

WEANING AGE AND SOURCE OF ENERGY INFLUENCE BEEF CATTLE
PERFORMANCE, CARCASS CHARACTERISTICS, AND ECONOMICS

BY

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THESIS

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ABSTRACT

WEANING AGE AND SOURCE OF ENERGY INFLUENCE BEEF CATTLE PERFORMANCE, CARCASS CHARACTERISTICS, AND ECONOMICS

Angus and Angus x Simmental calves (n=200) were randomly allotted to one of five dietary treatments at two locations: Early Wean Starch Diet (EWS), Early Wean Fiber Diet (EWF), Creep Fed Starch Diet (CFS), Creep Fed Fiber Diet (CFF), or Control (CON). Control calves were normal weaned and received no supplemental feed while they grazed with their dams. The diets fed to early-weaned and creep-fed cattle were formulated to be isonitrogenous. Early-weaned calves (133±21 days of age) were placed in the feedlot, while normal-weaned calves remained with their dams on pasture (2 or 3 replications per location). Creep feed was offered ad-libitum to CFS and CFF. After a 100 d treatment phase, calves were placed in the feedlot on a common diet. GrowSafe® was used to measure individual intake of all calves in the feedlot. In the treatment phase, early-weaned gained more than creep-fed (1.6 vs. 1.5 kg, $P < 0.01$), and creep-fed gained more than control calves (1.5 vs. 1.2 kg, $P < 0.01$). EWS had 15% lower intakes and were 13% more efficient than EWF ($P < 0.01$). In the finishing phase, creep-fed calves gained 9% more, had 7% lower intakes, and were 16% more efficient ($P < 0.01$) than early-weaned calves. CON were 5% more efficient and spent 19 more d on feed ($P < 0.01$) than the other treatments. Backfat was lower for the CON (1.2 vs. 1.1 cm, $P = 0.02$). Marbling score was higher for early-weaned cattle when compared to creep-fed cattle (586 vs. 500) and lower for the CON (476 vs. 543) than all other treatments ($P < 0.01$). Marbling score did not differ significantly when comparing source of energy. Economic analysis of marketing cattle as feeder calves post-treatment showed profit was 17% higher for EWF than EWS ($P = 0.06$), 14% higher for CFF than CFS ($P = 0.06$), 24% higher for creep-fed than early-weaned ($P < 0.01$), and 23%

higher for CON than the remaining treatments ($P < 0.01$). Economics analysis of a retained-ownership showed profit was 31% higher for EWF than EWS ($P = 0.03$), 32% higher for creep-fed calves than early-weaned calves ($P < 0.01$), and 22% higher for CON ($P < 0.01$). Early weaning and creep feeding will increase carcass quality and growing phase gains, but reduce profit in this study. Co-product feeds, due to higher fat levels, could initiate marbling similar to that of starch based diets in young beef calves.

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TABLE OF CONTENTS

List of Tables	vii
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Chapter 1

Literature Review	1
CREEP FEEDING	1
Calf Performance and Carcass Traits.....	1
Cow Performance and Reproduction	7
Subsequent Performance of Replacement Heifers.....	8
Reduction of Calf Forage Intake and Decreased Fiber Digestibility.....	10
EARLY WEANING	12
Calf Performance and Carcass Traits.....	12
Cow Performance and Reproduction	17
Reduction in Intake/ Increased Stocking Rates	22
Subsequent Performance of Replacement Heifers.....	23
SOURCE OF ENERGY	24
Volatile Fatty Acid Concentration an Ruminant pH.....	24
Insulin and Insulin sensitivity	27
Cattle Performance and Carcass Traits	28
SUMMARY	31
LITERATURE CITED	32

Chapter 2

WEANING AGE AND SOURCE OF ENERGY INFLUENCE BEEF CATTLE PERFORMANCE, CARCASS CHARACTERISTICS, AND ECONOMICS

.....	41
ABSTRACT	41
INTRODUCTION.....	42
MATERIALS AND METHODS.....	43
Experimental Animals.....	43
Experimental Design.....	43
Management and Diets.....	43
Performance Data Collection	45
Carcass Data Collection.....	46
Economic Analysis.....	46

Statistical Analysis	47
RESULTS AND DISCUSSION	48
Live Animal Performance	48
Carcass Evaluation	50
Economics	53
IMPLICATIONS	56
TABLES	57
LITERATURE CITED	64

LIST OF TABLES

CHAPTER 2

TABLE 1	Composition of early-weaned diets on a dry matter percentage basis	57
TABLE 2	Composition of creep feeds on a dry matter percentage basis	57
TABLE 3	Composition of finishing diet on a dry matter percentage basis	57
TABLE 4	Composition of growing phase supplements on a dry matter basis	57
TABLE 5	Composition of finishing phase supplements for steers and heifers	58
TABLE 6	Five-year average grid premiums and discounts	58
TABLE 7	Effects of weaning age and source of energy on calf performance.....	59
TABLE 8	Effects of weaning age and source of energy on feedlot performance.....	60
TABLE 9	Effects of weaning age and source of energy on beef cattle carcass traits.	61
TABLE 10	Effects of weaning age and source of energy on feeder calf economics....	62
TABLE 11	Effects of weaning age and source of energy on retained ownership economics	63

Chapter I

Literature Review

Creep Feeding

Increasing profit is the ultimate goal of nearly any business, and the cattle business is no exception. In an effort to maximize profit, cattlemen have focused on producing the greatest amount of high quality product without sacrificing production efficiency. The ability to produce more pounds of a high quality product results in more income for the beef producer. Realizing the cow can only provide nutrition to the calf at a certain level, creep feeding can offer additional nutrition to maximize growth and weight in beef calves. Early research was focused on the effects of post-weaning nutrition on performance and carcass characteristics of beef cattle. Pre-weaning nutrition began to draw more interest in the 1960's. The original creep feeding trials were focused on increasing weaning weights of beef calves. However, it was later realized that creep feeding had effects on carcass characteristics, post-weaning performance, fiber digestion, as well as cow performance, reproduction, and stocking rate. More recent research has also shown creep feeding has an effect on replacement heifer performance and reproduction. Also, type of creep feed can result in different performance and carcass traits in beef calves.

Calf Performance and Carcass Characteristics

Bray (1934) conducted a trial to explore the effect of creep feeding and length of creep feeding on calf performance. There were three treatments: creep fed, 133 days; creep fed, 70 days; pasture only. All treatments remained with their dams for the duration of the trial. Calves that were creep fed for 133 days had the highest ADG and the 70 day creep treatment gained more than the control (0.81 kg/d vs. 0.74 kg/d vs. 0.58 kg/d). The 70 day creep treatment did

have lower daily intakes when compared to the 133 day creep (1.5 kg/d vs. 1.68 kg/d). No carcass characteristics were measured or collected.

Scarth et al. (1968) utilized fifty three crossbred calves (Hereford x Angus-Holstein or Charolais x Angus-Holstein) to determine the effects of creep feeding on rate of gain and carcass composition. Creep-fed calves were compared to non-creep-fed calves during a 175 day period. Creep-fed cattle exhibited higher gains (174 kg vs. 133 kg) during the 175 day creep period. Even though the creep-fed calves entered the feedlot at heavier weights, they still had more feedlot gain (1.06 kg vs. 0.90 kg). As a result, creep-fed calves had heavier carcass weights (265 kg vs. 206 kg) and spent fewer days in the feedlot (95 vs. 168) than non-creep-fed calves.

Stuedemann et al. (1968) performed a creep feeding study to evaluate differing levels of nutrition imposed from birth to eight months of age. They utilized sixty Hereford steers and subjected them to five different levels of nutrition. At eight months of age, half of the calves were slaughtered and half entered the feedlot. Those cattle entering the feedlot received a common, Milo-based finishing ration. Those cattle were then harvested once they met a target finished weight (430 kg). Calves on the highest plain of nutrition exhibited higher gains (0.89 kg vs. 0.66 kg) than those on the lowest plain of nutrition during the eight month creep feeding phase. Gains in the feedlot did not differ. Calves on the highest level of nutrition had higher carcass weights (137.1 kg vs. 88.2 kg), dressing percents (56.7% vs. 46.1%), conformation scores (15.8 vs. 12.2), and marbling scores (8.3 vs. 5.0) than calves on the lowest level of nutrition. No differences in carcass traits were seen when the cattle were harvested at a constant weight. This could be due to the fact that the cattle on the lower levels of nutrition would have needed to be on feed longer in the finishing phase to reach the target weight. May et al. (1992)

and Duckett et al. (1993) showed increasing days on a high energy diet resulted in higher quality grades and marbling scores.

Garrigus et al. (1969) studied the effects of a 140 day creep prior to weaning on Angus bulls. Creep feeding had no effect on post-weaning gains, thus implying that no compensatory gain was seen by non-creep-fed cattle. In one year of this two year trial, creep-fed bulls had higher marbling scores (4.3 vs. 3.6) although it should be noted that the non-creep-fed cattle had larger rib-eye area (71.0 cm vs. 66.4 cm). In both years subcutaneous fat and carcass grade did not differ.

Anderson et al. (1978) evaluated creep feeding effects on weaning weight and post-weaning performance. They utilized calves sired by Angus, Holstein, Simmental, and Chianina sires. An interaction was detected between creep feeding and breed. No differences were observed for Angus or Holstein sired calves in terms of weaning weights, however Simmental and Chianina sired calves had higher (21.5% and 15.6% respectively) weaning weights than the non-creep-fed calves of the continental sires. This suggests that continental breed sired calves may need supplemental nutrition during the suckling phase to take advantage of higher pre-weaning growth potential (Anderson et al., 1978). Creep-fed calves spent fewer days in the feedlot, but no other differences were seen in feedlot performance.

Deutscher and Slyter (1978) conducted a study to compare calf production from ninety Angus-Hereford crossbred cows in a drylot or pasture management system. Treatments were: drylot cow/calf pairs, drylot cow/calf pairs with creep feed, and pasture cow/calf pairs with no creep. The drylot creep calves exhibited higher weaning weights (198 kg) than drylot calves with no creep (153 kg). The pasture calves had the highest weaning weight (208 kg), however they only differed from the drylot calves with no creep. Post-weaning the calves were placed

into the feedlot where they were stepped up to a seventy-five percent concentrate ration and harvested at a point when the group was determined to have reached 70% USDA choice cattle. Although feedlot ADG did not differ, pasture cattle (424 kg) ended heavier than drylot creep-fed cattle (403 kg) and drylot non-creep-fed cattle (353 kg). Pasture calves carcass weight was different than both drylot treatments. Although the drylot creep-fed calves had 15.8% less fat thickness, they had higher marbling scores (5.26 vs. 4.85) and carcass grades (19.0 vs. 18.5) than pasture calves.

Stricker et al. (1979) grazed Hereford spring-calving cows on fescue-ladino clover pasture for four consecutive years. A 180d creep feeding period was applied to the system. In 1973, creep-fed calves failed to learn to eat creep feed resulting in little intake of creep. However, creep-fed calves born in 1972, 1974, and 1975 proved to have 32.3 kg heavier observed and 30.6 kg heavier adjusted weaning weights.

Martin et al. (1981) performed a 21-year study to evaluate the effects of creep feeding on performance of male and female calves as well as subsequent cow productivity. The study utilized 831 Angus calves. Creep feeding increased 210 day weights by 8.7% when contrasted with no creep (188 kg vs. 173 kg). In males, creep feeding increased yearling weight by 18 kg, however in females it decreased yearling weights by 7 kg.

Prichard et al. (1989a) compared long term (LC) creep feeding (154 d), short term (SC) creep feeding (64 d), and no creep (NC) feeding. Creep feeding (both LC and SC) increased 210 d weights by 12.8% and the LC and SC calves had higher ($P < 0.01$) ADG from 146 to 210 d of age when compared to NC calves. The SC calves tended to gain faster from 146 to 210 d of age than LC calves. The author suggested this is likely due to a compensatory response (Pritchard et al. 1989a).

Faulkner et al. (1994) conducted an 84 d creep feeding study where they compared no creep feed, limited intake of corn (1kg/d), unlimited intake of corn, limited intake of soyhulls (1kg/d), and unlimited intake of soyhulls. To this point most creep feeds consisted of a high concentrate diet. This study utilized concentrate and fiber based feeds for creep feed. Concentrate creep feeds had resulted in poor supplemental feed efficiencies. This study looked at the effects of limit feeding and source of nutrition on supplemental feed efficiencies. Calves fed the limited amount of creep feed gained 39.4% higher and ended 8.5% heavier than the control. Calves fed the unlimited amount of creep feed gained 13% higher and ended 5.7% heavier than the limited cattle. There was no difference in supplemental feed efficiencies between levels or source of creep feed. When the cattle were evaluated in the finishing phase, control calves experienced increased gains (1.35 kg/d vs. 1.20 kg/d) and better efficiency (G/F) (.16 vs. .13) when compared to limited and unlimited calves. However, there were no differences in intake, gain, or efficiency when the growing and finishing periods were combined. There was a linear effect for increasing quality grade as creep feed increased from control to unlimited. Fat thickness tended to increase linearly with increasing level of creep feed. All other carcass characteristics resulted in insignificant differences.

Tarr et al. (1994) conducted a 2-year study to evaluate creep feeding during the last 84, 56, or 28 days prior to weaning on calf performance. There were significant year x treatment interactions for performance and carcass characteristics. In year 1, during all periods and overall time on creep increased there was linear increase in weight gain. Intake exhibited a linear relationship as time on creep increased. Also, supplemental G:F increased linearly as time on creep feed increased. In year 2, weight gain again showed a linear increase as time on creep feed increased. However, no differences were seen in intake or efficiency. As time on creep feed

increased, fat thickness tended to increase linearly in year 1, but increased quadratically in year 2. In year 1, the cattle that received zero days on creep feed exhibited compensatory gain in the feedlot, and gained 12% higher than the calves offered creep feed. In year 2, the creep-fed cattle came into the feedlot at heavier weights (237.4 kg vs. 206.7 kg). However, there was no difference in gain. There was a quadratic response for G:F with the calves creep fed 28 and 56 days being more efficient than the 0 and 84 day treatments. In both years there were no differences in carcass characteristics. The author implied that creep feeding for 28 days had no benefit.

Myers et al. (1999a) in 2 years, compared calves creep fed with grain for 55 d while on pasture nursing their dam (NWC) to calves receiving no creep feed while nursing their dam (NW). All cattle were placed on a finishing diet as soon as they were removed from the cow. In year 1, during the treatment phase, NWC calves exhibited 32% higher gains during the treatment phase (177-231 d of age). Also, NWC calves tended to gain higher than NW calves when the treatment and finishing phases were combined. No difference was observed in intake and efficiency. In year 2, NWC gained 36% more in the treatment phase and 7.6% more for the overall period. NWC also had 0.3 kg/d higher intakes and spent 17 fewer days in the feedlot than NW calves. No differences were observed in carcass quality in either year. The authors did report that NWC steers had an 84% decrease in respiratory morbidity when contrasted with NW calves.

Shike et al. (2007) utilized 168 Angus x Simmental steers to evaluate creep feeding on calf performance and carcass characteristics. Creep-fed cattle had 21% higher gains and 5.8% higher gains in the finishing phase than non-creep-fed cattle. Over the entire trial, creep-fed cattle had 9.7% higher gains, were more efficient (0.181 vs. 0.175), and spent 11 fewer days in

the feedlot than non-creep-fed cattle. Creep-fed calves had 18.5 kg heavier carcass weights, 4% larger rib-eyes, but no other carcass traits were significantly different.

Cow Performance and Reproduction

Original creep feeding efforts were designed to increase weaning weights of calves. However, it did not take long before other effects such as cow performance and reproductive efficiency were considered. The importance of calf weaning weights to the cow calf producer in terms of immediate return are well documented, however an effect on cow performance could be a long term factor in profitability. Effects of creep feeding on the cow have been studied, but results have been mixed. The amount and quality of forage available seems to be a large determining factor on the effectiveness of creep feeding on cow performance and reproduction.

Stricker et al. (1979), in a 4 year study, grazed cows on fescue-ladino pastures where the effects of creep feeding were evaluated. During an 84 day breeding season, 74% of cows with creep-fed calves conceived, where as 54.8% of cows with non-creep-fed calves conceived. Data for 1972 was not used due to later rotation and breeding season. The author did report that stale feed was removed and discarded on the ground where cows could have consumed it. This may have played a role in the cow reproduction response. Randel (1990) looked at postpartum energy status and rebreeding performance on cows after calving. Pregnancy rates were affected by postpartum energy intake. Cows at an adequate energy level exhibited pregnancy rates of 87 to 95%, where as cows with restricted energy intake had 50 to 76% pregnancy rates. However, Stricker et al. observed no differences in breeding period ADG. The author concluded that the difference in reproduction was unexplained.

Prichard et al. (1989a) evaluated the effects of long term (LC) creep feeding (154 d), short term (SC) creep feeding (64 d), and no creep (NC) feeding. Cows with LC calves tended to

have higher gains and had higher condition scores than the cows with NC calves during the breeding period. Although cows with LC calves had higher gains and higher condition score, there was no difference in pregnancy rate due to creep feeding treatments. The author did note that condition scoring is a subjective measure, and the cows did not differ in condition score at the time of weaning.

Tarr et al. (1994) conducted a 2-year study to evaluate creep feeding during the last 84, 56, or 28 days prior to weaning on cow performance. In both years, no differences were reported in cow weight or body condition score due to different length of creep feeding period. The study did not evaluate pregnancy rate, first service conception rates, or calving rate. This is likely due to the fact that breeding season would have already been over when the calves were offered creep. The calves were not started on creep until an average of 124 days of age.

Subsequent Performance of Replacement Heifers

Creep feed, in most cases, is offered to the entire calf crop. This would include potential replacement heifers, bull calves, and cull progeny. Although cull progeny will likely be sold at weaning and fed out in a feedlot, replacement cattle will remain in the herd for future production. The effect of creep feeding on replacement heifers has been evaluated. Level of nutrition during the prepubertal mammary development period effects future milk production (Sejrsen et al., 1982). This negative effect of creep feeding on replacement beef heifers is well reported.

Holloway and Totusek (1973) conducted a study that compared early weaning at 140 days, weaning at 240 days, and creep feeding then weaning at 240 days. Daily milk production of creep-fed heifers was recorded. In two of three years, creep-fed females yielded the least amount of daily milk production.

Martin et al. (1981), in a 21-year study, evaluated the effects of creep feeding on performance of male and female calves as well as subsequent cow productivity. Creep-fed heifers, as cows, produced 0.34 fewer weaned calves per cow, had 0.6 kg lower calf birth weights, 2.5 kg lower 120-day calf weights, 3.9 kg lower 210-day calf weights, and poorer lifetime productivity. Creep-fed cows did not wean heavier calves at any age during the 21 year study. The author suggested that if creep feeding was to be used, it should only be offered to males and cull progeny that will enter the feedlot, not replacement heifers.

Hixon et al. (1982) utilized 32 purebred heifer calves (16 Angus and 16 Hereford) that were creep fed for 90 days at approximately 115 days of age. The effect of creep feeding on performance and lactation of heifers was analyzed. No differences were seen for gestation length, cow weight at calving, cow weight at 120 days postpartum and postpartum interval. However, there was a decrease in 120 d milk yield for creep-fed heifers (3.5 kg vs. 4.5 kg).

Prichard et al. (1989b) studied the effects of creep feeding on reproductive development of heifer calves. Creep feeding did not affect reproductive tract development. No differences were seen in ovarian weight, ovarian size, uterine horn diameter, or follicle number in heifers at weaning. Also, creep feeding did not increase udder weight, lipid percentage in the udder or total lipid in the udder. However, LC heifers had 8.7% larger udder adipocytes than NC heifers. LC and SC heifers tended to have a higher percentage of total adipocytes volume made up of adipocytes greater than 160 μm in diameter than that of NC heifers.

Buskirk et al. (1996) conducted a study that looked at the effects of creep feeding heifers for 112 days on carry over performance as primiparous heifers. Creep-fed heifers had 20% lower milk production than non-creep-fed heifers. Calves of creep-fed heifers weighed 16 kg less than heifers that were not creep-fed at weaning.

Sexton (2004) offered creep feed to heifers for 84 days prior to weaning. Creep feeding resulted in increased heifer performance by 0.29 kg/d. Creep feeding also increased BCS at the time of breeding (5.75 vs. 5.5). Although the non-creep fed heifers had a numerical increase in pregnancy rate, there were no statistical differences in reproductive performance in the heifers. A statistical difference in reproduction could have been hard to detect with only 102 heifers on study. Milk production was also measured using a 12 hour weigh-suckle-weigh technique. Creep fed heifers had lower milk production at 52, 108, and 164 days postpartum. Creep feeding decreased total milk yield by 22%.

Reduction of Calf Forage Intake and Decreased Fiber Digestibility

Cremin et al. (1991) conducted a study with grazing nursing calves to determine the effects of limiting creep feed intake and increasing ruminal escape protein in creep feed on forage and milk intake, ruminal NDF digestion, and total tract digestibility. The treatments were: no creep (control), limited intake of moderate CP (13%) concentration creep feed (limited MP), limited intake of high CP (35%) concentration creep feed (limited HP), and unlimited intake of the moderate CP (13%) concentration creep feed (unlimited). The unlimited calves had lower ruminal pH (5.9 vs. 6.2) and this suggests poorer fiber digestibility. In the in situ study, fescue disappearance was lower for control cattle and less fescue disappeared in the unlimited cattle than the limited creep feed treatments. This all suggests a decrease in ruminal fiber digestibility, but no difference was seen in total tract NDF digestibility. Creep feed had no correlation to milk intake, however a negative correlation ($r = -.995$) between level of creep feed OM intake and fescue OM intake suggests that creep feeding decreases forage consumed by suckling calves.

Tarr et al. (1994) performed a digestion study in which differing levels of creep were fed to four ruminally cannulated steers in a 4x4 latin square design. The treatments were no creep or forage alone (C), low creep (L; .68 kg/d), moderate creep (M; 1.13 kg/d), or high creep (H; 2.27 kg/d). All cattle had free-choice access to high-quality forage. A trend was observed for forage OM intake to decrease as level of OM of creep feed increased. As creep intake was increased from low to moderate and then moderate to high, forage OM intake decreased 32% and 64% respectively. The researchers also showed that as creep feed increased pH decreased linearly. Also, as creep feed increased molar proportions of propionate increase and acetate decreased. As a result, the acetate:propionate ratio tended to decrease and is typical as concentrate increases in the diet.

Faulkner et al. (1994) conducted a digestibility study to evaluate different levels and sources of supplementation. Corn creep was compared to soyhull creep along with different levels. Level of supplementation did not affect NDF or ADF digestibility. However, source of energy (corn vs. soyhulls) had an effect; the soyhull creep resulted in higher digestibility of NDF, ADF, and CP fractions.

Soto-Navarro et al. (2004) like Faulkner et al. (1994) evaluated a fiber-based creep feed. A creep feed based on highly digestible fiber which consisted primarily of soyhulls and wheat middlings was used. All calves were cannulated and all pairs were given ad libitum access to brome hay. Supplementing calves with this fiber-based creep increased total tract OM digestibility when compared to non-supplemented calves (72.1 vs. 64.6). This fiber-based supplement had no effect on microbial efficiency (grams microbial N/kg OM truly fermented).

Early Weaning

Maddox (1965) suggested that by the time a calf reaches 120 days of age, more than half or the calf's energy requirement comes from sources other than milk. In spring calving herds, grass quality is declining at a corresponding time to when milk production levels off and calves are in need of other sources of nutrition. Boggs et al. (1980) showed that milk intake of calves declined 93% from April to August (6.14 kg/d vs. 3.18 kg/d). This could result in calves eating forage to compensate for the gap in nutrition, which can take available forage away from the cow. If the calf is not receiving more nutrition from milk or pasture, then another source of energy is the only choice. Other choices are creep feeding and early weaning. Many trials have been conducted to evaluate the effects of early weaning and accelerated finishing systems on calf performance and carcass traits, cow performance and reproduction, stocking rates, and replacement heifer performance.

Calf Performance and Carcass Traits

Harvey et al. (1975) conducted an experiment with 216 Angus calves to evaluate the effects of early weaning calves and feeding a concentrate diet. During the grazing phase, early-weaned cattle gained 51% more, however in the finishing phase the normal-weaned cattle had 9% higher gains. No differences were seen in carcass characteristics besides early weaned calves had lower kidney and heart fat. Early weaned calves tended to have higher marbling scores (16 vs. 14.1) and fat thickness (0.87 cm vs. 0.78 cm) when compared to normal weaned calves.

Richardson et al. (1978) compared weaning calves at 120 and 210 days. Calves weaned at 120 days had higher 210-day adjusted weights (205.6 kg vs. 195.5 kg). However, calves weaned at 210 days exhibited higher post-weaning gains (78.7 kg vs. 67.7 kg). Only heifers

were evaluated past 210 days. In every year of a six year trial, heifers weaned at 210 days had higher gains during the post 210 day period. Thus, yearling weights on the 120 day weaned heifers and the 210 day weaned heifers were not different.

Neville and McCormick (1981) early weaned calves at 67 days of age, fed them a high concentrate diet in the drylot (EWD) or pasture (EWP) until 230 days of age. The early weaned calves were compared with normal weaned calves (NW) that remained nursing their dams until 230 days of age. The EWD calves gained higher than EWP calves, and EWP calves had higher gains than NW calves. Lusby et al. (1981) also reported that early weaned calves in the drylot posted higher gains than those on pasture (169.8 kg vs. 149.8 kg). The author suggested that the early weaned cattle on this study may have needed higher quality forage to achieve potential gain.

Loy et al. (1999) conducted a trial to compare weaning ages of 67 days (EW) and 147 days (NW) in order to evaluate feedlot performance and carcass characteristics. EW calves entered the feedlot at heavier weights. As for feedlot performance, there was no difference between EW and NW calves in terms of daily gain, dry matter intake, feed efficiency, days on feed or harvest weight. EW calves had higher marbling scores, higher percentage of cattle grading average USDA Choice or higher (38 vs. 14), and a greater percentage of cattle grading USDA Prime (10 vs. 0). No differences were seen in fat thickness, but this is due to design as calves were marketed on a target 12th rib fat.

Meyers et al. (1999a), in a 2 year study, compared early weaning (yr 1 = 177d, yr 2 = 158d) to normal weaning (yr 1 = 231d, yr 2 = 213d). In year 1, EW steers were 19 kg heavier at harvest than NW steers, but they were fed 51 days longer. This added time on feed was due to the marketing of the steers at a common fat thickness. Across treatments, no differences were

seen in slaughter age. EW steers gained faster until the time of normal weaning (1.44 kg vs. 0.72 kg); however, the NW steers gained faster during the feedlot phase (1.38 kg vs. 1.28 kg). EW steers had lower DMI (7.7 kg/d vs. 8.16) and had better efficiency (.170 vs. .153). In year 2, EW steers again gained higher until the time of normal weaning, however no differences were seen in the finishing phase. In agreement with year 1, EW steers ended at heavier weights, spent more days in the feedlot, had 5% lower DMI, and were 13% more efficient. In both years, EW steers had higher marbling scores (yr 1, 1198 vs. 1132; yr 2, 1168 vs. 1123) and a greater percentage grading average USDA Choice or higher (yr 1, 93 vs. 68; yr 2, 81 vs. 58).

Myers et al. (1999b) compared three weaning ages (90, 152, 215) of steers. Steers weaned the earliest had 47% higher daily gains during the 90-152 day period than calves that remained nursing their dams. Steers weaned at 90 and 152 days of age had 117% higher daily gains during the 152-215 day period than the calves that were still nursing their dam. No differences were seen in daily gain in the finishing phase; however there was a linear increase in gains for the overall period as weaning age decreases. Along with this advantage in ADG, overall feed efficiency increased linearly when weaning age decreased. This advantage in feed efficiency is due to the high feed efficiency in the early periods. Days on feed decreased linearly as weaning age increased when slaughtered at a constant fat end point. There were no differences observed in yield grade or marbling score. It is important to bring to light that over 90% of the steers in this trial graded USDA Choice or higher.

Myers et al. (1999c) early weaned calves and compared pasture-fed or concentrate-fed cattle in the 82 days immediately following early weaning. During the 82 day period, concentrate-fed cattle had 177% higher ADG. Overall, the concentrate-fed cattle had higher gains (1.30 kg/d vs. 1.13 kg/d), had lower DMI (6.81 kg/d vs. 7.90 kg/d), and were more

efficient (0.190 vs. 0.177). No statistical differences in carcass traits were found between the two treatments, but the author noted that nearly 90% of all the cattle graded USDA Choice or higher. At these levels a true difference in carcass quality would be hard to detect.

Fluharty et al. (2000) looked at early weaning cattle at 100 days versus normal weaning cattle at 200 days. Early weaned cattle gained higher (1.28 kg/d vs. 0.82 kg/d) than the normal weaned cattle while they nursed their dams. There were no differences in ADG or DMI in the feedlot phase, but the early weaned cattle tended to be more efficient. In a similar evaluation, Barker-Neef et al. (2001) also compared weaning ages of 100 and 200 days. They observed early weaned steers being 18% heavier at time of normal weaning, had 24% lower intakes, and were 18% more efficient during the finishing period. In agreement with Fluharty et al. (2000), Barker-Neef et al. (2001) found no differences in carcass characteristics.

Schoonmaker et al. (2002) evaluated weaning ages of 111 days and 202 days. Performance results similar to those in Fluharty et al. (2000) and Barker-Neef et al. (2001) were seen. Early weaned cattle had 0.53 kg/d higher daily gains from early weaning to the time of normal weaning, 14% lower daily intakes overall, and 9% higher efficiency overall. Calves weaned at 202 days had larger LM area than the calves weaned at 111 days and 43.3 kg heavier hot carcass weights than early weaned steers. Schoonmaker et al. (2004a) also observed lower carcass weights in the early-weaned calves despite different diets (EW- ad libitum concentrate, 300.3 kg; EW-limit-fed concentrate, 311.9 kg; EW-ad libitum forage, 314.9 kg; Normal-Weaned, 329.1 kg). Still, Schoonmaker et al. (2002) observed no differences in fat thickness, yield grade, marbling score, and quality grade, which is in agreement with Fluharty et al. (2000), Barker-Neef et al. (2001), and Schoonmaker et al. (2004a).

Schoonmaker et al. (2001) evaluated the effects of weaning age and implant regimen on beef steers. The early-weaned steers had higher gains (302.4 kg vs. 250.9 kg) from early weaning to normal weaning. Early weaned steers had 7% higher overall gains, 15% lower overall DMI, and 4% increase in feed efficiency. No differences were found in final carcass traits. However, a sensory panel did rate the early-weaned steaks better in terms of juiciness and tenderness than normal-weaned steers.

Wertz et al. (2002) compared heifers that were weaned at 180 days and grazed endophyte-infected fescue for 16 months before entering the feedlot as 2 year olds to heifers weaned at 142 days of age and instantly put on a high concentrate finishing diet. The early-weaned heifers fed as calves had higher longissimus ether extract (13.8 vs. 11.4) than the heifers fed as yearlings. Feed efficiency was regressed on fat thickness and marbling score. At any given marbling score, heifers finished as calves were more efficient than the heifers finished as yearlings.

Meyer et al. (2005) assessed the growth rate, body composition, and meat tenderness in early-weaned and traditionally-weaned beef calves. Early-weaned (EW) calves were removed from the cow at an average of 90 days of age, where as the traditionally-weaned (TW) calves were removed at an average of 174 days of age. Ultrasound was utilized to take intermediate carcass evaluations. At 202 days of age, EW calves scanned with larger loin muscle area (37.9 cm vs. 32.3 cm), backfat (0.38 cm vs. 0.26 cm), and had heavier body weights (271.6 kg vs. 218.9 kg) than TW calves. At harvest, EW calves had heavier hot carcass weights (290.4 kg vs. 279.7 kg) and greater marbling scores (51.25 vs. 46.26) than TW calves. This advantage in marbling score translated to more EW steers grading USDA choice or greater. No differences were found in BF, LM area, or liver abscess scores at slaughter.

Shike et al. (2007) evaluated the effects of weaning age, creep feeding, and source of energy on beef calves. Early weaned (EW) cattle were program-fed to achieve similar gains to the creep fed cattle. EW cattle had lower DMI (6.48 kg/d vs. 8.06 kg/d) and improved efficiency (0.215 vs. 0.181). No differences in terms of carcass yield were detected, however the EW calves had higher marbling scores (663 vs. 598) and a higher percentage of cattle that graded Average Choice or greater (72% vs. 39%).

Cow Performance and Reproduction

Not only can early weaning benefit the calf in certain situations, but this management practice can also have effects on the cow. In situations with limited forage availability, early weaning the calf can reduce the nutritional demands of the cow and pressure on the pasture. This can result in improved cow performance. If calves are weaned before the time of breeding, a positive reproductive response can be seen. These beneficial effects have been known to be most prevalent in cows that are experiencing a negative energy balance. Many trials have been conducted to explore the effects of early weaning calves on the mother cow.

Smith and Vincent (1972) evaluated the effects of early weaning calves 30 days postpartum on cow reproductive performance. Cows that had their calves early weaned had shorter intervals from parturition to estrus (45d vs. 55d) and from parturition to conception (57d vs. 70d). Oxenreider and Wagner (1971) found that suckling inhibited ovarian activity. They suggested that this inhibition is due to not only the nutritional stress of nursing a calf, but also due to sensory stimulation of the mammary glands. Nonsuckled cows also had 16% more cows exhibiting estrus and had 30% higher conception rates on first service (Smith and Vincent, 1972).

Laster et al. (1973) utilized cows from 5 different breed types (Angus, Hereford, Charlais x Angus, Red Poll, and Brown Swiss) and ranging in age from 2 to 11 years of age to evaluate the effects of weaning prior to breeding on postpartum reproduction. Calves were weaned 8 days prior to the breeding season. This resulted in an average calf age of 55 days. Early weaning increased the percentage of cows showing estrus from calving through breeding by 29% in 2-year-olds, 26.7% in 3-year-olds, but only increased cows 4 years of age and older by 16%. Similar results were seen in terms of estrus in the first 21 days of breeding season. Early weaning increased the percentage of 2-year-olds by 39.2%, and 3-year-olds by 23.5%, but no effect was observed in mature cows. The author stated that the increased percentage of 2- and 3-year-old cows exhibiting estrus was likely due to a combination of nutritional and suckling factors. The removal of the calf eliminated inhibition of ovulatory factors from suckling and negative energy balance. The lack of response seen in mature cows is likely due to the fact mature cows are no longer growing and are less likely to be in a negative energy balance (Laster et al., 1973). Bellows et al. (1974) also found that early weaning shortened postpartum interval from calving to first estrus by 22.7 days in trial one and by 19.5 days in the second trial.

Lusby et al. (1981) compared early weaning calves from first-calf heifers at 6-8 weeks and normal weaning calves at 7 months from first-calf heifers. The first-calf heifers that had their calves early weaned gained 22.7 kg more weight from calving to breeding season, gained 11.3 kg more weight during the breeding season, had a higher percentage of ovarian cyclicity, reduced days from calving to conception (73.0 vs. 90.5), and higher conception rate (96.8% vs. 59.4%). The reproductive response due to early weaning could have been amplified due to the fact the heifers in this trial were thin (body condition score 3-4). Bishop et al. (1994) stated that body energy reserves influence the onset of luteal activity after early weaning beef calves. Cows

with BCS greater than 5 initiated onset of luteal activity 7 days earlier than cows with a BCS less than 5. Randel (1990) summarized four trials evaluating the effects of postpartum nutrition and energy status on pregnancy rates. Cows that were adequate in terms of energy had an average pregnancy rate of 91.5%, where as cows that were inadequate in energy status had 61.5% pregnancy rates.

Arthington and Kalmbacker (2003) evaluated early weaning on the performance of three-year-old, first-calf heifers. They utilized fall calving Braford and Brangus cows. Early weaning was done in January and normal weaning was conducted in August. They observed that early weaning resulted in 39 kg heavier cow weights and higher BCS (6.34 vs. 4.75) in the first-calf heifers in August. Cows were exposed to bulls for a 90 day breeding period that started in January. First-calf heifers on the early weaning treatment had higher pregnancy rates than the normal-weaned heifers in year 1 (89.5% vs. 50%). In year 2, the early weaned treatment tended to have higher pregnancy rates than that of the normal weaned heifers (96.1% vs. 79.0%). This improvement in pregnancy rate in heifers is in agreement with Laster et al. (1973) and Lusby et al. (1981).

The literature shows that early weaning calves from first calf heifers and young cows can improve reproductive performance. Young cows are still devoting energy to growth and thus negative energy balance occurs more frequently. Early weaning the calf decreases the energy requirement of the cow and can also relieve added pressure from the forage source. Many studies have looked at the results of early weaning on mature cows. Results are differing and depend on weaning age, body condition, energy intake, and forage availability.

Richardson et al. (1978) compared weaning ages of 120 days and 210 days. At these ages, the breeding season is likely near the end or completely over by the time of early weaning.

Therefore, reproductive performance should not be affected for the current year. The early-weaned cows still gained 12 kg more from the time of early weaning to normal weaning. Even though calves were weaned too late to effect reproduction in the trial year, the weight gain experienced was correlated to improved reproduction in the following year. Dam's past year weight was found to be correlated with pregnancy rate, an earlier calving date, live calf percentage, as well as increased calving difficulty.

Neville and McCormick (1981) evaluated weaning calves at 67 days (early weaning) and 230 days (normal weaning) on cow performance. Cows with early weaned calves gained 0.34 kg/d higher. No differences were seen in conception or pregnancy rate despite the early weaned cows not being suckled during the time of breeding. In the following year, dams of early weaned calves calved 6 to 7 days later than that of normal weaned cows, but their normal-weaned calves had higher 205 day weights than that of calves of normal weaned cows from the previous year.

Myers et al. (1999a), in a 2 year study, compared early weaning (yr 1 = 177d, yr 2 = 158d) to normal weaning (yr 1 = 231d, yr 2 = 213d). At the time of normal weaning, cows with early weaned steer calves weighed 40 kg heavier and had 0.55 kg/d higher ADG. The cows with early weaned steer calves had a .23 unit higher BCS. There was a trend for the early weaned cows to have higher pregnancy percentages (78% vs. 67%). At the time of early weaning the cows would have already been bred. This increasing trend in pregnancy rate was likely due to reduced stress of lactation on cows grazing endophyte infected tall fescue (Porter and Thompson, 1992)

Myers et al. (1999b) compared three weaning ages (90, 152, 215 days). Cow weight at 215 days postpartum increased linearly as weaning age decreased. Body condition score was also improved linearly as weaning age decreased. Pregnancy rates were improved by 18% for

cows that had their calves removed at 90 days. No difference in pregnancy rate was found between the 152-day weaning and the 215-day weaning treatments. This is to be expected as the breeding season is likely over when the calves were weaned.

Story et al. (2000), over a 5 year period, evaluated three different weaning ages. The treatments were early weaning (150 days, EW), normal weaning (210 days, NW), and late weaning (270 days, LW). EW cows were heavier at time of normal weaning (561 kg vs. 532 kg vs. 532 kg) than the NW and LW cows. At time of late weaning, the EW cows were the heaviest and the NW cows were heavier than the LW cows (583 kg vs. 560 kg vs. 541 kg). Forty two days after late weaning the EW cows were still the heaviest and the NW cows weighed more than the LW cows (585 kg vs. 567 kg vs. 552 kg). Body condition score followed the same trends as body weight. EW cows had higher BCS at time of normal weaning, late weaning, and 42 days post late weaning. NW cows had higher BCS than LW at time of late weaning and 42 days post late weaning. No differences were found in terms of pregnancy rate, but this was anticipated as all treatments were after breeding season.

Shultz et al. (2005) compared early weaning (108 days of age) to normal weaning (205 days of age) on cow performance. Even though cows with normal weaned calves were heavier at time of early weaning there were no difference in weight at time of normal weaning. This resulted in the cows subjected to the early wean treatment gaining 42 kg more from time of early weaning to normal weaning. Similar results were found in terms of body condition score. Early weaned cows had lower BCS at time of early weaning, but at time of normal weaning there were no differences. Thus, a BCS change of 1.6 units greater was found for the early weaned cows. No reproductive performance was measured.

Odhiambo et al. (2009) utilized 408 beef cows that ranged in age from 2-12 years of age to evaluate effects of weaning age on cow reproduction and performance. Early weaning occurred at approximately 180 days and normal weaning 45 days later. Early weaned cows had heavier weights at time of normal weaning, but the overall cow body weight was not affected. This reveals that normal weaned cows compensated in terms of weight gain after they were weaned. Early weaning only had an effect on BCS in 3-5 year old cows, in which EW increased BCS. Rib fat and rump fat measurements were also taken via ultrasound. Rump fat tended to be higher for EW cows, but no differences were seen in rib fat. The author suggested that because of impetus growth, fat accretion occurs in later stages of growth and thus, in younger cows, nutrients could have been directed towards protein accretion. The effect of early weaning on rib fat could have been diminished by this redirection of nutrients. The author concluded that early weaning improved weight and BCS in cows and that current data suggest that first and second parity cows benefit the most from early weaning (Odhiambo et al. 2009).

Reduction in Feed/ Increased Stocking Rates

The main focus of early weaning research has been to evaluate the effect of performance on the calf or the cow. Early weaning can also have an effect on forage availability. A few studies have looked at the effects of early weaning on available feed resources, nutrient requirements, and stocking rates.

Peterson et al. (1987) weaned calves from cows at 110 and 222 days of age. All cows were maintained in a drylot where intake was collected after early weaning until normal weaning. Early weaned calves were fed Alfalfa hay free choice and supplemented with 1.6% of body weight of a grain mix. Early weaned calves and cows gained more during the treatment phase (29 kg and 20.7 kg, respectively) than normal weaned calves and cows. Cows that were

not being suckled consumed 45.3% less TDN than the suckled cows. When the cow and calf intakes were combined, the early weaned cow-calf pairs consumed 20.4% less TDN than the normal-weaned cow-calf pairs and were 43.9 % more efficient at converting kilograms of TDN into kilograms of calf gain.

Harvey and Burns (1988) conducted a study to look at three different cow scenarios. They were evaluating if early weaning could improve stocking rates or allow for increased gain at normal stocking rates. They had normal-weaned cow-calf pairs stocked at 2.3 cows/ha, early-weaned cows stocked at 3.66 cows/ha, and early-weaned cows stocked at 2.55 cows/ha. There were no differences in cow performance when comparing the normal-weaned cows with the heavily stocked early-weaned cows. This showed that early weaning can allow increased stocking rates without sacrificing cow gains. When early-weaned cows were compared with normal-weaned cows at similar stocking rates, the early-weaned cows gained 0.18 kg/d more and were 20.7 kg heavier. From an economical standpoint, the author suggested increasing stocking rates would be more profitable to a cow-calf system than to allow additional cow weight gain.

Subsequent Performance of Replacement Heifers

As in creep feeding, early weaning can alter the traditional nutritional plane of heifer calves during critical mammary development stages and thus studies have looked at the subsequent performance of early weaned females.

Holloway and Totusek (1973) compare three different management strategies; weaning at 140 days weaning at 240 days, or creep feeding for 100 days and weaning at 240 days. They then evaluated the heifers through breeding and three calf crops. In year one, creep fed heifers had higher birth weights than the other treatment, but in years 2 and 3 no differences were observed. Weaning weight was not affected by pre-weaning treatment in any year. Early

weaned heifers produced less milk in all three years (23% less in year one, 4% less in year two, and 10% less in year three).

Richardson et al. (1978) early weaned heifers at 120 days and compared them to normal-weaned heifers at 210 days of age. The heifers were evaluated for pre-weaning, post-weaning, reproductive, and progeny performance over 6 years. No significant differences were observed in terms of reproductive or maternal performance between treatment groups.

Sexton (2004) conducted a study to look at the effects of weaning replacement heifers at either 89 or 232 days of age. Early weaned heifers had higher percentages pubertal at 8 months of age (81.3% vs. 59.4%) and all heifers were pubertal at 12 months of age. Pregnancy rates tended to be higher for early-weaned heifers (90% vs. 74%). There were no differences in calving rate, weaning rate, milk production, or calf performance.

Source of Energy

In years past, most differences in performance of beef cattle due to diet have been attributed to level of nutrition. However, there are many different sources from which that nutrition is derived. With the expansion of the bio-fuels industry, more untraditional feedstuffs are becoming available to beef producers at economically inviting prices. The variation of traditional feedstuffs and addition of new energy sources may play a large role in the performance of the today's beef animal. More recent studies have looked into these differences in source of energy and how source of energy factors into beef cattle performance and carcass characteristics.

Volatile Fatty Acid Concentration and Ruminal pH

Smith and Crouse (1984) reported that relative contributions of carbon precursors differ in subcutaneous and intramuscular adipose tissue. They showed that glucose provides 51-76%

of acetyl units in intramuscular fat and that lactate and acetate were a lesser percentage of acetyl units. However, in subcutaneous fat, acetate supplies 68-77 % of the acetyl units and glucose is an extremely small percentage. These percentages imply that if blood glucose is increased and acetate is decreased, then intramuscular fat should be able to increase without increasing subcutaneous fat. Also, fatty acid ratios play a role in the deposition of intramuscular and subcutaneous fat. Shifting fermentation patterns can alter the acetate:propionate ratio. Since propionate is a precursor to glucose, if the acetate: propionate ratio is lower, we can assume intramuscular adipocytes could increase without increasing subcutaneous adipose tissue.

Cremin et al. (1991) conducted a trial to look at digestion criteria in nursing beef calves that were offered creep feed at different energy levels and amounts. They looked at volatile fatty acid (VFA) concentrations, ruminal pH, and molar proportions of volatile fatty acids. Ruminal pH decreased as creep feed increased. Total VFA concentrations were the greatest for unlimited creep feed. Similar to pH, the acetate:propionate ratio decreased as amount of creep feed increased. Cremin et al. (1991) evaluated the effects of a starch-based creep feed and did not look at a fiber-based complement.

Faulkner et al. (1994) conducted an 84 d creep feeding study where they compared no creep feed, limited intake of corn (1kg/d), unlimited intake of corn, limited intake of soyhulls (1kg/d), and unlimited intake of soyhulls. This trial compared two different sources of energy with corn being the starch and soyhulls being the fiber source. As level of supplementation increased pH decreased, total molar proportions of VFA increased, acetate percentage decreased, propionate increased, and thus the acetate:propionate ratio decreased. As for source of energy, corn decreased pH and decreased acetate percentages when compared to soyhulls. Unlimited corn creep decreased pH (5.8 vs. 6.0) and lowered the acetate to propionate ratio (1.9 vs. 3.0)

when compared to unlimited soyhull creep. Starch (corn) creep also decreased the digestibility of NDF by 11%, ADF by 26%, and CP by 4% when compared to fiber (soyhull) creep. Negative associative effects have been observed when high levels of starch or grain are supplemented to a forage based diet (Hart, 1987). Despite the negative impact on digestibility, corn creep did result in higher quality grades than the soyhull creep (10.7 vs. 10.2). The lower acetate:propionate and lower ruminal pH that are the direct cause of negative associative effects and poorer fiber digestion seen in the corn creep may be the culprit of improved marbling in the beef carcass.

Wertz et al. (2001) fed a forage-based diet, composed primarily of alfalfa haylage and soyhulls, and a concentrate diet, composed primarily of cracked corn, in the growing phase. The concentrate diet resulted in a trend to increase in percentage DM, OM, CP, and GE disappearance when compared to the forage-based diet. Volatile fatty acids were also evaluated. The concentrate diet increased propionate (31.9 vs. 18.0) and decreased acetate (58.9 vs. 72.9). Despite this change in acetate:propionate ratio, only a trend for marbling score to increase existed at slaughter.

Buckner (2010) cannulated seven steers to evaluate fiber digestibility and rumen pH when diets containing different percentages of corn and co-product feeds were fed. Three diets were fed. The diets were 35% wet distillers grains with solubles and 53% corn (35WDGS), 35% wet corn gluten feed and 53% corn (35WCGF), and 88% wet corn gluten feed and no corn (88WCGF). The remainder of these diets was made up of alfalfa hay and a dry supplement. The 88WCGF diet had the lowest dry matter digestibility, but was numerically the highest in NDF digestibility and not statistically different from 35WDGS. The 88WCGF diet had the highest, most neutral pH (6.07 average). The 35WDGS diet was intermediate in pH (5.38 average). The 35WCGF was the lowest and most acidic in pH (5.13 average). Amount of time spent below a

pH of 5.6 was also evaluated. The 88WCGF diet spent the least amount of time below 5.6, followed by 35WDGS and then 35WCGF (125, 1160, and 1261 min/day). The author concluded that feeding 88WCGF helped to alleviate acidosis.

Schoonmaker et al. (2003) found a high concentrate diet fed to ruminally fistulated steers resulted in a lower pH (5.4 vs. 6.0 at 9hr), higher concentrations of propionate (38.2 vs. 17.8) and lower acetate concentrations (41.1 vs. 59.1) compared to a high fiber diet. Huntington (1997) also stated that, via starch fermentation, growing animals fed high-concentrate diets have greater ruminal production of propionate, which is quantitatively the most important source of carbon for gluconeogenesis in ruminants. Even though there were no differences in plasma glucose, the same high concentrate diet resulted in elevated levels of insulin, which regulates uptake of blood glucose.

Insulin and Insulin sensitivity

Although glucose levels may be increased in the blood, regulation of glucose uptake may be the limiting factor in whether intramuscular fat can be increased by diet. Insulin stimulates uptake of glucose by peripheral tissues and increases lipogenesis or reduces lipolysis. Studies have been conducted to evaluate the effect of dietary source of energy on insulin and insulin sensitivity.

Rhoades et al. (2007) evaluated the effects of source of energy on muscle and adipose tissue and insulin sensitivity. Cannulated steers were fed either a corn-based diet or a hay-based diet. Insulin addition failed to stimulate an increase in glucose conversion to carbon dioxide when hay diets were fed. However, when corn diets were fed, a 116% increase in the rate of conversion of glucose to carbon dioxide occurred. Similar to the previous data, dietary energy source manipulated glucose conversion to lactate. Steers fed corn-based diets converted 190%

more glucose to lactate than a hay-based diet. Tissues from high forage diets tended to incorporate more glucose into fatty-acids than that of corn diets. Insulin addition to subcutaneous adipose tissue of steers fed corn-based diets resulted in failed stimulation of glucose into fatty acids. However, when added to intramuscular adipose tissue of corn-fed steers there was a 165% increase in glucose incorporation into fatty acids. Similarly, insulin addition decreased incorporation of glucose into glyceride-glycerol in adipose tissues from steers fed hay-based diets. Conversely, adding insulin to tissues from steers fed a corn-based diet increased glyceride-glycerol synthesis from glucose. Glucose was not limiting in the culture media for tissues from steers fed either hay or corn-based diets. It is easy to see from these data that diet influences insulin sensitivity. Tissues from cattle fed hay-based diets became more insulin resistant. Tardiff et al. (2001) further described insulin resistance. Ketones accumulate as a result of the forage based diet and interrupt insulin signaling transduction. This reduction in insulin-sensitive glucose transporter translocation results in a reduction in insulin-stimulated glucose uptake and potentially glucose metabolism. Rhoades et al. (2007) suggested that feeding a hay-based diet limited tissues capacity to increase glucose to increase glucose utilization due to insulin resistance. They also concluded that high concentrate diets enhance glucose and insulin effects on muscle and adipose tissues through increased production of propionic acid, which is a preferred gluconeogenic substrate.

Cattle Performance and Carcass Traits

Along with traditional fiber-based feedstuffs such as hays, soyhulls, corn gluten feed, and wheat middlings, new co-products such as DDGS have emerged. As new co-products from the bio-fuels boom have arrived in the animal feeding industry, many studies have evaluated them as dietary energy sources in ruminant rations. Through the wet and dry milling processes, starch is

removed making these co-products a fiber-based energy source. This presents the cattle industry with a new source of energy to evaluate.

Schoonmaker et al. (2004a) conducted a study to look at if source of energy would affect performance and carcass traits in normal- and early-weaned steers. Calves fed ad libitum concentrate had 28% higher gains from day 119 to day 204 and 6% higher gains in the feedlot phase. Calves fed concentrate diets had lower intakes in the feedlot (7.1 kg vs. 7.8 kg) and were more efficient in both the growing and finishing phases (290 g/kg vs. 239 g/kg and 224 g/kg vs. 192 g/kg, respectively). No differences in carcass characteristics were found.

Schoonmaker et al (2004b) found contrasting results in performance of Holstein steers. Steers fed ad libitum concentrate diets had higher ADG in the growing phase (1.39 kg vs. 0.96 kg), but in the finishing phase exhibited poorer gains (1.41 kg vs. 1.68 kg) than steers fed an ad libitum fiber-based diet. Efficiency was greater for the fiber-based diet (246 g/kg vs. 223 g/kg) than the concentrate diet. No difference existed in carcass characteristics at slaughter.

Nichols et al. (2009) conducted a finishing study to evaluate diets containing different levels of wet corn gluten feed (WCGF) and wet distillers grains with soluble (WDGS) and no corn. The control diet was composed of primarily high moisture corn. The control cattle had higher ADG and were more efficient than the co-product diets (1.56 kg vs. 1.37 kg). In contrast, Nuttleman et al. (2010) evaluated the feedlot performance of cattle fed either corn-based diets (starch) or WDGS-based diets (fiber). Cattle fed WDGS-based diets had 9.5% higher ADG and were 9% more efficient. In Nichols' study the control cattle tended to have higher marbling scores (531 vs. 503) than the co-product diets. The author concluded that diets containing mixtures of WDGS and WCGF although not statistically similar, resulted in the numerical

differences small enough for these diets to be considered in times of high corn prices (Nichols et al., 2009).

Wilken et al. (2009) also conducted a finishing study to evaluate different combinations of co-products with or without corn on steer performance and carcass traits. Six different diets were tested. The diets were 82.5% corn (CORN), 43.8% corn and 43.8% WDGS (WDGS:corn), 21.9% corn and 32.8% WDGS and 32.8% WCGF (Low blend:corn), 21.9% soyhulls and 32.8% WDGS and 32.8% WCGF (Low blend: hulls), 43.8% WDGS and 43.8% WCGF (High blend), 21.9% hay and 65.6% WDGS (WDGS: hay). Cattle fed the CORN diet had the leanest backfat and lowest yield grades, and were intermediate for all other performance and carcass characteristics. Cattle on the WDGS:corn diet had the highest ADG, were the most efficient, had the heaviest HCW, and were intermediate for all other traits. The cattle on the Low blend:corn diet were intermediate for all traits except they had the highest backfat at slaughter. The Low blend:hulls diet proved to be the most disappointing as the cattle had the poorest gains, efficiency, HCW, and marbling scores while being intermediate for all remaining characteristics. The High blend cattle exhibited the lowest intakes and remained intermediate for all other performance and carcass traits. The WDGS:hay diet, though the farthest from a traditional feedlot diet, did remain intermediate for all traits except for being the high intake group. Marbling scores did not differ except for the Low blend cattle were significantly lower. The author concluded that it is possible to feed co-products (fiber-based energy) without corn (starch-based energy) and maintain performance and carcass traits. Source of energy had differing effects on feedlot performance and carcass traits, but diets were not isonitrogenous or isocaloric.

Rich et al. (2011) evaluated diets with corn compared to diets that contained no corn in finishing cattle. Corn diets consisted of differing levels of corn, WDGS, and straw. Obviously,

“no corn” diets contained different combinations of WDGS and straw. Diets containing primarily corn resulted in higher gains, were more efficient, and had higher marbling scores than the diets that were composed primarily of fiber-based energy. Diets were not isonitrogenous or isocaloric making it difficult to distinguish if the performance and carcass results are due to source of energy.

Co-products may pose different challenges when evaluating their effects on cattle performance and carcass characteristics than traditional feeds due to a large amount of variability and lack of consistency. The changing nutrient composition of these feedstuffs makes comparing studies using co-products difficult and at times impossible.

Summary

The longevity of the beef industry is dependent on its ability to continue to evaluate and implement more efficient management and nutrition practices. Creep feeding increases calf weights at time of weaning and has shown to improve carcass quality. Creep feeding has minimal effects on cows of creep-fed calves; however creep-fed heifers will have lower milk production as cows. Early weaning has shown to improve gains over creep feeding at weaning and, when calves are applied to accelerated finishing systems, improve carcass quality. Early weaning improves cow body weight and condition scores and, if performed prior to breeding, can improve reproductive performance. Source of energy has been determined to have effects on concentrations of volatile fatty acids, pH levels, and insulin sensitivity. Starch fermentation has been shown to shift the acetate:propionate ratio and lower pH. Forage-based diets have been shown to increase acetate and inhibit insulin sensitivity, thus lowering glucose metabolism. Newer fiber-based co-products have shown mixed results in terms of performance and carcass characteristics, which can be attributed to large variation in nutrient composition and consistency

in product. Fat levels and pH levels in co-product diets can also influence cattle performance and carcass traits.

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CHAPTER 2

WEANING AGE AND SOURCE OF ENERGY INFLUENCE BEEF CATTLE PERFORMANCE, CARCASS CHARACTERISTICS, AND ECONOMICS

Abstract

Angus and Angus x Simmental calves (n=200) were randomly allotted to one of five dietary treatments at two locations: Early Wean Starch (EWS), Early Wean Fiber (EWF), Creep Fed Starch (CFS), Creep Fed Fiber (CFF), or Control (CON). Control calves were normal weaned and received no supplemental feed while they grazed with their dams. The diets fed to early-weaned and creep-fed cattle were formulated to be isonitrogenous. Early-weaned calves (133±21 days of age) were placed in the feedlot, while normal-weaned calves remained with their dams on pasture (2 or 3 replications per location). Creep feed was offered ad-libitum to CFS and CFF. After a 100 d treatment phase, calves were placed in the feedlot on a common diet. GrowSafe® was used to measure individual intake of all calves in the feedlot. In the treatment phase, early-weaned gained more than creep-fed (1.6 vs. 1.5 kg, $P < 0.01$), and the average of creep-fed and early-weaned calves gained more than control calves (1.5 vs. 1.2 kg, $P < 0.01$). EWS had 15% lower intakes and were 13% more efficient than EWF ($P < 0.01$). In the finishing phase, creep-fed calves gained 9% more, had 7% lower intakes, and were 16% more efficient ($P < 0.01$) than early-weaned calves. CON were 5% more efficient and spent 19 more d on feed ($P < 0.01$) than the other treatments. Backfat was lower for the CON (1.1 vs. 1.2 cm, $P = 0.02$). Marbling score was higher for early-weaned cattle when compared to creep-fed cattle (586 vs. 500) and lower for the CON (476 vs. 543) than all other treatments ($P < 0.01$). Marbling score did not differ significantly when comparing source of energy. Economic analysis of marketing cattle as feeder calves post-treatment showed profit was \$15.01 higher for EWF than

EWS ($P = 0.06$), \$15.69 higher for CFF than CFS ($P = 0.06$), \$45.66 higher for creep-fed than early-weaned ($P < 0.01$), and \$24.72 higher for CON than the remaining treatments ($P < 0.01$). Economics analysis of a retained-ownership showed profit was \$44.63 higher for EWF than EWS ($P = 0.03$), \$54.05 higher for creep-fed calves than early-weaned calves ($P < 0.01$), and \$42.82 higher for CON ($P < 0.01$). Early weaning and creep feeding increased carcass quality and growing phase gains, but reduced profit in this study. Co-product feeds with higher fat levels could initiate marbling similar to that of starch based diets in young beef calves.

Introduction

Accelerated finishing systems for beef calves consistently produce high quality carcasses with high marbling scores (Myers et al. 1999a). High concentrate diets were commonly evaluated in these studies. These diets are high in starch and cause reduced fiber digestion and lower ruminal pH (Faulkner et al., 1994, Tarr et al. 1994). One alternative to traditional high concentrate diets is co-product feeds. Co-product feeds, the result of biofuel production, have recently become available to beef producers as a cost efficient option. During biofuel production, the wet and dry milling process removes all the starch leaving a fiber-based feed which has been evaluated in both creep feed and early weaned diets (Faulkner et al., 1994, Soto-Navarro et al., 2004). Traditional fiber-based co-products like corn gluten feed, soyhulls, and wheat middlings were previously evaluated; however, distillers grains with solubles and corn bran, which have much different nutrient profiles, need to be evaluated.

The source of energy in the diets of young calves can have an effect on performance and carcass characteristics. Smith and Crouse (1984) showed that glucose provides 51-76% of acetyl units in intramuscular fat and that lactate and acetate were a lesser percentage of acetyl units. However, in subcutaneous fat, acetate supplies 68-77% of the acetyl units with glucose

supplying a small percentage of units. Starch fermentation results in elevated blood glucose and insulin, thus could contribute to an increase in marbling. There is limited data evaluating diets containing DDGS or corn bran in early weaning and creep feeding diets. This study investigated the addition of these co-products in the fiber-based diet. This study evaluates weaning age and source of energy on beef cattle performance, carcass characteristic, and economics.

Materials and Methods

Experimental Animals

Two hundred spring-born Angus and Simmental x Angus calves from the Orr Research Center in Baylis, IL, and the University of Illinois Beef Field Research Laboratory in Urbana, IL were utilized to investigate the influence of weaning age and source of energy on performance, carcass characteristics, and economics. Animals used in this trial were managed according to the guidelines recommended in the *Guide for the Care and Use of Agriculture Animals in Agriculture Research and Teaching* (Consortium, 1988). All experimental procedures followed those approved by the University of Illinois Laboratory Animal Care Advisory Committee.

Experimental Design

A randomized complete block design was applied to the 200 head of cattle. Calves were randomly allotted to their treatment groups. This resulted in 5 treatments containing 40 calves per treatment and allowed for 5 replications of 8 head pens. Pen was used as experimental unit in the treatment phase, however individual animal was used in the finishing phase.

Management and Diets

The diets fed to early-weaned and creep-fed cattle were formulated to be isonitrogenous, but not isocaloric. Diets were balanced to meet or exceed NRC requirements (NRC, 1996). Calves were applied to five treatments: Early Wean Starch (EWS), Early Wean Fiber (EWF),

Creep Fed Starch (CFS), Creep Fed Fiber (CFF), or Control (CON). Control calves were normal weaned and received no additional feed while they grazed with their dams on pasture. Control and creep-fed pairs were rotated through mixed pastures of endophyte infected tall fescue (*Festuca arundinacea*), red clover (*Trifolium pretense*), and orchard grass (*Dactylis glomerata* L.). All calves received a two week adaptation period prior to the start of the trial in which they were all allowed ad libitum access to a fiber based creep diet. A fiber based creep was used to eliminate responses from starch in calves assigned to the fiber-based diet. Early weaning occurred at 133 ± 21 days of age, and normal weaning occurred 100 days later. The start of the trial corresponded with the time of early weaning, when cattle were vaccinated, implanted, and identified with an electric identification tag.

Calves were vaccinated for bovine syncytial respiratory virus, infectious bovine rhinotracheitis, bovine viral diarrhea, parainfluenza-3, *Pasteurella multocida*, *Clostridium chauvoei*, *Clostridium septicum*, *Clostridium novyi* Type B, *Clostridium haemolyticum*, *Clostridium tetani* and *Clostridium perfringens* Types C and D. Calves were implanted with Component TE-IS (80 mg trenbolone acetate, 16 mg estradiol, 29 mg tylosin 99 tartate; VetLife, Overland Park, KS) at the initiation of the trial and received Compudose 200 implant (25.7 mg estradiol; VetLife, Overland Park, KS) at the time of normal weaning when all cattle entered the feedlot.

Early weaned calves were housed at the University of Illinois Beef Research Facility and received their ration ad libitum (Table 1). Creep-fed calves remained on pasture suckling their dams and were offered creep feed ad libitum (Table 2). Control calves received no supplemental feed, having nutrition provided by only their dam and the pasture. In the finishing phase, all

cattle received a common finishing ration (Table 3) for the remainder of the period. All diets were balanced with supplements (Table 4 and Table 5).

Performance Data Collection

The experimental growing period was from early weaning to normal weaning (100 days). At the initiation of the trial, weights were taken two consecutive days. These weights were averaged to calculate initial growing phase weights. Intakes in the experimental growing period were measured in the form of feed disappearance. Bunks for early-weaned steers were maintained so that once a day feeding resulted in ad-libitum consumption of feed in concrete fence line bunks during the growing phase. Bunks were monitored daily and disappearance was recorded. At the completion of the experimental growing phase, shrunk weights were taken on all cattle and used for the growing phase end weights and finishing phase initial weights. Interim weights were taken every 42 days corresponding with collection of ultrasound data. To limit the variation in cattle, ultrasound was used to determine a common 12th rib fat thickness of 1.2 cm for harvest. Ultrasound measurements were taken with an Aloka 500SV (Wallingford, CT) B-110 mode instrument equipped with a 3.5-MHz general purpose transducer array. Backfat and marbling measurements were taken in a transverse orientation between the 12th and 13th ribs approximately 10 cm distal from the midline. Marbling image analysis was performed according to Brethour (1994). Individual intakes were collected using the Growsafe automated feeding system (Model 4000E, GrowSafe Systems Ltd., 86 Airdrie, Alberta, Canada) during the finishing phase. Intakes were audited daily by trained personnel. Feed intake data was considered acceptable if at least 85% of feed supplied to the bunk and 90% of corresponding feed assigned to individual ID was accounted for. Data was also considered acceptable if 95% of the data sent from the weight panel was received at the computer compared to all data points sent for a 24

hour period. Also, 95% of the data from an individual electronic identification tag needed to be received at the computer compared to all possible data sent from the electronic identification panel. A log was kept for repair or replacement of component parts and data was subsequently discarded that day for the affected pens. The GrowSafe system has been validated and is a viable method for obtaining individual feed intake (Basarab et al., 2003; Nkrumah et al., 2004; Lancaster et al., 2009). Final weights were calculated from hot carcass weights using a standard dressing percentage of 62%. Supplemental feed efficiencies were calculated for creep-fed cattle by subtracting the control gain from the creep-fed gain and then divided by feed disappearance. Feed efficiency was calculated for the early weaned cattle and all cattle in the finishing phase.

Carcass Data Collection

Upon reaching the target 12th rib fat thickness, cattle were transported via commercial trucking to be harvested at a commercial abattoir (Tyson Fresh Meats, Joslin, IL). Trained University of Illinois personnel collected harvest day data (harvest order, liver scores, and hot carcass weights (HCW). Carcass measurements were taken with Video Image Analysis (VIA) with the USDA camera system and were obtained from Tyson Fresh Meats, Joslin IL.

Economic Analysis

Average price data was used to standardize conditions across years. Five-year averages were used for the live and dressed beef prices as well as the premiums and discounts (USDA, 2010b, USDA 2010c). Three-year price averages were used for corn, soyhulls, Dakota Gold Bran, hay, and wet gluten feed. Ingredient price for corn was collected from the National Agricultural Statistics Service (NASS, 2010) and averaged \$3.97 per 25.5 kg over three years (2007 to 2009). Price for soybean hulls and wet gluten feed was obtained from the Missouri Dairymen's By-Product Feed Page (University Of Missouri, 2010). Price data for the alfalfa

mixed hay was collected from annual commodity reports for the years 2007 to 2009 (NASS, 2010). Price data for the bran was attained from Dakota Gold Research Association (K. Karges, personal communication). Price for corn husklage was calculated based on corn price using the following equation: $[(6.5 * \text{price} / 25.45 \text{ kg}) + \$5.00/\text{T harvest and storage cost})/35\% \text{ DM}]$. Live cattle price was \$88.09/45.4 kg for heifers and \$88.16/45.4 kg for steers. Average dressed beef price was \$139.90/45.45 kg and \$139.80/45.45kg (2005-2009, USDA, 2010a). Input costs included feed costs, creep feeder, pasture charge, processing (medical/veterinarian/labor), interest, and yardage costs. Depreciation costs and labor costs associated with delivering the creep feed were calculated to be \$0.115/day (Shike et al., 2007). Cremin et al., 1991 showed that as creep feed intake increases forage intake decreases. To more accurately economically assess calf intake costs, a pasture charge was applied. Calves that had higher creep feed disappearance had lower pasture fees. Pasture charge, applied to creep-fed and control calves, was calculated based on voluntary forage calf intakes (Adcock, unpublished). Processing charge was \$35/head and yardage was calculated at \$0.35 calf/day. Interest was assessed at 8% on calf purchase price and 50% of feed consumed per calf. Calf purchase price was calculated using a regression equation based on 5-year average feeder calf prices attained from USDA (USDA, 2010a). Carcass value was calculated for each animal using actual carcass weight and associated premiums and discounts for carcass merit. Five-year average grid premiums and discounts used in this study are shown in Table 6. Profit per steer was defined as the difference between carcass value and total input costs. No cow economics were evaluated.

Statistical Analysis

Non-categorical data were analyzed using the MIXED procedure of SAS (SAS Inst, Inc. Cary, NC) using single degree of freedom orthogonal contrasts (EWS vs. EWF, CFS vs. CFF,

EWS and EWF vs. CFS and CFF, and EWS, EWF, CFS, and CFF vs. CON). Categorical data were analyzed using the GENMOD procedures of SAS (SAS Inst, Inc. Cary, NC) using single degree of freedom orthogonal contrasts (EWS vs. EWF, CFS vs. CFF, EWS and EWF vs. CFS and CFF, and EWS, EWF, CFS, and CFF vs. CON). During the 100 day treatment phase pen was used as experimental unit. During the finishing phase individual intakes were recorded, thus individual animal served as experimental unit. The independent variable in the model was treatment.

Results and Discussion

Live Animal Performance

Treatment phase performance data are shown in Table 7 and feedlot performance data are shown in Table 8. As expected, early weaned cattle had the highest ADG, creep-fed calves were intermediate, and control calves had the lowest ADG. Many studies have shown both creep feeding (Prichard et al., 1989; Faulkner et al., 1994; Tarr et al., 1994) and early weaning (Fluharty et al., 2000; Myers et al., 1999a; Tarr et al., 1994) improve ADG prior to weaning compared to normal weaning. Although the CON cattle were the lowest for ADG, they still gained 1.2 kg/d, which is higher than previous studies. Normal weaned calves gained 1.03 kg/d, 0.86 kg/d, 0.62 kg/d (Schoonmaker et al., 2001, Barker-Neef et al., 2001, Myers et al., 1999a respectively) in previous trials. High gains of the CON calves found in this trial are attributed to abundant, high quality forage in pastures due to above average rainfall during the trial year. There were no differences in ADG due to source of energy. In the experimental growing phase, EWS calves had .88 kg/d lower intake and were 13% more efficient than EWF calves ($P < 0.01$). This is in contrast to Schoonmaker et al. (2004a) where EW calves fed ad libitum concentrate

had higher intakes than EW calves fed ad libitum forage (1.49 kg/d vs. 1.16 kg/d) in the growing phase with similar gain to feed.

There were no differences found between source of energy in feedlot performance. All cattle were on a common finishing diet during the feedlot phase, so the lack of differences in feedlot performance due to experimental growing phase starch-based and fiber-based diets was expected. When evaluating early-weaned vs. creep-fed in the finishing phase, creep-fed calves had 8.5% higher gains, 6.5% lower intakes, and were 15.6% more efficient than early weaned calves ($P < 0.01$). These gains are in agreement with those previously reported (Shike et al., 2007; Myers et al., 1999a), while the finishing phase intakes of early weaned calves found in this trial are lower than those previously reported (Barker-Neef et al., 2001; Shoonmaker et al., 2002; Shike et al. 2007). The reason behind lower intakes of the creep-fed calves in the finishing phase is unknown. The literature shows conflicting reports on efficiency of early-weaned calves from time of normal weaning to harvest. In concurrence with this trial, Schoonmaker et al., (2001) reported poorer efficiency in early weaned calves. Others have reported no differences in efficiency in the feedlot phase (Myers et al., 1999b; Schoonmaker et al, 2002; Shike et al, 2007). Some have reported improvements in efficiency in early-weaned steers (Barker-Neef et al., 2001). CON calves when compared to the average of all other treatments were more efficient in the feedlot (0.160 vs. 0.152). CON calves may have been compensating for lower performance during the experimental growth phase. Faulkner et al. (1994) also reported supplemented calves converted feed to gain less efficiently during the feedlot phase than calves that received no supplement. These CON cattle also spent 19 days longer on feed than the average of the other treatments to achieve standard harvest endpoint.

Carcass Evaluation

The carcass characteristics for this trial are presented in Table 9. Despite spending more days on feed, CON cattle had less backfat than the average of the remaining treatments at harvest ($P = 0.02$). This difference is quantitatively minimal (1.24 cm vs. 1.14 cm) but is significant since cattle were harvested at a target backfat minimizing variation thus lowering the standard error. Previous studies have shown lower HCW in early-weaned cattle (Schoonmaker et al., 2002; Schoonmaker et al., 2004a); however, in this trial there were no differences in HCW. CON cattle had lower percent KPH ($P = 0.04$) than the remaining treatments. Creep-fed cattle had a larger LMA ($P = 0.03$), but when LMA was reported per 100 kg of HCW there were no differences ($P = 0.18$) between creep-fed cattle and early-weaned cattle. Previous studies show no differences in LMA (Myers et al., 1999b; Shike et al., 2007). There were no differences in carcass yield grade or the percentage of cattle that were yield grade 1, 2, 3, or 4. This was expected since 12th rib fat thickness and LMA were similar across treatments. Early-weaned calves had higher marbling scores than creep-fed cattle (586 vs. 500, $P < 0.01$). Early weaned and creep-fed calves combined had higher marbling scores than CON cattle (543 vs. 476, $P < 0.01$). Previous studies have shown early weaning improves marbling scores and thus quality grades (Loy et al., 1999; Meyers et al., 1999a; Shike et al., 2007). Deutscher and Slyter (1978) observed that creep-fed cattle exhibit higher marbling scores and quality grades than normal-weaned calves. Most creep feeding studies show no difference in quality grade or marbling score when creep-fed calves are compared to control calves (Garrigus et al., 1969; Tarr et al., 1994; Myers et al. 1999a). Both early-weaned and creep-fed cattle graded over 90% USDA Low Choice. Early-weaned calves graded a higher percentage Average Choice or better, Low Prime or better, and Certified Angus Beef (CAB) than creep-fed. CON cattle graded a lower percentage

Low Choice or better, Average Choice or better, Low Prime or better, and CAB than the remaining treatments.

No differences in marbling score or quality grades were found when evaluating source of energy. The literature shows mixed results for the effects of source of energy on carcass quality. Schoonmaker et al. (2004a) and Schoonmaker et al. (2004b) found no differences in final carcass grades or marbling scores between an ad libitum concentrate diet and ad libitum fiber diet. In contrast, Faulkner et al. (1994) showed that calves creep fed a high concentrate corn diet resulted in higher quality grades than calves creep fed a fiber-based soyhull diet. Despite mixed results in terms of carcass characteristics, mechanisms behind increasing intramuscular fat deposition have been consistent. Smith and Crouse (1984) showed that glucose provides 51-76% of acetyl units in intramuscular fat and that lactate and acetate where a lesser percentage of acetyl units. However, in subcutaneous fat, acetate supplies 68-77 % of the acetyl units and glucose is an extremely small percentage. Also, volatile fatty acid ratios play a role in the deposition of intramuscular and subcutaneous fat. Shifting fermentation patterns can alter the acetate:propionate ratio. Since propionate is a precursor to glucose, if the acetate:propionate ratio is lower, we can assume intramuscular adipocytes could increase without increasing subcutaneous adipose tissue because more glucose substrate is available. In agreement with Smith and Crouse, Schoonmaker et al. (2003) found a high concentrate diet fed to ruminally fistulated steers resulted in a lower pH (5.4 vs. 6.0 at 9hr), higher concentrations of propionate (38.2 vs. 17.8) and lower acetate concentrations (41.1 vs. 59.1) compared to a high fiber diet. Huntington (1997) also showed that, via starch fermentation, growing animals fed high-concentrate diets have greater ruminal production of propionate. With variation in carcass characteristics, but similar results in metabolism trials, other factors could be affecting carcass quality.

The bran used in this trial was a fiber source that is higher in fat than feeds used in previous studies. This higher fat content of the bran could have had an effect on the acetate:propionate ratio, and propionate production. As dietary fat enters the rumen, ester linkages of dietary fatty acyl glycerol undergo hydrolysis by microbial lipolytic enzymes. This forms glycerol and free fatty acids (Jenkins, 1993). Glycerol is then metabolized by rumen microorganisms to produce VFAs (Nagaraja et al., 1997). Fatty acids that were produced at the same time as glycerol are then freed by lipolysis. These free fatty acids (FFA) may then cause antimicrobial effects in the rumen (Palmquist and Jenkins, 1980), which results in a shift in molar proportions of VFAs (Doreau and Chilliard, 1997). This shift in molar proportions could have been initiated by the high levels of fat in the fiber diet used in this trial. The fat in the bran product may have acted similar to fat supplementation. Whitney et al., (2000) found that when adding 2.9% soybean oil as a fat supplement to the diet of beef cattle the acetate:propionate ratio declined and molar proportions of propionate increased. When the level was increased to 6.2%, the opposite was observed, suggesting rumen fermentation was impaired and that there is an upper limit to fat supplementation. Scholljegerdes et al., (2004) added safflower seeds to beef cattle rations as a fat supplement and they found a decrease in the acetate:propionate ratio.

A shift in the production of VFA also can occur due to the bio-hydrogenation of fat. When unsaturated fats are bio-hydrogenated forming saturated fats hydrogen is used. This results in a shift of the volatile fatty acid patterns towards an increase in propionic acid and a decrease in acetic and butyric acids (Doreau and Chilliard, 1997). This results in a more efficient rumen environment and leads to a decrease in methanogenesis. This suggests that bio-hydrogenation of fat could lead to an increase in propionate production shifting the acetate:propionate ratio in favor of propionate. Through this process, the high fat level of the fiber-based diet in this trial

may have resulted in similar propionate production and an acetate:propionate ratio to that of a starch based diet.

Another factor that could be affecting intramuscular fat deposition in young beef calves in this trial is rumen pH. Felix and Loerch (2011) when evaluating high dietary inclusion of DDGS (60% DDGS on DM basis) on hydrogen sulfide gas production, observed low pH values and low acetate:propionate ratios. The diet that had no added haylage or monensin had a pH of 5.16 an hour and a half post-feeding and an acetate:propionate ratio of 0.94 six hours post-feeding. Authors suggest sulfuric acid may be responsible for lowering ruminal pH and causing a shift in the acetate:propionate ratio. The bran in this study is comparable in sulfur content to DDGS and was included at 60.26% in the creep feed and nearly 50% in the early weaned diet on a DM basis. The effects of high dietary inclusion of DDGS found by Felix and Loerch (2011) may also be a reason that cattle on the fiber-based diet had similar carcass characteristics to cattle fed the starch-based diet in this trial. It is most likely that a combination of these processes and mechanisms caused the fiber-based diet used in this trial to result in similar carcass characteristics to the starch-based diet.

Economics

Two different economic evaluations were conducted with this data. The economics of selling calves at weaning are shown in Table 10. EWF calves had \$13.06 lower total feed costs per head than EWS despite higher creep intakes ($P < 0.01$). EWF calves also had \$15.01 higher profit per head than EWS ($P = 0.06$). Similar to source of energy in early-weaned cattle, NWF had \$25.10 lower feed costs ($P < 0.01$) and \$15.69 higher profit ($P < 0.05$). The difference in total feed costs can be attributed to the higher price of corn compared with the co-products which resulted in higher diet cost for the starch-based diet. When comparing early-weaned cattle with

creep-fed cattle, CF calves had \$49.80 lower total feed costs per head ($P < 0.01$), \$0.46 lower interest costs ($P = 0.05$), \$38.26 lower total costs ($P < 0.01$), and \$22.83 higher profit ($P < 0.01$). Creep-fed cattle were assessed a pasture fee and early-weaned cattle were not. Creep-fed cattle were more profitable in the feeder calf economics because they had lower intakes. When all other treatments were compared to the control, CON calves had the lowest total costs. This is a result of the CON calves having no feed costs, no feed interest which ends in lower total interest, and no yardage. CON calves did have the highest pasture fee ($P < 0.01$). As a result of CON cattle having the lowest costs and no statistical difference in value, the CON were the most profitable ($P < 0.01$). The CON cattle did experience higher gains than previous studies (Schoonmaker et al., 2001, Barker-Neef et al., 2001, Myers et al., 1999a). In years with more normal rainfall or drought these gains would be unlikely and thus profit and economic advantages are likely to diminish for the CON cattle. With higher gains observed for the CON cattle, if calves were marketed at the time of normal weaning as feeder calves, CON would be the most profitable.

Economic evaluation of this data as a retained ownership is displayed in Table 11. EWF calves received \$3.06 higher price (\$/45.5 kg) than EWS, meaning EWF calves received more yield and quality grade premiums added to the base price of the carcass. This resulted in EWF calves having \$44.63 more profit than EWS ($P = 0.03$). There were no significant differences in other economical categories between EWS and EWF. Although there were no statistical differences between CFS and CFF aside from the pasture fee, the CFF calves were still numerically \$18.39 more profitable per head than CFS. Creep-fed calves had \$63.55 lower total feed costs per head, \$33.96 lower yardage costs per head, and \$49.94 lower total costs per head than early weaned calves ($P < 0.01$). Despite the fact that early-weaned cattle received a higher

price (\$143.21 vs. \$141.22, $P = 0.02$), creep-fed cattle ended \$54.05 more profitable per head than EW ($P < 0.01$). This is in agreement with Shike et al., (2007) where they found creep-fed calves were \$79.86 more profitable than early-weaned calves. The CON cattle experienced the highest pasture fee and the highest yardage costs. The yardage costs increase as a result of CON calves spending the most days on feed in the finishing phase. The CON calves had the lowest carcass price, which is reflective of the poorer quality grades. Still, CON cattle had the lowest feed costs, lowest total costs, and were the most profitable ($P < 0.01$). CON cattle did however experience higher gains than expected. In contrast to the present trial, Shike et al., (2007) found that creep-fed cattle were more profitable than control cattle, but gains of control cattle were not as high as the present trial. Differences in carcass quality were minimal and could not to overcome the added costs associated with early-weaned and creep-fed cattle. Barker-Neef et al., (2001) evaluated the economics of early weaned (100 days) and normal weaned calves (200 days). In spite of using different pricing schemes, early weaning was associated with less return to the cow-calf producer and higher feeder calf breakeven prices. Story et al. (2000) also looked at the economics between EW and NW cattle. NW cattle resulted in a \$1.44 profit per cow and EW resulted in a \$51.29 loss per cow. Previous studies have shown that early weaning beef calves can increase stocking rates (Harvey and Burns, 1988) and reduce cow intake (Peterson et al., 1987). Other trials have also found that if early weaning takes place before breeding, reproduction can be improved in cows (Laster et al., 1973; Lusby et al., 1981; and Arthington and Kalmbacker, 2003). This study did not look at the effects of weaning age, creep feeding, and source of energy on cow performance and reproduction. To truly measure the economic impact of these management systems, cow performance and reproduction should be considered.

Implications

Early weaning improved growing phase gains and marbling scores when compared to creep feeding. However, creep-fed calves had higher gains and were more efficient than early-weaned calves in the finishing phase. Control calves had the worst gain in the growing phase, spent the most days on feed in the feedlot, and had the lowest marbling scores. Due to having the lowest costs, control calves were the most profitable in both economic evaluations. In this study, when the control cattle gained well, there was not a large enough advantage in carcass quality to overcome the added costs associated with early weaning and creep feeding. No differences in carcass characteristics were found due to source of energy. This suggests that high-fat co-products could be as effective as corn or starch-based diets in initiating marbling in young beef calves.

Tables

Table 1. Composition of early weaned diets on a dry matter percentage basis

Ingredient	Starch-based Diet	Fiber-based Diet
Corn Bran ^a	-	49.75
Soybean Hulls	-	24.60
Ground Hay	16.20	15.81
Dry Whole Kernel Corn	66.80	-
Supplement 869 ^b	17.00	-
Supplement 870 ^b	-	9.84

^aDakota Gold Corn Bran

^bRefer to Table 4

Table 2. Composition of creep feeds on a dry matter percentage basis

Ingredient	Starch Creep	Fiber Creep
Dry Whole Kernel Corn	82.03	-
Corn Bran ^a	-	60.26
Soybean Hulls	-	29.80
Supplement 869 ^b	17.97	-
Supplement 870 ^b	-	9.94

^aDakota Gold Corn Bran

^bRefer to Table 4

Table 3. Composition of finishing phase diet on a dry matter percentage basis

Ingredient	Inclusion level
Corn Husklage	64.26
Wet Corn Gluten Feed	21.00
Dry Rolled Corn	10.08
Supplement 712 ^a	4.66

^a Refer to Table 5

Table 4. Composition of growing phase supplements on a dry matter basis

Ingredient	Starch (869)	Fiber (870)
Soybean Meal	90.23	81.80
Limestone	9.00	16.80
Trace Mineralized Salt	0.67	1.00
Thiamine	-	.25
Copper Sulfate	0.03	0.05
Vitamin ADE	0.07	0.10

Table 5. Composition of finishing phase supplements for steers and heifers^a

Ingredient	Supplement 712
Ground Corn	85.10
Limestone	11.00
Urea	2.50
Trace Mineralized Salt	1.00
Thiamine	.25
Copper Sulfate	0.05
Vitamin ADE	0.10

^a MGA was added to the heifer supplement at 0.4 mg/hd/d

Table 6. Five-year average^a grid premiums and discounts (\$/45.4 kg)^{bc}

Item	1	2A	2B	3A	3B	4	5
Prime	18.08	16.02	15.94	13.88	13.88	-0.75	-8.53
Premium Choice	5.89	3.83	3.75	1.69	1.69	-12.94	-20.72
Low Choice	4.11	2.05	1.97	-0.09	-0.09	-14.72	-22.50
Select	-4.55	-6.61	-6.69	-8.75	-8.75	-23.38	-31.16
Standard	-10.97	-13.03	-13.11	-15.17	-15.17	-29.80	-37.58

^a2005-2009 (USDA, 2010)

^bDressed beef price: 131.78/45.4 kg (USDA, 2010)

^cWeight discounts: 181- 227 kg, -\$32.04; 227-249 kg, -\$23.78; 250-272 kg, -\$0.80; 273-431 kg, \$0.00; 432-454 kg, -\$1.44; over 454 kg, -\$22.21

Table 7. Effects of weaning age and source of energy on calf performance

Item	Treatments ^a					SEM ^b	Contrasts ^c			
	EWS (1)	EWf (2)	CFS (3)	CFF (4)	CON (5)		1 vs. 2	3 vs. 4	1 & 2 vs. 3 & 4	1,2,3,4, vs. 5
No. of Pens	5	5	5	5	5					
Growing										
Start Wt., kg	177	175	177	179	176	5.7	0.81	0.80	0.67	0.92
ADG, kg	1.63	1.62	1.53	1.50	1.20	0.03	0.87	0.34	< 0.01	< 0.01
DMI, kg	5.96	6.84	-	-	-	0.17	< 0.01	-	-	-
Supp DMI, kg	-	-	3.83	3.44	-	0.61	-	0.66	-	-
G/F	0.270	0.239	-	-	-	0.004	< 0.01	-	-	-
Supp. G/F	-	-	0.096	0.096	-	0.009	-	0.96	-	-
Final Wt, kg	338	337	330	327	293	7.5	0.93	0.81	0.26	<0.01

^aEWS = early wean- starch based diet, EWf = early wean- fiber based diet, CFS = normal wean- creep fed starch based diet, CFF = normal wean- creep fed fiber based diet, CON = normal wean-no creep

^bPooled standard error of the mean

^cContrasts: EWS vs. EWf, CFS vs. CFF, EWS & EWf vs. CFS & CFF, and EWS, EWf, CFS, & CFF vs. CON

Table 8. Effects of weaning age and source of energy on feedlot performance

Item	Treatments ^a					SEM ^b	Contrasts ^c			
	EWS (1)	EWf (2)	CFS (3)	CFF (4)	CON (5)		1 vs. 2	3 vs. 4	1 & 2 vs. 3 & 4	1,2,3,4, vs. 5
No. of Pens	5	5	5	5	5					
Finishing										
Start Wt, kg	338	337	330	327	293	7.5	0.93	0.81	0.26	<0.01
ADG, kg	1.48	1.46	1.58	1.61	1.60	0.09	0.63	0.56	<0.01	0.09
DMI, kg	10.63	10.33	9.87	9.80	10.09	0.46	0.31	0.82	<0.01	0.77
Final Wt, kg	535	539	539	554	541	11.0	0.81	0.33	0.37	0.94
G/F	0.140	0.142	0.161	0.165	0.160	0.003	0.61	0.29	<0.01	< 0.01
DOF ^d	135	139	134	140	156	4.58	0.49	0.28	0.97	< 0.01

^aEWS = early wean- starch based diet, EWf = early wean- fiber based diet, CFS = normal wean- creep fed starch based diet, CFF = normal wean- creep fed fiber based diet, CON = normal wean-no creep

^bPooled standard error of the mean

^cContrasts: EWS vs. EWf, CFS vs. CFF, EWS & EWf vs. CFS & CFF, and EWS, EWf, CFS, & CFF vs. CON

^dDays on Feed

Table 9. Effects of weaning age and source of energy on beef cattle carcass traits

Item	Treatments ^a					SEM ^b	Contrasts ^c			
	EWS (1)	EWf (2)	CFS (3)	CFF (4)	CON (5)		1 vs. 2	3 vs. 4	1 & 2 vs. 3 & 4	1,2,3,4, vs. 5
No. of pens	5	5	5	5	5					
Yield										
HCW, kg	332	334	334	342	335	6.7	0.82	0.39	0.41	0.97
Backfat, cm	1.22	1.24	1.24	1.24	1.13	0.04	0.64	0.99	0.72	0.02
KPH	2.19	2.21	2.16	2.12	2.08	0.036	0.72	0.46	0.07	0.04
LMA, cm ²	76.7	74.9	78.4	79.4	79.7	1.43	0.35	0.61	0.03	0.13
LMA, cm ² /100 kg	23.2	22.5	23.5	23.2	23.8	0.33	0.12	0.46	0.18	0.08
Ave Yield Grade	2.59	2.63	2.48	2.64	2.43	0.09	0.78	0.22	0.63	0.11
Yield Grade 1, %	0.0	2.6	0.0	0.0	2.5	-	0.26	1.00	0.43	0.31
Yield Grade 2, %	48.7	34.2	54.1	37.8	52.5	-	0.21	0.16	0.58	0.32
Yield Grade 3, %	43.2	60.5	43.2	59.5	45.0	-	0.14	0.16	0.95	0.46
Yield Grade 4, %	8.1	2.6	2.7	2.7	0.0	-	0.18	1.00	0.36	0.20
Quality										
Marbling Score ^d	574	598	506	493	476	16.5	0.30	0.57	<0.01	<0.01
≥ Low Choice, %	91.9	100.0	89.2	91.7	75.0	-	0.24	0.72	0.26	<0.01
≥ Ave Choice, %	78.4	81.6	51.4	41.7	40.0	-	0.76	0.37	<0.01	<0.01
≥ Low Prime, %	13.5	23.7	8.1	0.0	0.0	-	0.11	0.20	<0.01	0.02
% CAB ^e	75.7	76.3	45.9	41.7	35.9	-	0.95	0.69	<0.01	<0.01

^aEWS = early wean- starch based diet, EWf = early wean- fiber based diet, CFS = normal wean- creep fed starch based diet, CFF = normal wean- creep fed fiber based diet, CON = normal wean-no creep

^bPooled standard error of the mean

^cContrasts: EWS vs. EWf, CFS vs. CFF, EWS & EWf vs. CFS & CFF, and EWS, EWf, CFS, & CFF vs. CON

^d400 = Low Choice, 500 = Average Choice, 600 = High Choice

^eCertified Angus Beef

Table 10. Effects of weaning age and source of energy on feeder calf economics

Item	Treatments ^a					SEM ^b	Contrasts ^c			
	EWS (1)	EWf (2)	CFS (3)	CFF (4)	CON (5)		1 vs. 2	3 vs. 4	1 & 2 vs. 3 & 4	1,2,3,4, vs. 5
No. of pens	5	5	5	5	5					
Costs										
Feeder Calf, \$/head	437.39	433.93	438.10	441.82	436.72	10.3	0.81	0.80	0.68	0.92
Total Feed, \$/head	129.77	116.71	84.99	59.89	0	2.54	<0.01	<0.01	<0.01	<0.01
Creep Feeder ^d	-	-	11.5	11.5	-	-	-	-	-	-
Pasture Fee ^e , \$/head	0	0	31.76	33.05	44.39	.41	1.0	0.03	<0.01	<0.01
Processing ^f , \$/head	25.0	25.0	25.0	25.0	25.0	-	-	-	-	-
Yardage ^g , \$/head	35	35	0	0	0	-	-	-	-	-
Interest ^h , \$/head	11.01	10.78	10.53	10.34	9.57	0.23	0.50	0.56	0.05	<0.01
Total Costs, \$/head	638.17	621.43	601.69	581.40	515.68	11.2	0.29	0.20	<0.01	<0.01
Value, \$/head	737.56	736.08	725.64	721.72	670.39	11.5	0.92	0.51	0.78	0.40
Profit, \$/head	86.20	101.21	108.69	124.38	129.84	5.5	0.06	0.05	<0.01	<0.01

^aEWS = early wean- starch based diet, EWf = early wean- fiber based diet, CFS = normal wean- creep fed starch based diet, CFF = normal wean- creep fed fiber based diet, CON = normal wean-no creep

^bPooled standard error of the mean

^cContrasts: EWS vs. EWf, CFS vs. CFF, EWS & EWf vs. CFS & CFF, and EWS, EWf, CFS, & CFF vs. CON

^d\$0.115/day for creep feeder depreciation and labor costs associated with feeding

^eAdcock, Unpublished

^f\$35/ head for vaccinations, implants, fly tags, and medications

^g\$ 0.35/day

^h8.0% Annual Percentage Rate

Table 11. Effects of weaning age and source of energy on retained ownership economics

Item	Treatments ^a					SEM ^b	Contrasts ^c			
	EWS (1)	EWF (2)	CFS (3)	CFF (4)	CON (5)		1 vs. 2	3 vs. 4	1 & 2 vs. 3 & 4	1,2,3,4, vs. 5
No. of pens	5	5	5	5	5					
Costs										
Feeder Calf, \$/head	437.39	433.93	438.10	441.82	436.72	10.3	0.81	0.80	0.68	0.92
Total Feed, \$/head	305.24	297.44	240.89	234.69	200.25	7.42	0.46	0.56	<0.01	<0.01
Creep Feeder ^d	-	-	11.5	11.5	-	-	-	-	-	-
Pasture Fee ^e , \$/head	0	0	31.76	33.05	44.39	.41	1.0	0.03	<0.01	<0.01
Processing ^f , \$/head	35.0	35.0	35.0	35.0	35.0	-	-	-	-	-
Yardage ^g , \$/head	84.90	81.96	49.56	49.37	50.50	1.6	0.22	0.93	<0.01	<0.01
Interest ^h , \$/head	28.10	26.62	26.94	26.90	26.55	0.8	0.19	0.97	0.59	0.50
Total Costs, \$/head	890.63	874.96	833.56	832.14	793.42	12.9	0.39	0.93	<0.01	<0.01
Price ⁱ , \$/45.4 kg	141.83	144.59	141.88	140.56	139.33	0.87	0.03	0.29	0.02	<0.01
Value, \$/carcass	1034.96	1063.91	1045.06	1066.99	1031.80	22.6	0.37	0.51	0.78	0.41
Profit, \$/head	144.33	188.96	211.50	229.89	236.49	14.5	0.03	0.38	<0.01	<0.01

^aEWS = early wean- starch based diet, EWF = early wean- fiber based diet, NWS = normal wean- creep fed starch based diet, NWF = normal wean- creep fed fiber based diet, CON = normal wean-no creep

^bPooled standard error of the mean

^cContrasts: EWS vs. EWF, CFS vs. CFF, EWS & EWF vs. CFS & CFF, and EWS, EWF, CFS, & CFF vs. CON

^d\$0.115/day for creep feeder depreciation and labor costs associated with feeding

^eAdcock, Unpublished

^f\$35/ head for vaccinations, implants, fly tags, and medications

^g\$ 0.35/day

^h8.0% Annual Percentage Rate

ⁱBase Price: 139.80-steers; 139.90-heifers

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