diet consisting of chopped alfalfa and dried distillers' grains for 84 d. Two diets were formulated: 1) fiber (F; 65% chopped alfalfa, 35% dried distillers' grains) and corn (C; 40% dry-rolled corn, 25% alfalfa hay, and 35% dried distillers' grains) and heifers were provided *ad libitum* access to a mineral/vitamin supplement (Table 5). Feeding periods were divided into 4 month periods creating three dietary regimes: 1) C from month 12 through 15 and F from month 16 through 23 (CFF); 2) F from month 12 through 15, C from month 16 through 19, and F from month 16 through 23 (FCF); 3) F from month 12 through 19 and C from month 20 through 23 (FFC). Heifers were fed diets C or F through GrowSafe Systems®, which measured individual intake each day. Heifers were weighed prior to feeding at 14-day intervals. Ultrasound measurement was conducted at 120-d intervals, corresponding with dietary changes, to provide an estimate of backfat thickness over the 12th- and 13th-rib, rump fat thickness, and intramuscular fat percentage (IMF). Ultrasonography was performed by an Ultrasound Guidelines Council field-certified technician, using an Aloka 500V instrument with a 17-cm 3.5-MHz transducer (Aloka Co. Ltd., Wallingford, CT). Images were collected and interpreted using Beef Image Analysis Pro software (Designer Genes, Inc., Harrison, AR). Ultrasound IMF was converted to marbling scores and quality grades based on a standard equation (Leblanc, personal communication).

Diet samples were analyzed by SDK Laboratories (Hutchinson, KS), and vitamin mineral premix was provided to each group *ad libitum* during each period. Cost of diet C and F were $198.80 and $222.80 per ton, and costs of NEg were $0.27 and $0.29/Mcal, respectively.

Table 5. Nutritive values and ingredient composition of diets fed during the growing and finishing phase

Nutritive Composition[1]	Ingredient composition	
Item	Concentrate	Forage
Dry-rolled corn, %	40	0
Chopped alfalfa, %	25	65
Dried distillers' grain, %	35	25
NE_m, Mcal/kg	1.89	1.56
NE_g, Mcal/kg	1.20	0.86
CP, %	17.86	20.89
Ca, %	0.34	0.82
P, %	0.56	0.55
NEg Cost, $/Mcal	0.27	0.29

*Premix was provided *ad libitum* and contained 19-21% Ca, 0.01% P, 0.20% K, 0.10% Mg, 19-21% NaCl, 450 ppm Cu, 2800 ppm Zn, 10 ppm Se, 100,000 IU/lb Vit. A, 9,000 IU/lb Vit. D3, 1600 IU/lb Vit. E.

[1] Analysis conducted by SDK Laboratories, Hutchinson, KS. 2019.

At the end of the feeding trial, heifers were transported 164.2 km to the Texas A&M University Rosenthal Meat Science & Technology Center (College Station, Texas). Prior to harvest, heifers were fasted for 18 h, and HCW was recorded after slaughter. Harvest was completed over a period of 4 days with an equal representation of treatment groups each day. Heifers were slaughtered by humane, industry standard procedures. After a 48-h chilling period at 4°C, carcasses were graded by Texas A&M personnel according to USDA grading standards (USDA, 1997). Fat thickness, *Longissimus* muscle area (LM), kidney, heart, and pelvic fat percentage (KPH), marbling score, lean maturity, and skeletal maturity, and quality grade were collected . Yield grades were calculated using the following formula:

$$YG = 2.5 + (2.5 \times \text{adjusted fat thickness}) + (0.2 \times KPH) + (0.0038 \times HCW) - (0.32 \times \text{ribeye area})$$

Animal purchase price was determined using Texas weekly weighted average price for base weights between 250 and 300 kg with medium and large framed feeder heifers weighing 227 to 295 kg from 01-06-2019 to 01-27-2019. A price slide (up and down) of \$0.22 per 100 kg, based on observed market prices, was used to establiush price for each heifer (USDA AMS, 2019). Corn and alfalfa prices were \$160 and \$220 per ton, respectively, in Texas during 2019 (USDA NASS, 2019). Actual delivered prices for dried distillers' grains (\$228 per ton) and trace mineral premix (\$820 per ton) were applied. A yardage cost of \$0.37 per heifer per day was applied. Freight from Texas AgriLife Research-McGregor Center (McGregor, TX) to Rosenthal Meat Science & Technology Center (College Station, TX), 164.2 km, was calculated using local commercial livestock rates, \$4.00 per mile per truck capacity, 22,727.7 kg. Carcass price was calculated using grid prices from 10-17-19 (USDA AMS, 2019). Quality and yield grades were used to determine carcass value using grid prices from USDA Beef Carcass Price Equivalent Index Value and carcass weights (642.4 kg ± 47.8). Carcass weights from Choice and Select carcasses ranging from 272.7 kg to 409.1 kg were used to derive base values of \$410.98 and \$355.34 per 100 kg, respectively. Carcasses below weight range resulted in a discount of \$17.64 per 100 kg. Carcasses with quality grades 400 and greater resulted in a \$5.21 premium. Yield grades of 1 and 2 resulted in premium of \$3.79/45.4 kg and \$1.70/45.4 kg, respectively. Marbling score was used to determine quality grade, and heifers with quality grades between 200-299, 300-399, and 400-499 were considered Low, Select, Low Choice, and Premium Choice, respectively.

Statistical analysis

Effects of treatment, period and their interaction were analyzed using MIXED procedures of SAS (SAS Inst. Inc., Cary, NC). Terms in the model included treatment, period, and treatment × period. The repeated term was period, with animal within treatment serving as the subject. Autoregressive was used for the covariance structure.. Treatment means were calculated using the LSMEANS option and the diff function was used to separate treatment means. Significance was determined at $P \leq 0.05$.

Results and discussion

There were treatment × period interactions ($P < 0.01$; Table 6) for BW, ADG, Intake, and G:F. Heifer BW increased in each period regardless of diet offered. In each period, ADG was greatest ($P < 0.05$) for heifers fed C versus F with the greatest gain (1.24 kg/d) being observed in period 2 when FCF heifers were provided C. Feeding grain- versus forage-based diets to cattle during finishing increased ADG by 20% to 50% (Oltjen et al., 1971; Utley et al., 1975; Bennett et al., 1995) as a result of grain-based diets providing more ME per kg than forage-based diets. Similarly, within period ADG was 17 - 46% greater when heifers were fed C versus F in the current project. Heifers subjected to FFC did not have significantly different (P = 0.29) ADG between periods 2 and 3 (0.98 and 1.02 kg/d, respectively), when diets F and C were fed. At the beginning of period 3 FFC heifers were 82 kg heavier than at the beginning of period 2, increasing the proportion of gain deposited as fat versus protein (NASEM, 2016). Fat deposition is energetically more efficient than lean deposition; however, BW gain per calorie is less with fat deposition than protein deposition because muscle is primarily water. Heifers on the FFC treatment consumed 11.8 kg/d in period 2 and 10.0 kg/d in period 3. Accordingly, FFC heifers in period 2 had 6.55 Mcal of NEg available each d and 7.18 Mcal of NEg available each d in period 3, which is less of a difference than anticipated. Finally period 3 occurred in July, August, and Septamber and cattle may have been attempting to manage heat load by reducing intake and potentially experienced heat stress which can increase maintenance energy requirements up to 18% (NASEM, 2016).

Intake was greatest ($P < 0.05$) during the grain feeding periods for CFF and FCF, while FFC heifers consumed the most during period 2 ($P < 0.05$), when F was fed. As metabolizable energy in the diet increases, the animal is able to meet its requirements for maintenance and genetic capability for growth with less feed, resulting in improved feed conversion (Brokken et al., 1976). Dinius et al. (1976) evaluated five diets ranging from 1.43 to 1.99 Mcal NEm/kg that were made by increasing the proportion of corn. Steers fed rations with the greatest energy concentration (1.85 and 1.99 Mcal NEm/kg) had the lowest DM intakes (6.18 and 6.00 kg/d, respectively). Rations consisting of 1.70, 1.54, and 1.42 Mcal NEm/kg had DM intakes of 7.34, 7.27, and 7.17 kg/d, respectively (Dinius et al., 1976). Thus, increasing available energy in a finishing ration results in more efficient gains. Accordingly, feed conversion was greater in each period when heifers were fed diet C. Grain-based diets result in 8 to 70% greater G:F than forage-based rations, during finishing when fed *ad libitum* (Oltjen et al., 1971; Utley et al., 1976; Meissner et al., 1995). In heifers fed C, G:F ranged from 25 – 33% greater than F.

Table 6. Influence of timing of grain feeding during the growing and finishing phase on animal performance[1]

	Treatment				*P*-value		
Item	CFF	FCF	FFC	SEM[2]	Diet	Period	Diet × Period
BW, kg				11.39	0.62	<0.01	<0.01
Initial	288^{a}	284^{a}	278^{a}				
Period 1	361^{b}	340^{b}	331^{b}				
Period 2	421^{c}	444^{c}	413^{c}				
Period 3	491^{d}	512^{d}	498^{d}				
ADG kg/d				0.07	0.03	<0.01	<0.01
Period 1	0.87^{ax}	0.67^{ay}	0.63^{ay}				
Period 2	0.71^{bx}	1.24^{by}	0.98^{bz}				
Period 3	0.83^{abx}	0.82^{abx}	1.02^{by}				
Intake, kg/d				0.43	0.40	<0.01	<0.01
Period 1	11.0^{a}	10.7^{a}	10.6^{a}				
Period 2	10.3^{bx}	12.0^{by}	11.8^{by}				
Period 3	10.1^{b}	10.1^{a}	10.0^{a}				
G:F				0.004	0.27	<0.01	<0.01
Period 1	0.08^{x}	0.06^{ay}	0.06^{ay}				
Period 2	0.07^{x}	0.10^{by}	0.08^{bz}				
Period 3	0.08^{x}	0.08^{cx}	0.10^{cy}				

[1] CFF = heifers fed diet C from 12-15 mo of age; FCF = heifers fed diet C from 16-19 mo of age; FFC = heifers fed diet C from 20-23 mo of age

[2] SEM = standard error of the mean

^{a,b,c} = means with different superscripts differ within column $P < 0.05$.

^{x,y,z} = means with different superscripts differ within row $P < 0.05$.

There were no significant treatment × period interactions or treatment effects for ($P \geq 0.10$; Table 7) ultrasonic measurements of intramuscular fat (IMF), 12th rib fat thickness (RBFT), or rump fat or for the ratio of IMF:RBFT and IMF:rump fat. There was a period effect ($P < 0.01$) for IMF, RBFT, and rump fat. Specifically, IMF was greater across dietary regimens at the end of period 3 than other periods, with the largest numerical gains in IMF occurring during period 3. In contrast, measures of subcutaneous fat generally increased demonstrating that cattle were getting fatter as they progressed throughout the feeding periods. There was a period effect ($P < 0.01$) for the ratio of IMF to subcutaneous fat (IMF:RBFT and IMF:rump fat) with initial values being greater for all three dietary regimens than at the conclusion of periods 1, 2, or 3, which were similar ($P > 0.05$). These results indicate that subcutaneous fat thickness tended to increase at a faster rate than IMF during periods 1 and 2 of the feeding trial ($P = 0.07$; data not shown).

Increases in cell number (hyperplasia) and cell size (hypertrophy) both occur as the animal matures, and adipose tissue mass is affected by hyperplasia and hypertrophy (Cianzo et al., 1985). The majority of accumulated fat is a result of hypertrophy of adipocytes (Robelin, 1986), which occurs during growing up to 19 mo of age (Cianzo et al., 1985). According to Hood and Allen (1973), hyperplasia of subcutaneous and perirenal adipose depots are complete by 8 months of age, and fat deposition occurs in subcutaneous tissue before intramuscular tissue (Pethick et al., 2004). Intramuscular adipose tissue deposition occurs as a result of both hyperplasia and hypertrophy, and cell hyperplasia occurs in IMF depots as early as 11 mo of age (Baik et al., 2017; Cianzo et al., 1985). In the current study, timing of grain feeding commenced when heifers were 12 months of age. Had timing of grain feeding started between 5 and 6 months of age, differences in ultrasound parameters may have been detected as a result of developing fat depots, and exposing animals to grain at a younger age may allow for earlier expression of fat deposition.

Table 7. Effect of timing of grain feeding on ultrasonic measurements during the growing and finishing phase[1]

	Treatment				*P*-value		
Item	CFF	FCF	FFC	SEM[2]	Diet	Period	Diet × Period
IMF, %				0.44	0.66	<0.01	0.21
Initial	2.8^{a}	2.9^{a}	2.9^{a}				
Period 1	3.0^{a}	2.7^{a}	2.6^{a}				
Period 2	3.4^{a}	3.4^{ab}	2.7^{a}				
Period 3	4.0^{b}	4.5^{c}	4.0^{b}				
12th rib fat, cm				0.05	0.31	<0.01	0.10
Initial	0.17^{a}	0.18^{a}	0.16^{a}				
Period 1	0.42^{bx}	0.38^{bxy}	0.32^{by}				
Period 2	0.46^{bxy}	0.54^{cx}	0.44^{cy}				
Period 3	0.57^{c}	0.56^{c}	0.55^{d}				
Rump fat, cm				0.03	0.52	<0.01	0.82
Initial	0.14^{a}	0.14^{a}	0.15^{a}				
Period 1	0.31^{b}	0.27^{b}	0.27^{b}				
Period 2	0.42^{c}	0.41^{c}	0.36^{c}				
Period 3	0.53^{d}	0.54^{d}	0.50^{d}				
IMF:12th rib fat				1.60	0.90	<0.01	0.81
Initial	16.5^{a}	18.4^{a}	17.9^{a}				
Period 1	7.4^{b}	7.6^{b}	8.3^{b}				
Period 2	7.5^{b}	6.3^{b}	6.2^{b}				
Period 3	7.3^{b}	8.0^{b}	7.6^{b}				
IMF:Rump fat				1.87	0.84	<0.01	0.99
Initial	21.3^{a}	22.6^{a}	19.6^{a}				
Period 1	10.0^{b}	10.5^{b}	9.7^{b}				
Period 2	8.5^{b}	8.1^{b}	7.6^{b}				
Period 3	8.2^{b}	8.4^{b}	8.5^{b}				

[1] CFF = heifers fed diet C from 12-15 mo of age; FCF = heifers fed diet C from 16-19 mo of age; FFC = heifers fed diet C from 20-23 mo of age

[2] SEM = standard error of the mean

[a,b,c] = means with different superscripts differ within column $P < 0.05$.

While grain-based diets increase IMF deposition, subcutaneous fat deposition is unavoidable with increased energy concentration in the diet and composition of growth associated with age. Degree of IMF relative to amount of external fat (rib fat/backfat) can be difficult to predict accurately at slaughter. While a high degree of IMF is desirable, excess subcutaneous fat lowers carcass yields and increases cost of gain (Schoonmaker et al., 2004; Sharman et al., 2013). Feeding grain-based diets increases IMF deposition because fermentation of starch increase the production and proportion of propionate and provides glucose for intestinal absorption increases blood glucose concentrations (Smith and Crouse, 1984). According to research by Smith and Crouse (1984) the lipogenic precursor glucose provided 50-75% of acetyl units for *in vitro* lipogenesis in intramuscular adipose tissue compared to 1-10% of acetyl units for subcutaneous adipose tissue. In contrast, fermentation of fiber results in a greater proportion of acetate, which is preferentially used by subcutaneous adipocytes. Acetate, provided 70-80% acetyl units for lipogenesis in subcutaneous adipose tissue while only10-20% acetyl units to lipogenesis in intramuscular adipose tissue (Smith and Crouse, 1984). Diet C was formulated to provide starch for lipogenesis, however, this did not translate into greater IMF accumulation during grain feeding, as measured by ultrasound.

Motivation behind grain-feeding to impact carcass characteristics stems from consumer perception of forage-finished beef resulting in decreased marbling, palatability, tenderness, and juiciness, and undesirable fat and lean color. In the current study HCW (642.4 kg ± 47.80), LM area (76.8 cm^2 ± 0.99), KPH (20% ± 0.01), dressing percentage (58.3% ± 1.17), and fat thickness (1.8 cm ± 0.16) at slaughter were not significantly different between the treatments ($P > 0.05$; Table 8). Significant differences due to treatment were also not detected for marbling score, yield grade, or quality grade ($P > 0.05$), and all animals graded Select or higher.

Table 8. Influence of timing of grain feeding during growing and finishing on carcass characteristics [1]

	Treatments				
Item	CFF	FCF	FFC	SEM[2]	*P*-value
HCW, kg	286	300	290	18	0.51
LM, cm^2	74.8	76.8	78.9	0.4	0.52
KPH, %	1.8	2.3	2.1	0.01	0.17
Dressing percentage, %	58	58	58	0.5	0.91
Skeletal maturity	62.9	69.6	61.4	3.5	0.32
Lean maturity	60.0	72.9	62.9	5.1	0.20
Fat thickness, cm	1.5	1.8	1.4	0.1	0.37
Marbling score[3]	361	384	373	23	0.78
Yield grade[4]	2.9	3.1	2.6	0.2	0.26
Quality grade					
% Premium Choice	14.3	42.9	28.6	-	-
% Low Choice	85.7	42.9	71.4	-	-
% Select	0.0	14.3	0.0	-	-

[1] CFF = heifers fed diet C from 12-15 mo of age; FCF = heifers fed diet C from 16-19 mo of age; FFC = heifers fed diet C from 20-23 mo of age

[2] SEM = standard error of the mean

[3] Marbling scores: 200-299 = Slight; 300-399 = Small; 400-500 Modest.

[4] Yield grade = 2.5 + (2.5 × adjusted fat thickness) + (0.2 × KPH) + (0.0038 × HCW) – (0.32 × ribeye area)

Composition of the diet has been shown to increase marbling score, and grain-finishing resulted in marbling scores 16% greater than forage-finishing (Utley et al., 1975). Similarly, Bennett et al. (1995) reported 20% higher marbling scores for carcasses from concentrate versus forage-finished cattle. Additionally, grain-finished carcasses result in 20 to 80% greater fat thickness than forage-finished carcasses (Oltjen et al., 1971; Utley et al., 1975; Bennett et al., 1995). The forage diet used in the current project contained 0.86 Mcal NEg/kg and had greater nutritive value than diets used in other studies. Additionally, the forage diet contained 3% more crude protein, which if digested and absorbed in the small intestine can provide precursors required for glucogenesis, which potentially masked differences in marbling accumulation. According to Krehbiel et al. (2006), increased RE as a result of increased metabolizable energy, is associated with increased proportion of fat in gain and slightly decreased proportion of protein in gain when grain diets are fed. However, some research indicates marbling does not differ between grain- and forage-based diets (Oltjen et al., 1971; Muir et al., 1998). Muir et al. (1998) reported no differences in intramuscular fat between pasture- and grain-finished cattle. According to these researchers, carcasses from cattle finished on pasture or forage can exhibit similar marbling scores to those of grain-fed cattle as long as they achieve growth rates similar to those observed in a feedlot (Muir et al., 1998).

No differences ($P \geq 0.22$; Table 9) were detected for an of the economic comparisons as a result of similar finishing costs and carcass values across the feeding regimens. Carcass prices ($403.67, $409.55, and $412.04 /100 kg) and carcass value ($1158.54, $1229.31, and $1198.24 per heifer) did not differ significantly between CFF, FCF, and FFC groups, respectively ($P > 0.05$). Heifers in groups CFF, FCF, and FFC had net losses of $490.00, $437.88, and $459.81, respectively, but losses were not significantly different between treatments ($P > 0.33$).

Table 9. Economic comparison of heifers provided a high-grain diet at different stages of production[1]

	Treatments				
Item	CFF	FCF	FFC	SEM[2]	*P*-value
Cost					
Initial price of calf, \$/100 kg[3]	295.26	296.49	300.74	2.24	0.22
Initial value of calf, \$/heifer	849.01	842.37	835.03	25.87	0.93
Feed cost, \$/head	666.75	691.65	690.11	14.31	0.41
Freight cost, \$/head	8.98	9.38	9.12	0.22	0.45
Yardage cost, \$/head	123.79	123.79	123.79	-	-
Revenue					
Carcass price, \$/100 kg	403.67	409.55	412.04	7.67	0.73
Carcass value, \$/heifer[4]	1158.54	1229.31	1198.24	81.08	0.62
Net Loss, \$/heifer	-490.00	-437.88	-459.81	50.83	0.33

[1] CFF = heifers fed diet C from 12-15 mo of age; FCF = heifers fed diet C from 16-19 mo of age; FFC = heifers fed diet C from 20-23 mo of age

[2] SEM = standard error of the mean

[3] Initial price of calf based on USDA Market Reports for Texas (2019).

[4] Carcass price based on USDA Beef Carcass Price Equivalent Index Value. Report NW-LS410. (October 17, 2019).

Conclusion

Timing of grain feeding during finishing did not affect overall performance; however, when concentrate was fed ADG and G:F was greater than in those fed forage. Similarly, timing of grain feeding did not significantly affect carcass traits nor profitability. Maturity of animals prior to the trial and similar NEg intake may have affected detectable differences in performance, ultrasonic measurements, and carcass traits.

CHAPTER IV

CONCLUSIONS

After weaning differences in performance such as decreased intake and ADG, accompanied with stress related behaviors are exhibited. Health outcomes associated with stress at weaning can further decrease performance and increase likeliness of morbidity. Results from the previous study (CHAPTER II) indicate preweaning in confinement as a management strategy positively impacts pre- and postweaning performance of calves. These results indicate acclimating calves to a similar environment and weaning diet reduce dietary and environmental stress after weaning, leading to greater performance outcomes. Adaptation to a similar environment and diet did not impact postweaning antibody responses; however, both calf treatments mounted antibody response, suggesting stress levels after weaning were not sufficiently high to limit immunological function. Replication of this study and following animals through the feedlot receiving period would be beneficial witness the long-term term effects of acclimation to a weaning diet and feedlot environment.

Grain feeding during finishing increases intake, ADG and G:F compared to forage finishing. By increasing the available energy in the diet these performance outcomes as well as fat deposition, intramuscularly and subcutaneously, increase. However, as animals reach physiological maturity rate of fat accretion increases rapidly, while rate of protein deposition increases at a decreasing rate, leading to inefficient gains. Feeding grain earlier in production may increase efficiency of finishing cattle; however timing of grain feeding in the previous study (CHAPTER III) did not affect overall performance, carcass characteristics, nor profitability. However, physiological maturity of cattle and similar NEg intakes between treatments in this study may have affected detectable differences in these parameters. Replication of this study utilizing cattle immediately after weaning would be beneficial to evaluate timing of grain feeding on feeder cattle efficiency.

LITERATURE CITED

Aberle, E.D., E.S. Reeves, M.D. Judge, R.E. Hunsley, and T.W. Perry. 1981. Palatability and muscle characteristics of cattle with controlled weight gain: time on a high energy diet. J. Anim. Sci. 52(4):757-763.

Aguiar, A.D., J.M.B. Vendramini, J.D. Arthington, L.E. Sollenberger, G. Caputti, J.M.D. Sanchez, O.F.R. Cunha, W.L. da Silva. 2015. Limited creep-feeding supplementation effects on performance of beef cows and calves grazing limpograss pastures. Livestock Science. 180:129-133.

Albrecht, E., L. Schering, Y. Liu, K. Komolka, C. Kühn, K. Wimmers, T. Gotoh, and S. Maak. 2017. TRIENNIAL GROWTH AND DEVELOPMENT SYMPOSIUM: Factors influencing bovine intramuscular adipose tissue development and cellularity. J. Anim. Sci. 95:2244-2254.

Anderson, P. and J. Gleghorn. 2007. Non-genetic factors that affect quality grade of fed cattle. In: Proc. Beef Improvement Fed. 39th Annu. Res. Symp. Annu. Meeting, Fort Collins, CO. p. 31-43.

Arthington, J.D., J.W. Spears, and D.C. Miller. 2005. The effect of early weaning on feedlot performance and measures of stress in beef calves. J. Anim. Sci. 83:933-939. doi: 10.2527/2005.834933x.

Arthington, J.D., X. Qiu, R.F. Cooke, J.M.B. Vendramini, D.B. Araujo, C.C. Chase Jr., and S.W. Coleman. 2008. Effects of preshipping management on measures of stress and performance of beef steers during feedlot receiving. J. Anim. Sci. 86:2016–2023. doi: 10.2527/jas.2008-0968.

Baik, M., H.J. Kang, S.J. Park, S.W. Na, M. Piao, S.Y., Kim, D.M. Fassah, and Y.S. Moon. 2017. TRIENNIAL GROWTH AND DEVELOPMENT SYMPOSIUM: Molecular mechanisms related to bovine intramuscular fat deposition in the longissimus muscle. J. Anim. Sci. 95(5): 2284-2303. doi: 10.2527/jas.2016.1160.

Bailey, E.A., PAS, J.R. Jaeger, PAS, J.W. Waggoner, PAS, G.W. Preedy, L.A., Pacheco, and K.C. Olson, PAS. 2016. Effect of fence-line or drylot weaning on the health and performance of beef calves during weaning, receiving, and finishing. Prof. Anim. Sci. 32: 220-228. doi: 10.15232/pas.2015-01456.

Bennett, L.L., A.C. Hammond, M.J. Williams, W.E. Kunkle, D.D. Johnson, R.L. Preston, and M.F. Miller. 1995. Performance, carcass yield, and carcass quality characteristics of steers finished on Rhizoma Peanut (*Arachis glabrata)* – tropical grass pasture or concentrate. J. Anim. Sci. 73:1881-1887.

Berthiaume, R., I. Mandell, L. Faucitano, and C. Lafreniere. 2006. Comparison of alternative beef production systems based on forage finishing or grain-forage diets with or without growth promotants: 1. Feedlot performance, carcass quality, and production costs. J. Anim. Sci. 84:2168-2177. doi: 10.2527/jas.2005-328.

Blanco, M. D. Villalba, G. Ripoll, H. Sauerwein, and I. Casasús. 2008. Effects of pre-weaning concentrate feeding on calf performance, carcass and meat quality of autumn-born bull calves weaned at 90 or 150 days of age. Animal. 2:779-789. doi: 10.1017/S1751731108001808.

Boardman, C.J., T.A. Wickersham, L.A. Trubenbach, and J.E. Sawyer. 2020. Effect of monensin inclusion and level of intake in limit-feeding strategies for beef cows. Transl. Anim. Sci. 4(3):1-12. doi:10.1093/tas/txaa108.

Bowling, R.A., G.C. Smith, Z.L. Carpenter, T.R. Dutson, and W.M. Oliver. 1977. Comparison of forage-finished and grain-finished beef carcasses. J. Anim. Sci. 45(2):209-215.

Boyles, S.L., PAS, S.C. Loerch, and G.D. Lowe. 2007. Effects of weaning management strategies on performance and health of calves during feedlot receiving. Prof. Anim. Sci. 23:637-641. doi: 10.15232/S1080-7446(15)31034-2.

Brokken, R.F., T.M. Hammonds, D.A. Dinius, and J. Valpey. 1976. Framework for economic analysis of grain versus harvested roughage for feedlot cattle. Amer. J. Agri. Econ. 58(2):245-258. doi: 10.2307/1238975.

Cianzio, D.S., D.G. Topel, G.B. Whitehurst, D.C. Beitz, and H.L. Self. 1985. Adipose tissue growth and cellularity: changes in bovine adipocyte size and number. J. Anim. Sci. 60(4):970-976.

Dinius, D.A., R.F. Brokken, K.P. Bovard, and T.S. Rumsey. 1976. Feed intake and carcass composition of Angus and Santa Gertrudis steers fed diets of varying energy concentration. J. Anim. Sci. 42(5):1089-1097.

Dinius, D.A., and H.R. Cross. 1978. Feedlot performance, carcass characteristics and meat palatability of steers fed concentrate for short-periods. J. Anim. Sci. 47(5):1109-1113.

Enriquez, D.H., R. Ungerfeld, G. Quintans, A.L. Guidoni, M.J. Hötzel. 2010. The effects of alternative weaning methods on behavior in beef calves. Livestock Science. 128:20-27. doi: 10.1016/j.livsci.2009.10.007.

Enriquez, D.H., M.J. Hötzel, and R. Ungerfeld. 2011. Minimizing the stress of weaning of beef calves: a review. Acta Veterinaria Scandinavica. 53:28. doi: 10.1186/1751-0147-53-28.

Fanning, M.D., D.K. Lunt, L.R. Sprott, and D.W. Forrest. 1995. Reproductive performance of synchronized beef cows as affected by inhibition of suckling with nose tags or temporary calf removal. Theriogenology. 44:715-723.

Feuz, D.M., S.W. Fausti, and J.J. Wagner. 1993. Analysis of the efficiency of four marketing methods for slaughter cattle. Agribusiness. 9(5):435-463.

Fishell, V.K., E.D. Aberle, M.D. Judge, and T.W. Perry. 1985. Palatability and muscle properties of beef as influenced by preslaughter growth rate. J. Anim. Sci. 61:151-157.

Griffin W.A., T.J. Klopfenstein, G.E. Erickson, D.M. Feuz, J.C. MacDonald, and D.J. Jordan. 2007. Comparison of performance and economics of a long-yearling and calf-fed system.

Haley, D.B., D.W. Bailey, and J.M. Stookey. 2005. The effects of weaning beef calves in two stages on their behavior and growth rate. J. Anim. Sci. 83:2205-2214. doi: 10.2527/2005.8392205x.

Hemphill, C.L. 2017. Effect of monensin and forage source on digestion and energy metabolism in limit-fed beef cows. Thesis, Texas A&M University, College Station.

Hickey, M.C., M.Drennan, and B. Earley. 2003. The effect of abrupt weaning of suckler calves on the plasma concentrations of cortisol, catecholamines, leukocytes, acute-phase proteins and in vitro interferon-gamma production. J. Anim. Sci. 81:2847-2855.

Hood and Allen. 1978. Lipogenesis in isolated intramuscular adipose tissue from four bovine muscles. J. Anim. Sci. 46(6): 1626-1633.

Krebs, L.B., A. Lloyd, and E.G. Brown. 2010. Influence of weaning strategy on growth and immunity in beef calves. J. Dairy. Sc. 93:317.

Kriebhel, C.R., J.J. Cranston, and M.P. McCurdy. 2006. An upper limit for caloric density of finishing diets. J. Anim. Sci. 84(E. Suppl.):E34-E49. doi: 10.2527/2006.8413_supplE34x.

Lambertz, C., A. Farke-Röver, and M. Gauly. 2015. Effects of sex and age on behavior and weight gain in beef calves after abrupt weaning. Animal Science Journal. 86:345-350. doi: 10.1111/asj.12285.

Latham, N.R., and G.J. Mason. 2008. Maternal deprivation and the development of stereotypic behavior. Applied Animal Behaviour Science. 110:84-108.

Lefcourt, A.M. and T.H. Elasser. 1995. Adrenal responses of Angus × Hereford cattle to stress of weaning. J. Anim. Sci. 73:2669-2676. doi: 10.2527/1995.7392669x.

Lippolis, K.D., J.K. Ahola, C.E. Mayo, M.C. Fischer, and R.J. Callan. 2016. Effects of two-stage weaning with nose flap devices applied to calves on cow body condition, calf performance, and calf humoral immune response. J. Anim. Sci. 94:816-823. doi: 10.2527/jas2015-9624.

López-Campos, O., J.L. Aalhus, E.K. Okine, V.S. Baron, and J.A. Basarab. 2013. Effects of calf- and yearling-fed beef production systems and growth promotants on production and profitability. Can. J. Anim. Sci. 93:171-184. doi: 10.4141/CJAS2012-035.

Lynch, E.M., B. Earley, M. McGee, and S. Doyle. 2010. Effect of abrupt weaning on leukocyte distribution, functional activity of neutrophils, and acute phase protein response of beef calves. BMC. Veterinary Research. 6(39):1-9.

Lynch, E.M., M. McGee, S. Doyle, and B. Earley. 2012. Effect of pre-weaning concentrate supplementation on peripheral distribution of leukocytes, functional activity of neutrophils, acute phase protein, and behavioral responses of abruptly weaned and housed beef calves. BMC Veterinary Research. 8(1):1-11.doi: 10.1186/1746-6148-8-1.

Martin, T.G., R.P. Lemenager, G. Srinivasan, and R. Alenda. 1981. Creep feed as a factor influencing performance of cows and calves. J. Anim. Sci. 53:33-39.

Meissner, H.H., M. Smuts, and R.J. Coertze. 1995. Characteristics and efficiency of fast-growing feedlot steers fed different dietary energy concentrations. J. Anim. Sci. 73:931-936.

Moriel, P. and J.D. Arthington. 2013. Effects of molasses-bassed creep-feeding supplementation on growth performance of pre- and post-weaned beef calves. Livestock Sci. 151:171-178. doi: 10.1016/j.livsci.2012.11.008.

Myers, S.E., D.B. Faulkner, F.A. Ireland, L.L. Berger, and D.F. Parrett. 1999. Production systems comparing early weaning to normal weaning with or without creep feeding for beef steers. J. Anim. Sci. 77:300-310. doi: 10.2527/1999.772300x.

Muir, P.D., N.B. Smith, G.J. Wallace, G.J. Cruickshank, and D.R. Smith. 1998. The effect of short-term grain feeding on liveweight gain and beef quality. New Zealand Journal of Agriculture Research. 41(4):517-526.

NRC. 2016. Nutrient Requirements of Beef Cattle. 8th rev. ed. National Academy Press, Washington, DC.

Oltjen, R.R., T.S. Rumsey, and P.A. Putnam. 1971. All-forage diets for finishing beef cattle. J. Anim. Sci. 32(2):327-333.

Price, E.O., J.E. Harris, R.E. Borgwardt, M.L. Sween, and J.M. Connor. 2003. Fenceline contact of beef calves with their dams at weaning reduces the negative effects of separation on behavior and growth rate. J. Anim. Sci. 81:116-121. doi: 10.2527/2003.811116x.

Pritchard, D.L., D.D. Hargrove, T.A. Olson, and T.T. Marshall. 1989. Effects of creep feeding, zeranol implants and breed type on beef cattle production. I. Calf and cow performance. J. Anim. Sci. 67:609-616. doi: 10.2527/jas1989.673617x.

Reynolds, C.K., H.F. Tyrell, and P.J. Reynolds. 1991. Effects of diet forage-to-concentrate ratio and intake on energy metabolism in growing beef heifers: whole body energy and nitrogen balance and visceral heat production. J. Nutr. 121:994-1003. doi: 10.1093/jn/121.7.994.

Robelin, J. 1986. Growth of adipose tissues in cattle; partitioning between depots, chemical composition and cellularity. A review. Livestock Production Sci. 14(4):349-364.

Ross, J. 2003. Diagnosis of natural exposure to bovine viral diarrhea in a vaccinated herd by measuring extended antibody titers against bovine viral diarrhea virus. Can. Vet. J. 44(1):59-61. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC340021/

Sayre, K., K. Lippolis, and C. Clark. 2019. Effects of combining nose flap weaning with short-term creep feeding of beef calves on cow and calf performance. *Iowa State University Research and Demonstration Farms Progress Reports 2018(1).*

Schoonmaker, J.P., M.J. Cecava, F.L. Fluharty, H.N. Zerby, and S.C. Loerch. 2004. Effect of source and amount of energy and rate of growth in the growing phase on performance and carcass characteristics of early- and normal-weaned steers. J. Anim. Sci. 82:273-282

Sharman, E.D., P.A. Lancaster, C.R. Krebiel, G.G. Hilton, D.R. Stein, U. DeSilva, and G.W. Horn. 2013. Effects of starch- vs. fiber-based energy supplements during winter grazing on partitioning of fat among depots and adipose tissue gene expression in growing cattle and final carcass characteristics. J. Anim. Sci. 91:2264-2277. doi: 10.2527/jas2012-5284.

Smith, S.B. and J.D. Crouse. 1984. Relative contributions of acetate, lactate, glucose to lipogenesis in bovine intramuscular and subcutaneous adipose tissue. J. Nutr. 114(4):792-800. doi: 10.1093/jn/114.4.792.

Smith, D.L., D.L. Wiggers, L.L. Wilson, J.W. Comerford, H.W. Harpster, and E. H. Cash. 2003. Postweaning behavior and growth performance of early and conventionally weaned beef calves. Prof. Anim. Sci. 19:23-29. doi: 10.15232/S1080-7446(15)31370-X.

Solano, J., A. Orihuela, C.S. Galina, V. Aguirre. 2007. A note on behavioral responses to brief cow-calf separation and reunion in cattle (*Bos indicus)*. Journal of Veterinary Behavior. 2:10-14.

Stookey, J.M., K.S. Schwartzkopf-Genswein, C.S. Waltz, and J.M. Watts. 1997. Effects of remote and contact weaning on behavior and weight gain of beef calves. J. Anim. Sci. 75(Suppl. 1):83.(Abstr.).

Strachan, D.B., A. Yang, and R.D. Dillon. 1993. Effect of grain feeding on fat colour and other carcass characteristics in previously grass-fed *Bos indicus* steers. Aust. J. Exp. Ag. 33:269-273.

Trubenbach, L.A., T.A. Wickersham, L.N. Bierschwale, J.C. Morrill, J.R. Baber, and J.E. Sawyer. 2019. Limit feeding as a strategy to increase energy efficiency in intensified cow-calf production systems. doi: 10.1093/tas/txz039.

Utley, P.R., R.E. Hellwig, and W.C. McCormick. 1975. Finishing beef cattle for slaughter on all-forage diets. J. Anim. Sci. 40(6):1034-1038.

United States Department of Agriculture. Agriculture Marketing Service. https://marketnews.usda.gov/mnp/ls-report-config. (Accessed 1 September 2020).

Walker, K.H., L.R. Fell, L.A. Reddacliff, R.J. Kilgour, J.R. House, S.C. Wilson, and P.J. Nicholls. 2007. Effects of yard weaning and training on the behavioural adaptation of cattle to a feedlot. Livestock Sci. 106:210-217. doi: 10.1016/j.livsci.2006.08.004.

Watts, J.M., and J.M. Stookey. 2000. Vocal behaviour in cattle: the animal’s commentary on its biological processes and welfare. 67:15-33.

Weary, D.M., J. Jasper, and M.J. Hötzel. 2008. Understanding weaning distress. Applied Animal Behaviour Science. 110:24-41.

APPENDIX A

Table 10. Influence of timing of grain feeding on change in ultrasonic measurements

	Treatment				*P*-value
Item	CFF	FCF	FFC	SEM[2]	Grain feeding
IMF					
Period 0 to 1	0.22	-0.31	-0.31	0.25	0.21
Period 1 to 2	0.37	0.68	0.12	0.22	0.24
Period 2 to 3	0.52	1.10	1.27	0.32	0.24
12th rib fat, cm					
Period 0 to 1	0.25	0.20	0.16	0.03	0.10
Period 1 to 2	0.04	0.14	0.12	0.03	0.07
Period 2 to 3	0.12	0.02	0.11	0.05	0.22
Rump fat					
Period 0 to 1	0.16	0.13	0.11	0.02	0.37
Period 1 to 2	0.10	0.15	0.10	0.03	0.40
Period 2 to 3	-0.02	0.10	0.06	0.09	0.63

[1] CFF = heifers fed diet C from 12-15 mo of age; FCF = heifers fed diet C from 16-19 mo of age; FFC = heifers fed diet C from 20-23 mo of age

[2] SEM = standard error of the mean