Corn distillers dried grains with solubles supplementation in a pasture-based beef production system

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Corn distillers dried grains with solubles supplementation in a pasture-based beef production system

by

Peter Wallace Lasley

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CHAPTER 1. INTRODUCTION

Harvested feed costs are economically significant in beef production systems as feed costs represent 45 to 50% of cow maintenance costs (Strohbehn, 1990). This significance of feed costs make the decision of how and what to feed a driver in the profitability of most beef cattle production systems. The feeding of hay and processed feeds is a common practice in the beef industry (Lalman et al., 2000), but producers with lower feed costs generally allow cattle to harvest feeds (Strohbehn, 1990). Furthermore, grazing stockpiled forage has reduced feed costs for spring-calving beef cows by reducing the need for harvested feeds (Adams et al., 1994; Hitz and Russell, 1998; Allen et al., 2000). Similarly, August-calving cows and calves grazing stockpiled forage required 64% less hay than April-calving cows fed hay in a drylot (Janovick et al., 2004). Another driver of profitability is the value of the product produced, which in the case of beef production systems is the weaned calf or finished steer. It has been observed that the adjusted weaning weights of August calves whose dams grazed stockpiled forages were 9% less than spring calves from cows with similar genetic backgrounds. This potential difference in weaning weights has driven the use of supplemental feeds to either cows or calves.

Supplementation of energy and/or protein will improve body condition score (BCS) and/or body weight (BW) of cows grazing stockpiled forage over winter (Wheeler et al., 2002; Llewellyn et al., 2006; Poore et al., 2006). Protein or fiber-based energy supplementation of lactating cows grazing dormant or summer native forages, or pea-based creep feed supplementation of calves can increase calf BW gains from birth to weaning (Gelvin et al., 2004; Llewellyn et al., 2006; Reed et al., 2006b).

Grains have been fermented as a source of ethanol for centuries, often used in the production of beverages, and, before the early 1900s, the co-product of this ethanol production, distiller’s grains, have been used as an economical feed for ruminants. In recent years, production of ethanol has increased dramatically in the United States. From 2000 to 2008, ethanol production has increased over 5 fold (Renewable Fuels Association, 2009). This increase in production has caused both the increase in the cost of corn grain, one of the major substrates for modern ethanol production, and the increased availability, interest, and research in distillers grains as a source of feed for cattle throughout the stages of production.
Distiller’s dried grains (DDG) are a concentrated source of protein, fat, and fiber remaining after the fermentation of the starch resulting in a feed of interest for supplementation to grazing cattle.

In recent years corn, land, and beef prices have risen, increasing the need for systems research to assure that the changes within various stages of the beef production system have overall positive effects on profitability. In the case of supplementation, systems research is especially important as calves have demonstrated the ability to compensate for growth restriction in earlier stages of production with greater BW gains when provided adequate dietary energy (Carstens et al., 1991; Choat et al., 2003), pre-weaning supplementation may not be an efficient use of feed resources. Another consideration when supplementation of grazing cattle is considered is the effect of the supplemental feed on the utilization of the grazed forage from both the standpoint of intake effects (substitution rate), and also on the digestibility.

The objective of this study was to evaluate corn distillers dried grains with solubles (CDDGS) supplementation of August-calving cows or calves grazing stockpiled forage on cow and calf BW changes during winter and BW gain and carcass characteristics of the calves finished in a pasture-based system. Additionally, a metabolism study was conducted to evaluate the effect of CDDGS supplementation of cattle fed smooth bromegrass hay on the intake and digestibility of DM and its components of the hay and total diet.

The format of this thesis is composed of an Introductory section, a literature review, a manuscript entitled ‘Effects of corn distillers dried grains supplementation of August-calving cows or calves grazing stockpiled forage on performance of cows and calves during the winter and subsequent performance of calves in a pasture-based finishing system’ to be submitted to the Journal of Animal Science, a manuscript entitled ‘Effects of distillers dried grains with solubles supplementation of smooth bromegrass hay on forage and total diet intake and digestion’ to be submitted to Animal Feed Science and Technology, and a general conclusion.
CHAPTER 2. LITERATURE REVIEW

Stockpiled forage

In the Midwestern United States, beef cattle have traditionally been maintained during winter by providing stored feeds (Lalman et al., 2000). This feeding of hay and processed feeds is a common practice in the beef industry (Lalman et al., 2000) allowing producers a measure of risk management by facilitating the storage of feeds in excess of what would be consumed and produced in a given year. This ability to store feeds allows producers to better manage both feed resources and cattle nutrition in years of decreased hay production or increased feed use caused by inclement weather. One disadvantage to mechanically harvested forages is the financial cost. This cost of harvested feeds is economically significant as feed costs represent the highest single input in cow-calf operations, accounting for 45 to 50% of cow maintenance cost. Feed cost is also one of the most variable costs among operations with the most profitable operations having the lowest feed cost (Strohbehn, 1990). Grazing stockpiled forage can offset this additional cost as grazing of stockpiled forages can reduce the need for harvested feeds (Allen et al., 2000; Adams et al., 1994; Hitz and Russell, 1998). Driskill et al. (2007) determined that production costs were higher for cows fed hay in the drylot over winter than for cows grazing stockpiled tall fescue-red clover because of the cost of hay feeding. Schoonmacher et al. (2003) found that feeding hay was approximately twice as expensive as limit-feeding corn or grazing stockpiled orchardgrass. Adams et al. (1994) suggested that the availability of winter range or other grazing lands could become the limiting factor for cattle producers wanting to reduce feeding cost by grazing during winter.

While grazing of stockpiled forage has been shown to reduce feed costs, maintenance of BCS, reproductive ability, and BW of cows are still important considerations. Hitz and Russell (1998) found that grazing of stockpiled forages could reduce a cow’s need for baled hay by 67% while maintaining similar BCS. Driskill et al. (2007) observed that cows in the drylot had greater BW gains and less BCS loss than those grazing stockpiled forage because of the higher nutritional value of hay than stockpiled forage. However, all cows including those in a minimal supplementation group were at or above the previously established target BCS of 4.33 on a 9-point scale. Cows grazing stockpiled forage in winter were able to
maintain acceptable body condition in spite of snow cover of greater than 2.54 cm for 64 and 34 d in 2 years, respectively. Cattle have the ability to graze through up to 0.5 m of fresh snow, but this ability is reduced if the snow has undergone freeze thaw cycles or if the snow has become trampled or crusted (Riesterer et al., 2000a). Allen et al. (1992a) indicated that cows that grazed stockpiled tall fescue in fall and winter showed differences in BCS between years primarily because of weather differences.

Regardless of the winter-feeding practice, when cow-calf pairs grazed sub-irrigated meadows in May, weaning weights of the calves were 5 kg greater than calves of cows that were fed hay or grazed dormant range. The greater weaning weights resulted in greater profitability than grazing native range or feeding hay in a drylot when opportunity costs were considered (Adams et al., 1994). As long as reasonable weight gains are maintained in winter, minor differences can be overcome during spring and summer through adequate nutrition. Therefore, grazing range or sub-irrigated meadow during the winter did not have detrimental effects on reproduction when followed by adequate nutrition (Adams et al., 1994).

Schoonmacher et al. (2003) found that limit-feeding corn and hay (5.8 kg corn, 1.1 kg pelleted corn soybean meal supplement, and 1.2 kg hay), ad libitum hay feeding, or grazing stockpiled forage did not affect the birth weights, and weaning weights of calves or conception rates of cows. However, cows that were limit-fed corn and hay had higher post-calving BW than cows grazing stockpiled forage. Grazing stockpiled tall fescue during winter provided cattle with high quality forage which resulted in greater ADG in stocker steers than feeding hay baled from the same species as the stockpiled forage (Allen et al., 1992b). This increase in average daily gain (ADG) was attributed to higher digestibility of the stockpiled tall fescue. Poore et al. (2006) also found that stockpiled fescue has sufficient nutritive value to meet the requirements of heifers, but if low ADG or BCS is observed, some level of supplemental protein or energy may be advisable.

Hedtke et al. (2002) found that the quality of stockpiled forages decreased over winter. Concentration of crude protein (CP) and in vitro dry matter digestibility (IVDMD) in stockpiled tall fescue forage declined from 11.6 to 10.7% and 73.4 to 65.5%, respectively, while concentrations of neutral detergent fiber (NDF) and acid detergent fiber (ADF)
increased from 59.4 to 66.7% and 36.7 to 43.5%, respectively, by the end of a winter.

Effects of N fertilization on nutritive value of stockpiled forage varied between species and location. However, across species, N fertilization increased forage CP concentration, but had no effect on the concentrations of IVDMD, NDF, or ADF. Even with the declining forage quality over winter, Hedtke et al. (2002) concluded that the nutritional value of stockpiled forage was generally sufficient for beef cows if forage was accessible and appropriate stocking rates were maintained.

The quality of the stockpiled forage is dependent on some of the same conditions that affect the quality of hay. Specifically, the maturity of the forage at the beginning of dormancy, the temperature and amount of daylight during the growing season, the moisture levels of soil and precipitation, forage species and variety, and level of N fertilization affect the forage mass and quality (Lalman et al., 2000). Wolf and Opitz von Boberfeld (2003) found that the shortening of the forage growing season before the onset of dormancy increases the forage quality.

Fertilization with N has been shown to have mixed effects depending on the timing of application and weather conditions before and after its use. Reisterer et al. (2000a) found that fertilization with 67 kg N/ha increased stockpiled forage mass by 54 to 107% and increased the plant mass above 8 cm when applied in late summer. The greatest response in forage mass to fertilization occurred in years with greater precipitation. Singer et al. (2003) found that late summer fertilization increased forage mass and nutritional quality with late season weather playing a role in N effects. Nitrogen fertilization in May may have no effect on the mass of stockpiled forage (Reisterer et al., 2000a) and application in August as compared to July can reduce forage mass, physiological age of the plants, and acid detergent lignin concentration, and increase metabolizable energy concentration of the forage (Wolf and Opitz von Boberfeld, 2003). At the same time, increasing the rate of N application can increase DM yields and the concentrations of CP, and acid detergent lignin (ADL) (Wolf and Opitz von Boberfeld, 2003). Not only is the timing of application of N fertilizer important, but Reisterer et al. (2000b) found that one application was more effective in increasing the yield of forage than a split application of fertilizer.
While all types of forages can be used for stockpiled grazing, the characteristics of the forage make some species more desirable for stockpiling than others. Reisterer et al. (2000a) found that tall fescue and early maturing orchardgrass followed by late maturing orchardgrass had higher yields than reed canarygrass, timothy, quackgrass or smooth bromegrass throughout the winter. Early maturing orchardgrass, reed canarygrass, and tall fescue had the highest biomass after the winter grazing season with losses ranging from 24 to 38% compared to losses of 50 to 59% in other grasses (Reisterer et al., 2000a). Tall fescue is considered to be an ideal choice for stockpiling (Baron et al., 2004; Allen et al., 1992a; Poore et al., 2000) because of its ability to accumulate nonstructural carbohydrates (NSC), response to N fertilization (Reisterer et al., 2000b), productivity (Wolf and Opitz von Boberfeld, 2003, Poore et al., 2000; Bagley et al., 1983), reduced deterioration over winter (Singer et al., 2003, Poore et al., 2000, Reisterer et al., 2000a), re-growth characteristics (Baron et al., 2004), and persistence from year to year (Reisterer et al., 2000b).

Weather is an important factor in any stockpiled grazing situation. Low levels of precipitation in the fall require stockpiling to begin in early August for sufficient accumulation (Poore et al., 2000). Freezing will halt forage growth in the winter, which requires additional adjustment of stockpiling period (Lalman et al., 2000). Heavy snow fall after the killing frost until March when regrowth begins will cause increased forage loss (Reisterer et al., 2000a). Winter weather causes deterioration in the forage quality and may decrease the voluntary intake of the forage from November to March (Bagley et al., 1983). Bagley et al., (1983) found that CP, NSC, and digestibility of the forages decreased over winter grazing from 10.6 to 9.5%, 15.9 to 5.5%, and 63.3 to 42.7%, respectively. Forage nutritive value is typically highest in the fall and deteriorates over winter (Singer et al., 2003; Kallenbach et al., 2003) as indicated by increasing ADF concentrations. Kallenbach et al. (2003) found that with the mild winter conditions in Missouri, forage quality did not deteriorate quickly after mid-December. Average CP, ADF, and NDF concentrations at that time were 13, 30, and 58% in stockpiled tall fescue respectively, which should be sufficient to meet the needs of lactating and non-lactating cows.
Supplementation of cows, calves, and steers with protein and/or energy

With the variation in forage production and nutritional value, nutritional supplementation of cattle may be necessary if forages are unable to meet animal requirements during late gestation, lactation, or periods of rapid growth. In general, supplementation of energy, protein, or protein and energy may improve cow BCS and/or BW through the winter grazing season (Wheeler et al., 2002; Llewellyn et al., 2006; Farmer et al., 2001; Poore et al., 2006). Llewellyn et al. (2006) found that pre-weaning protein supplementation of spring-calving cows grazing low quality forages over winter increased cow BW gains over that of the unsupplemented cows, but these gains did not change cow reproduction rates or calf birth weight. Farmer et al. (2001) also found that daily supplementation of protein decreased BCS loss and increased BW of cows grazing over winter, but calf birth weight was not affected. Wheeler et al. (2002) observed that cows grazing stockpiled forage supplemented with protein lost less BCS than unsupplemented cows. The improved animal BCS in supplemented cows resulted from higher forage intake as shown by increased utilization rate of stockpiled forage. As little as 1.62 kg/d of protein supplementation can increase cow BW gains by increasing the digestibility of low quality native grass pastures in winter (Llewellyn et al., 2006).

For cattle grazing winter range, effects of additional protein or energy have been related to forage nutritive value and digestibility (Kartchner, 1981; Karn, 2000). High forage concentrations of energy and protein may reduce effects of supplemental protein or energy on cow forage DMI, DM digestibility, or cow ADG. When the concentration of energy and protein in the forage were reduced, protein-supplementation increased total DMI, and the digestibilities of DM and cellulose (Kartchner, 1981). With primiparous heifers grazing stockpiled endophyte-free tall fescue, supplementation with increased undegradable intake protein (UIP) did not affect postpartum interval or milk production implying that total metabolizable protein intake from the stockpiled forage was sufficient (Strauch et al., 2001). These results imply that there is no advantage to supplementing beyond the cattle requirement for UIP (Strauch et al., 2001) or CP (Karn, 2000). But CP supplementation is advantageous when forage does not meet the requirements for CP. When forage quality is
high, supplementation of energy with or without protein may be of some benefit to increase animal gains (Karn, 2000).

Energy and protein supplementation

While protein supplementation may improve animal ADG, BCS, or BW when the concentration of CP is deficient in the forage, further improvement in ADG, BCS, or BW may require energy supplementation as well (Karn, 2000), especially when forage quality is low. Bodine and Purvis (2003) observed that supplementation of beef steers grazing dormant native tallgrass prairie with corn and soybean meal (SBM) increased cattle average daily gain (ADG) over cattle that only received SBM supplementation. However, supplementation of energy in the form of corn grain with or without SBM to cattle while grazing dormant native tall grass prairie decreased organic matter intake and digestibility compared to cattle receiving no supplementation (Bodine and Purvis, 2003). Even with this decrease in forage digestibility and intake, the higher energy density and digestibility of supplements resulted in improved BW gains in cattle compared to unsupplemented cattle. Hess et al. (1998) observed that steers grazing endophyte-free fescue pastures and supplemented with cracked corn or wheat bran consumed less forage and OM, but had higher ADG than unsupplemented steers. Machado et al. (2006) found that supplementation of maize to cattle grazing tall fescue-white clover pastures improved live weight gain and the overall digestibility of the diet, but significantly decreased forage intake and grazing time.

Supplementation of energy might alter the energy required by grazing ruminants by altering their grazing behavior or influencing their efficiency of nutrient use (Caton and Dhuyvetter, 1997). The efficiency of dietary metabolizable energy (ME) for maintenance and gain is influenced by the ratio of forage to concentrate in the diet, with higher proportions of concentrate leading to improved efficiency (Caton and Dhuyvetter, 1997). This improvement in efficiency results from the energy from concentrate being more effectively used for maintenance and gain than is ME from forage due to decreased energy expended in grazing activities (Caton and Dhuyvetter, 1997). In summer, fall, or winter, if forage availability or quality is not sufficient to meet production goals, this improved efficiency can be particularly important.
Oil supplementation

While grain supplementation may increase diet digestibility by supplying increased NSC, oils offers a high energy density alternative to grain. Pavan et al. (2007) observed that, when supplemented to steers grazing endophyte-free tall fescue, corn oil decreased forage and total DMI linearly. *In vivo* DM, OM, and NDF digestibilities were also decreased by corn oil supplementation. In spite of these decreases in intake and digestibility, ADG, final BW, dressing percentage, carcass weight, and carcass backfat of the steers tended to increase linearly in response to oil. In contrast to Pavan et al. (2007), Brokaw (2001) found that soybean oil supplementation improved total tract OM digestibility, but decreased microbial N flow, efficiency and postruminal disappearance in these heifers grazing high quality bermudagrass. One difference between these studies was that Brokaw (2001) fed soybean oil at 0.0375% BW as a part of a cracked corn and corn gluten meal supplement representing 0.3% BW, whereas Pavan (2007) fed corn oil at 0.15% BW with cottonseed hulls as a carrier at 0.7 to 1.0% BW. This difference could represent a combined effect of feeding grain and oil in a supplement. But as a result of the observed decrease in nitrogen efficiency, Brokaw (2001) suggested that with oil supplementation, the metabolizable protein (MP) supply could become deficient.

Soybean and linseed oil supplementation at approximately 0.07 % of BW can allow animals with restricted forage intakes to maintain ADG, pre-slaughter weights, carcass weights, dressing percentage, or perirenal fat weight compared to heifers with *ad lib* forage intakes (Noci et al., 2007). Such supplementation may be beneficial when forage allowance or nutritive value limit BW gain. Using oils as a source of supplemental energy could allow increased pasture stocking rates or the ability to maintain cattle BW gains in years of reduced forage productivity.

Fiber supplementation

Supplementation of both grain and oil to ruminants can reduce forage intake and digestibility (Noci et al., 2007; Pavan et al., 2007). In contrast to grain and oil, energy intake may be increased without reducing forage digestion through the supplementation of fiber-containing energy supplements (Royes et al., 2001).
Hess et al. (1998) found that BW gains were similar in steers grazing endophyte-free tall fescue fed isocaloric amounts of wheat bran or corn. Heldt et al. (1998) observed that wheat middlings supplementation at a high level to beef cows grazing winter range resulted in greater BW gains than supplementation wheat middlings at a lower level or soybean meal at an isonitrogenous level. But cows receiving corn and soybean meal supplement had greater BW gains than cows supplemented with wheat middlings or soybean meal. Because cows fed the corn and soybean meal-supplemented diet had the highest BW gain and metabolizable protein supply, diets supplemented with wheat middlings or soybean meal may have been deficient in metabolizable protein. Highly digestible fiber supplements can also be used effectively as creep feeds without negatively affecting OM intake, total tract OM digestibility, or ruminal fermentation characteristics (Soto-Navarro et al., 2004).

Supplementation of non-structural carbohydrates (NSC) to cattle grazing native rangeland during winter with 0 to 0.96 kg NSC cow\(^{-1}\) \cdot day\(^{-1}\), as mixtures of soy hulls, wheat mids, barley, and SBM, increased total DM intake, but decreased the digestibility of DM and CP (Bowman et al., 2004). This supplement was balanced to supply varying levels of NSC, and additional CP was also supplied resulting in the cumulative increase in CP intake. While supplementation resulted in less BW loss and greater intake of total CP in one year, NSC supplementation resulted in greater BW loss and a decreased intake of total CP in the subsequent year. Results imply that CP and not NSC may have been the limiting nutrient in the diet. The NSC supplement diluted the CP in the ration and, thereby, limited the CP intake and increased BW losses. These results imply that the most limiting nutrient in the diet should be identified and the supplement should be formulated to complement the base feed or forage (Gelvin et al., 2004).

In summary, supplementation may be advantageous when the ADG of grazing steers is lower than desired or maintenance of BCS of grazing cows is difficult because of inadequate forage nutritive value or availability (Caton and Dhuyvetter., 1997). Protein supplements are especially useful when forage CP is low, as it can increase DM digestibility and intake (Köster et al., 1996). In cases of high forage nutritive value, but where greater BW gains are desired, energy supplementation with or without protein is likely to result in higher BW gains (Woods and Scholl, 1962, Brokken and Bywater, 1982). Caution should be
taken in supplement formulation, as grain and oil supplementation can decrease forage intake and digestibility (Caton and Dhuyvetter, 1997; Bodine and Purvis, 2003; Pavan et al., 2007). Negative effects of supplementation can be alleviated while increasing gain by the use of highly digestible fiber sources for ruminants (Soto-Navarro et al., 2004). While supplementation of cows will often increase cow BCS and BW (Caton and Dhuyvetter, 1997), calf birth weights or reproduction are minimally affected as long as cow weight and BCS remain within an acceptable range (Bohnert et al., 2002; Bowman et al., 2004). Energy and protein or energy supplementation of calves with a creep feed often results in higher weaning weights (Faulkner et al., 1994; Meyers et al., 1999; Gelvin et al., 2004), but those differences are not as significant when animals are retained into maturity (Berge, 1991; Drouillard and Kuhl, 1999; Myers et al., 1999). It is only prudent that supplementation decisions be made in light of the economics of the system.

**Compensatory gain**

Compensatory gain is a phenomenon that has been observed when cattle are fed inadequate levels of nutrients to maintain desired BW gains, followed by a period of adequate nutrition (Berge, 1991; Owens et al., 1993; Drouillard and Kuhl, 1999). Compensatory gain may occur after energy and/or protein restriction (Heinemann and Van Keuren, 1956; Abdalla et al., 1988; Drouillard et al., 1991; Knoblich et al., 1997). This shifting of gain can be of major economic importance for cattle production, especially if compensation is realized after the change of ownership (Owens, 1993). This economic importance results from feeder cattle being sold on a live weight basis (Owens, 1993). The ability for cattle to compensate can be advantageous because it allows gain to be shifted between production phases to best utilize low cost inputs, allowing for greater overall efficiency (Drouillard and Kuhl, 1999). The term, compensatory gain, was defined in 1955 (Bohman, 1955), and subsequently, compensatory gain has been reported in numerous studies (Choat et al., 2003; Coleman and Evans, 1986; Poppi and McLennan, 1995; Rompala et al., 1985; Drouillard et al., 1991; Sainz et al., 1995).

*Compensatory gain effects on feed efficiency*

Increased feed efficiency resulting from compensatory gain has been observed in a number of studies (Choat et al., 2003; Coleman and Evans, 1986; Poppi and McLennan,
1995; Rompala et al., 1985; Drouillard et al., 1991; Sainz et al., 1995). Limit feeding of cubed grass-alfalfa hay, cottonseed hulls, and soybean meal to achieve an ADG of 0.25 kg/d which allowed segregation of steers by both age and weight resulted in older steers compensating from 30 to 120 d during realimentation. Steers that were restricted at an earlier age had greater ADG during realimentation than steers that were unrestricted, but lower ADG than those of older restricted steers. Steers that were restricted had slightly higher feed efficiency. This improved feed efficiency did not result from increased digestibility of feed, but from more efficient post-absorptive utilization. Poppi and McLennan (1995) observed that under-nutrition may reduce the metabolically active tissues in the gut and liver, reducing an animal’s maintenance requirement. Steers that were limit-fed concentrate had 17% lower maintenance requirements than ad lib concentrate or forage-fed steers when subsequently fed concentrates (Sainz et al., 1995).

When the difference in growth rate and BW gain between restricted and unrestricted animals is less drastic, differences in feed efficiency are not as strong, but can still be observed. Drouillard et al. (1991) observed that steers fed to gain 0.23 kg/d for 77 to 154 d with energy or MP restriction had similar ADG, but greater feed efficiency during realimentation than steers restricted to 0.45 kg/d.

Sainz et al. (1995) found that steers with growth restriction resulting from feeding high forage or limited concentrate diets had improved feed efficiency when fed a high concentrate diet during finishing.

*Compensatory gain effects on dry matter intake*

Differences in feed efficiency observed in studies reporting compensatory gain are not drastic (Coleman and Evans, 1986; Rompala et al., 1985; Choat et al., 2003), and do not explain all of the compensation observed. Another factor contributing to compensatory gain is increased feed intake (Horton and Holmes, 1978; Choat et al., 2003; Lewis et al., 1990; Drouillard et al., 1991; Horn et al., 1995; Lofgreen and Kiesling, 1985). Drouillard et al. (1991) found that steers that were restricted in ADG to 0.23 kg/d by protein intake tended to have higher DMI while energy-restricted steers had significantly higher DMI than control steers during finishing. Horn et al. (1995) also found that during the feedlot period, steers unsupplemented (gaining 0.92 kg/d) during the growing period tended to have higher feed
intakes, but no difference in feed efficiency compared to steers supplemented with starch or fiber. This increased DMI resulted in a tendency for control cattle to finish with an average BW 15 kg greater than the high fiber and starch-supplemented steers, even though control steers entered the realimentation period 20 kg lighter than supplemented steers.

During the finishing period, steers had previously grazed on native range and been restricted to 0.29 kg/d ADG had 16.8% higher DMI than steers that had ADG of 1.03 kg/d while grazing winter wheat for 180 d (Choat et al., 2003). Increased gains associated with increased intake and no differences in digestibility during finishing were also observed in steers that gained 0.22 kg/d before the finishing period (Horton and Holmes, 1978). Lofgreen and Kiesling (1985) observed compensation caused by increased intake when transport-stressed steer calves were realimented on a concentrate diet.

Timing of compensatory gain

Experiments largely demonstrate that compensatory gain primarily occurs during the first four to eight weeks of the realimentation period (Horton and Holmes, 1978; Coleman and Evans, 1986; Cassar-Malek et al., 2001). Horton and Holmes (1978) observed that steers that had grazed at a high stocking rate gained more BW in the first eight weeks of finishing than steers that had grazed at lower stocking rate. During the first four weeks of finishing, ADG of steers grazing at the highest stocking rate were nearly four times that of steers grazing at the lower stocking rate. During the entire finishing period, steers from the higher stocking rate treatment were able to compensate for about 26 of the initial 48 kg difference in BW between the high and low stocking rate groups. Cassar-Malek et al. (2001) observed that steers with restricted BW gains of 0.64 kg/d for three months had compensatory gains during the first 42 d of re-feeding. However, no difference in BW was detected thereafter compared to steers that were fed to gain 1.01 kg/d before finishing. Coleman and Evans (1986) also observed that the compensatory gains of steers that had been previously restricted to 0.25 kg/d took place early in the finishing period resulting in no differences in the overall daily gains during the finishing period between treatments and ages.

Gut fill has been implicated as being a factor in the BW gains occurring early after realimentation (Stock et al., 1983; Owens et al., 1993; Drouillard and Kuhl, 1999). But the composition of gain during early realimentation can also contribute to the BW gains
observed in the first weeks of realimentation (Rompala et al., 1985; Berge, 1991; Sainz et al., 1995).

*Changes in composition of gain during compensatory gain*

It has been observed that during periods of compensatory gain, the composition of gain is different than for cattle gaining at a continuous rate (Rompala et al., 1985; Carstens et al., 1991; Sainz et al., 1995). Carstens et al. (1991) observed that during the realimentation period, steers experiencing compensatory gain had greater non-carcass protein, non-carcass water, and greater empty body protein accretion and 18% lower net energy requirements than steers fed for continuous gain. Steers with compensatory gain also had greater empty body protein (16.6 vs. 14.8%) and lower empty body fat (24.2 vs. 34.4%) at harvest than steers with continuous gain. As a result, steers with compensatory gain deposited more protein, water, ash, but less fat in both carcass and non-carcass locations. Owens et al. (1995) also observed that steers experiencing compensatory gain had carcasses with a higher protein to fat ratio. This elevated protein deposition along with deposition of water and ash in the carcass can add substantial weight. The inclusion of water and protein accretion on a live weight basis requires one-fourth of the energy that fat accretion requires (Owens et al., 1995).

Rompala et al. (1985) found that steers realimented at 200 kg BW showed greater gains of lean tissue during compensatory gain than control steers. But the composition of gain was not different between the two groups after steers experiencing compensatory gain reached 300 kg. Composition of gain was affected by both empty body weight gain and empty body weight. Increasing empty body weight gain resulted from increased protein deposition rates compared to control animals. But as empty body weight increased, protein deposition rates decreased until the weight gain of protein deposition of compensating steers did not differ from control steers. Berge (1991) indicated that when restricted animals are slaughtered at the same weight, they tend to have carcasses of comparable weight, but are leaner than nonrestricted steers.

Sainz et al. (1995) observed that growth limitation by feeding an all forage or limit-fed concentrate diet during the growing period affected fat deposition with little effect on muscular growth. Steers fed concentrate *ad libitum* during growing and finishing periods had
more backfat than steers that were fed concentrate at 70% of the *ad libitum* level. Marbling scores at harvest did not differ between groups that were finished on *ad libitum* intake of a concentrate ration, but were lower for steers that were fed *ad libitum* forage or limit-fed concentrate for both periods. Backfat, kidney pelvic and heart fat (KPH), abdominal fat, marbling, and total carcass fat were lower for forage-fed steers than steers fed concentrates at either *ad lib* or limited levels during the growing period, but there were no differences in ribeye area (REA).

*Effects on length of finishing period*

Steers with limited growth as calves pre- (Bohman, 1955; Abdalla et al., 1988; Perry et al., 1971; Sainz et al., 1995) or post-weaning (Lake et al., 1974; Sainz et al., 1995; Drouillard and Kuhl, 1999; and Choat et al., 2003) needed longer to obtain similar weights to steers without limited gain, even with compensation. Abdalla et al. (1988) found that although Holstein steers that had received low protein or energy diets for 133 d had 14 to 30% greater BW gain than control steers during realimentation, these steers required an additional 12 to 117 days to reach similar BW as control steers.

Bohman (1955) observed that when steers were wintered and grazed as weanlings, steers that were fed a diet restricted in protein and phosphorus had a lower average BW than their unrestricted peers after one grazing season. But even with restricted growth during a second winter, yearlings were able to fully compensate during the second summer grazing season.

In two studies, Perry et al. (1971) found that steers fed limited concentrate for 58 d on pasture required less total concentrate to reach similar weights, but required more time to finish in a drylot. Similarly, Choat et al. (2003) observed that feedlot steers that grazed native range for 180 d were able to compensate for about 60% of the BW difference compared to steers that grazed winter wheat. However, native range-grazed steers required longer to finish to a lower hot carcass weights (HCWT) and carcass merits.

Drouillard and Kuhl (1999) indicated that there are potentially innumerable ways to reach a sufficient level of finish in beef cattle using discontinued growth patterns. Fat deposition resumes after sufficient nutrition is offered, allowing steers that previously were
fed at a lower plane of nutrition to achieve adequate body fat if fed enough energy prior to harvest.

**Nutrition during realimentation**

To reduce the extra time to finish and avoid the reduced carcass weights and fat associated with compensatory gains, it is important to supply adequate nutrition during the realimentation period (Bohman, 1955; Drouillard et al., 1991; Perry et al., 1972). Bohmann (1955) indicated that in years when weanlings had higher quality pasture, they were able to compensate BW to a greater extent than in years when forage quality was average. Perry et al. (1972) noted that steers fed restricted amounts of silage in winter and not supplemented while grazing pasture were unable to fully compensate for the reduced gain. During finishing on a concentration ration, these steers were able to compensate, although incompletely.

Drouillard et al. (1991) found little difference in finishing performance between steers fed mildly or severely protein-restricted diets for 77 to 154 d before finishing on high concentrate diet. However, this result may have been caused by a diet that contained inadequate protein to meet the needs of compensating steers that had been severely restricted in protein intake. Steers that were fed restricted levels of protein or energy for only 77 d had similar compensatory gains during finishing. But when restricted for 154 d, energy-restricted steers had higher compensatory gain than those restricted in protein. This result may be related to potentially inadequate protein to sustain higher compensation in steers that had longer protein restriction. Poppi and McLennan, (1995) also observed that compensating animals may require more protein. Growth restriction essentially reduces the animal’s physiological age (Coleman and Evans, 1986), which would increase its protein requirement. If there is a reduction in physiological age, it would follow that there would be a need for a higher plane of nutrition following the restriction period in order to optimize compensatory gain and realize the full economic potential associated with that compensation.

**Age effects**

Age of the animal at the time of restriction has also been shown to be a factor affecting the ability of growing cattle to compensate for nutrient restriction (Bohman, 1955; Desai and Hales, 1997; Berge, 1991). Bohman (1955) found that weanling steer calves had
difficulty compensating for decreased winter gain, while grazing summer pasture. However, yearling steers were able to finish the summer grazing season with no significant differences in BW compared to control steers. The inability for animals with restricted gain early in life to compensate may be caused by metabolic programming if inadequate nutrition at a young age permanently altered the animal metabolically (Desai and Hales, 1997). Rapidly growing neonates and fetuses can be more affected by under-nutrition than animals at later stages of development (Desai and Hales, 1997). This programming may result in decreased mature body size and protein mass, if protein was restricted. Restriction before weaning is unlikely to be compensated by later realimentation as the rate of weight gain from 0 to 4 months is highly correlated to future gains (Berge, 1991).

Abdalla et al. (1988) found that stunting of growth was possible when young steers were restricted in protein for as long as 213 d. Steers that were the most severely stunted had restriction that was not only long, but also severe. Drouillard and Kuhl (1999) observed that in periods of growth restriction, skeletal and muscular growth take precedence over fat accretion. If there was insufficient protein for the muscle accretion pre- or post-realimentation, energy may be shifted toward fat over muscle accretion causing permanent stunting.

Coleman and Evans (1986) observed that restricting gains reduced skeletal growth of spring- and fall-born calves from which they were never able to compensate. Upon harvest, steers with BW gains restricted to 0.25 kg/d prior to finishing were not significantly different in carcass dressing percentage, but were lighter than calves that had BW gains of 0.75 kg/d prior to the finishing period.

Choat et al. (2003) found that during the feedlot period, steers that had previously grazed native range for 180 d were able to compensate for about 60% of the initial BW difference from steers that grazed winter wheat, resulting in a HCWT difference of 26 kg when harvested at similar body condition based on subjective evaluation. Thus, steers grazing native range were not able to overcome the severe restriction in protein and energy compared to steers that grazed winter wheat, although their initial BW was approximately 220 kg before they were subjected to restriction. These results imply that not only is age a consideration in response to realimentation and stunting, but severity of restriction is also a
factor (Abdalla et al., 1988; Drouillard et al., 1991; Poppi and McLennan 1995; Choat et al., 2003).

**Definition of compensatory gain**

Compensatory gain is a phenomenon that has been observed when cattle are fed below optimal levels of nutrients resulting in diminished gains, followed by a period of adequate nutrition (Berge, 1991; Owens et al., 1993; Drouillard and Kuhl, 1999). This definition is somewhat vague, making it difficult to know if an animal is truly undergoing compensatory gain. The lack of clarity in the definition of compensatory gain may cause one to ask if the gain that is seen is a result of compensatory gain or simply a resulting growth pattern from a particular feeding regime. If an animal had restricted growth resulting from dietary restrictions and was able to regain part or all of that difference in weight with higher ADG then it would probably be considered compensatory gain. The limitation with this definition is whether the growth restriction in cattle undergoing nutrient restriction compared to peer animals is submaximal gain, suboptimal gain, or truly restricted or hindered growth. However growth restriction is defined, there are conditions that don’t seem to fit the pattern for compensatory gain.

Denham (1977) found that although continuous supplementation of steers grazing native range with supplementation of 2.66 Mcal of ME for 133 d resulted in greater BW gains than no supplementation; supplementation while grazing had negative effects on BW gains during the feedlot phase. Thus, while control steers may have compensated during finishing, the supplementation may have hindered BW gains during finishing. The differences between treatments depend on the limitation of the control during grazing. These results show the importance of evaluating the system as a whole.

Coleman et al. (1976) observed no compensatory gain in steers finished in a feedlot after grazing pasture with supplementation to daily gains of 0.38 to 0.67 kg/d. The lack of any compensatory gain could be caused by the low BW gains on pastures and in the drylot for all treatments. In addition to the low gains, steers were all taken to a set weight on pasture requiring more time and potentially limiting the ability for steers to compensate. Regardless of supplementation, steers entered and left the feedlot at the same weight, and
steers grazing with lower supplemental levels had less carcass fat and were leaner than steers supplemented at higher levels.

Meyers et al. (1999) observed that although calves early weaned at 168 d had greater BW gains up to 231 d than calves weaned at the normal time of 231 d, calves weaned at the normal time had greater BW gains to finish. While normal-weaned steers gained an average 44.3 kg more during finishing and required fewer days to finish than did early-weaned steers, compensatory gain seems unlikely because there’s no evidence that normal-weaned steers were restricted. Larger steers may exhibit slower subsequent gain than smaller steers in spite of age because of a suggested sigmoidal-shaped growth curve for steers (Coleman and Evans, 1986).

**Plane of nutrition**

Although calves fed a high plane of nutrition may have greater BW gains than calves at a lower plane of nutrition, calves at the lower plane of nutrition are not necessarily predisposed to undergo compensatory gain. Faulkner et al. (1994) found that feedlot performance was not affected by supplementation of pre-weaned calves with limited and unlimited corn or soy hulls. However, calves receiving unlimited supplementation of corn had greater quality grades at harvest than did unsupplemented calves. Unsupplemented steers were unable to compensate for differences imposed by creep feeding not because of growth restriction, but because creep-fed steers were simply fed at a higher plane of nutrition.

Owensby et al. (1995) found that early in a grazing season, supplementation with sorghum grain did not significantly change the BW gains of steers grazing bluestem range, but supplementation resulted in increased residual forage later in the grazing season. This greater forage availability later in the grazing season resulted in higher BW gains over the entire grazing season and heavier steers at the beginning and end of the feedlot period. Hot carcass weight increased linearly with supplement, but the carcass quality did not differ between treatments. Relatively small differences in ADG resulted in a lack of compensatory gain.

**Gut fill effects**

Compensatory gain can be overlooked or incorrectly evaluated as a result of issues with the method of weighing study animals. Weighing procedures in studies evaluating
growth rates are especially important in ruminants because of gut fill. Stock et al. (1983) noted that considerable variation can be added to animal weights by problems with endpoint weighing. This variation in weight caused by weighing procedures is especially important for shorter periods of feeding. Rumen fill differences caused by single beginning and ending weigh points contribute largely to weight variation in ruminants (Stock et al., 1983). Ideally animals would be weighed two to three times at the beginning and end of periods (Stock et al., 1983). Using weights from 3 consecutive days removed variation to a greater extent than weighing on 2 consecutive days. But weighing on 2 consecutive days was capable of removing approximately 75% of the variation (Stock et al., 1983). If animals were weighed two or three times at the beginning and the end of growth trial with weekly or regular weigh periods in between, regression analysis could be run on the data to detect relatively small differences in treatments. This regression technique was especially useful if fewer weigh days were used at the beginning or the end of the period.

Horton and Holmes (1978) noted that there was an inverse relationship between ADG during grazing and ADG during the beginning stages of finishing. During the first four weeks of finishing, ADG of steers with low BW gain on pasture were nearly four times that of the steers with higher ADG on pasture. A portion of those BW gains, were likely caused in part by gut fill differences. Drouillard and Kuhl (1999) also found that gut fill can be a bias in reporting compensatory gain.

Compensatory gain is a complicated topic, which has the potential to increase profitability or decrease profitability for any given segment of the cattle industry (Drouillard and Kuhl, 1999). It is important to understand how previous nutritional status and gains will affect subsequent performance (Drouillard and Kuhl, 1999). Producers need to understand the effect of increased efficiency, increased intake, timing of gain, composition of gain, time requirements for gain, nutrition during realimentation, age at restriction, severity of restriction, and gut fill issues associated with compensatory gain if they are to capitalize on the ability of cattle to undergo compensatory gain.
**Substitution rate**

Substitution rate is defined as the quantity of DMI of a basal diet substituted by a given quantity of supplement fed as illustrated by the calculation:

\[
\text{Substitution rate} = \frac{\text{DMI}_{\text{unsupplemented}} - \text{DMI}_{\text{supplemented}}}{\text{DMI}_{\text{supplement}}} \]

(Bargo et al., 2002) where DMI A is the DMI of the basal diet.

A substitution rate of one represents no change in net DMI, but values less than one will result in a net increase in total DMI (Bargo et al., 2002). This exchange between feeds can be represented as a production isoquant or trade-off curve that can be used to determine optimal levels of each feed to meet production needs of a system (Brokken and Bywater, 1982). From empirical data, this curve has been shown to be optimized at each end of the curve with either high forage or high grain diets (Brokken and Bywater, 1982). The production isoquant model, in general, represents what can be observed in the cattle industry today with the polarization between finishing systems based on high grain diets and primarily forage-based cow calf and stocker production systems. There are, of course, exceptions to this model where slight increases in grain or protein feeding are optimal in forage-based systems. The isoquant model is also only useful if the empirical data exists for a given set of feeds under a given production setting. It has been observed that supplementation with grain can decrease forage intake (Bodine and Purvis, 2003; Bowman et al., 2004; Carey et al., 1993). In spite of substitution effects, supplementation has been shown to improve BW gains (Woods and Scholl, 1962; Bodine et al., 2001; Horn et al., 2005; Sanson and Clanton, 1989).

The biology of the production setting plays an important role in the substitution rate of a given set of feeds. Some of the factors affecting substitution rate include: the pasture allowance (Bargo et al., 2002), chemical and physical properties of the concentrate (Bargo et al., 2002), quality of the forage (Stafford et al., 1996), level of supplementation (Stafford et al., 1996), level of intake (Brokken and Bywater, 1982), nutrient ratios of feeds (Brokken and Bywater, 1982), animal breed (McCarthy et al., 2007), feeding level compared to metabolic need (Stafford et al., 1996), and stage and level of animal production (Bargo et al., 2002).

**Factors affecting substitution of forage**

Bargo et al. (2002) found that dairy cows supplemented with 1 kg concentrate per 4 kg of milk decreased pasture intakes by 2 and 4.4 kg DM ‏•‏ cow⁻¹ ‏•‏ d⁻¹ at low and high
pasture allowances, respectively. This reduction resulted in substitution rates of 0.26 and 0.55 kg/kg concentrate at pasture allowances of 25 and 40 kg DM/d, respectively. These results are in close agreement with Stafford et al. (1996) who found a substitution rate of 0.56 g forage/g concentrate in cattle grazing low quality tall grass prairie supplemented with a moderate protein concentrate (17.5% CP) at 0.15, 0.30, and 0.45% BW. In contrast, a high protein concentrate (32.5% CP) or alfalfa pellets increased forage intake by 1.18 and 0.42, respectively. This deviation may be explained by the increase in passage rates associated with these supplements (Bargo et al., 2002), or increased digestion and passage rates (Stafford et al., 1996). Supplements decreasing intakes were found to also decrease passage rate (Stafford et al., 1996). In cases where supplement increased intake of a base forage and also passage rate, supplementation caused an increase in the amounts of digestible intake protein (DIP; Stafford et al., 1996). Sanson and Clanton (1989) calculated substitution rates of 0.43 g and 0.75 g/g of corn supplemented for low quality meadow hay in consecutive experiments. A similar result was noted by Goetsch et al. (1991) with a substitution rate of 0.46 observed when ground corn was fed up to 1.0% BW. The difference in two experiments by Sanson and Clanton (1989) may have resulted from the lower CP content of the low quality meadow hay in experiment one, as well as, the difference in physiological state of the cattle as mature steers and gestating cows were used in experiment 1 and 2, respectively. Gekara et al. (2001) also found a substitution rate of 0.77 kg forage/kg corn for cows grazing Kentucky bluegrass or perennial ryegrass. Vogel et al. (1989) found substitution rates of 0.66 and 0.63 for wheat and Bermudagrass pastures, respectively, when supplemented with silage. Grainger and Mathews (1989) related substitution rates to pasture intake according to the equation:

Substitution rate = -0.445 + 0.315PI

where PI is the pasture intake in kg DM • 100 kg cow live weight\(^{-1}\) • d\(^{-1}\) (at a level of zero supplementation) supplemented with grain-based pelleted concentrate (17.5% CP). This result implies a substitution rate of 0.5 for cows consuming pasture at 3% of BW and lower substitution rates with decreased pasture intake, which is in agreement with Bargo et al. (2002).
Effects supplementation on total dry matter intake

While supplementation can cause substitution of supplement for a basal diet, it can still have a positive effect on overall DMI. This increase in total DMI has been observed for cattle that are either grazing or fed high forage diets and supplemented with concentrate or fiber-based supplements (Stafford et al., 1996; Bodine et al., 2001; Sanson and Clanton 1989; Matejovsky and Sanson, 1995; Gekara et al., 2001; Goetsch et al., 1991). Most feeds have substitution rates that are less than one and greater than zero (Stafford et al., 1996; Bodine et al., 2001; Sanson and Clanton 1989; Matejovsky and Sanson, 1995; Gekara et al., 2001; and Goetsch et al., 1991) which results in a net increase in total DMI and increased animal productivity. Bargo et al., (2002) observed that dairy cows grazing at high and low pasture allowances had increased total DMI as concentrate was supplemented at 8.63 kg/d. But this increase in DMI was greater for cows at the lower than the higher forage allowance. Royes et al. (2001) also observed that supplementation with corn or soy hulls caused a linear decrease in hay intake while increasing total DMI. Although, this linear decrease in hay DMI/cow was small at 1.4 kg supplement/day, the difference was larger when 2.8 kg supplement/day were fed, indicating that substitution rate changes with increasing supplementation. Stafford et al. (1996) observed increased total DMI when fed a high CP supplement or an alfalfa pellet to steers grazing low quality forage. Bodine et al. (2001) observed an increase in total DMI in steers supplemented with cottonseed hulls, pelleted protein, high fiber, or high grain supplements while grazing bermudagrass. Sanson and Clanton (1989), Matejovsky and Sanson (1995), and Gekara et al. (2001) fed corn to cattle, sheep, and calves, respectively, with low to high quality grass forages and also found that total DMI was increased with supplementation. An observation that is less common is when supplementation increased both total DMI and intake of the base forage. Stafford et al. (1996) observed increasing forage and total DMI when a high CP supplement was fed steers. It seemed that this effect could be caused by a 96% increase in forage digestibility. Matejovsky and Sanson (1995) also observed an increase in low quality forage intake when supplemented with protein above the intake of the non-supplemented lambs. Bodine et al. (2001) found that steers supplemented with protein increased total OM intake and improved BW gain. In spite of substitution, total
DMI is quite often increased, even with cattle at different stages of production and consuming forages of different quality as indicated by reported substitution rates less than one (Stafford et al. 1996; Bodine et al. 2001; Sanson and Clanton 1989; Gekara et al. 2001; and Goetsch et al. 1991). Only in certain situations, such as supplementation of low quality forage with high protein supplement, can an increase in forage intake be observed as well. 

**Digestibility effects on substitution**

Another factor affecting substitution of supplement for forage DMI is the effect that the supplement has on the digestibility of the base feed (Sanson and Clanton, 1989; Staffòrd et al., 1996; Bodine et al., 2001; Bargo et al., 2002; Bargo et al., 2003). Overall, the effects of substitution on forage intake by concentrate supplementation may be caused by negative associative effects such as lower rumen pH, lower rate of forage digestion, lower NDF digestibility, and decreased grazing time (Bargo et al., 2002; Gekara et al., 2001). Royes et al. (2001) observed decreasing apparent digestibility of ADF and NDF of stargrass hay supplemented with increasing levels of corn. Bargo et al. (2002) found that when a higher substitution rate was observed, it was associated with the diet having reduced rumen degradable N without affecting total bacterial N flow. At the same time, cattle fed diets with lower substitution rates had greater rumen digestible OM and increased bacterial N flow resulting from greater availability of substrate for rumen microbes. Stafford et al. (1996) observed that moderate crude protein supplementation and long stem alfalfa hay supplementation caused reduced rates of passage (liquid and acid detergent insoluble ash) when supplemented at a level of 0.88% BW DM/d, which may have been associated with the higher starch content of the moderate crude protein and the physical form of the alfalfa. Decreased NDF disappearance from in situ bags and a 24% decrease in hay DM digestibility were observed when a high corn supplement was fed to steers consuming low quality meadow hay compared to an unsupplemented control, resulting in a decrease in hay intake (Sanson and Clanton, 1989). Simultaneously, the mean diet digestibility increased by 16 to 20% as corn supplementation increased from 0.25 to 0.75% BW. Increased intake can also be observed when moderate and high CP concentrate or long stem or pelleted alfalfa hay were supplemented to steers fed low quality tall grass prairie (Stafford et al., 1996). However, this result was associated with an increased passage rate. In cows fed higher
quality hay with corn, McCarthy et al. (2007) observed that the Holstein cows fed the same diet with higher milk production had lower substitution rates. This implies that an animal with greater metabolic requirements will have its intake depressed to a lesser extent by supplementation.

While high starch diets can impair forage digestion, grain has been observed to increase the total OM digestibility and/or total digestible dry matter intake (DDMI) because of the grains’ high digestibility (Goetsch et al., 1991; Gekara et al., 2001; Royes et al., 2001). Bodine et al. (2001) observed increased OM digestibility when high starch pellets were supplemented to heifers and stated that if sufficient degradable intake protein (DIP) were present in the diet, negative associative effects of starch would largely be avoided.

Negative associative effects of supplementation on forage digestibility can also be avoided by feeding high-fiber grain processing co-products like corn gluten feed, soy hulls, and wheat middlings (Royes et al., 2001; Soto-Navarro et al., 2004; Reed et al., 2006). These high fiber feeds can be advantageous because they contain relatively high energy densities and may increase total OM digestibility, while not affecting hay OM digestibility (Bodine et al., 2001). Similarly, Vogel et al. (1989) indicated that corn silage supplementation increased ruminal DM digestion in steers grazing wheat pasture representing a positive associative effect.

*Pasture allowance effects on substitution*

Substitution rate or the relationship between base diet intake and supplement intake can be affected by the digestibility of the individual feeds, and can impact the total DMI. Another factor which can influence the effect the substitution of supplement DMI for forage DMI is the forage allowance. Lower forage allowance tends to decrease the substitution rate compared to a higher forage allowance (Grainger and Mathews, 1989; Bargo et al., 2002). Grainger and Mathews (1989) found that supplementation with a concentrate decreased pasture forage intakes by 0, 0.25, and 0.69 kg DM/ kg concentrate in cows with pasture allowances of 7.6, 17.0, and 33.2 kg DM/cow. Bargo et al. (2002) observed that supplement decreased forage DMI by 2 and 4.4 kg/d at pasture allowances of 25 or 50 kg DM • cow$^{-1}$ • d$^{-1}$, resulting in substitution rates of 0.26 and 0.55 kg/kg concentrate.
Forage composition effects on substitution

Not only is the substitution rate affected by the forage allowance, but forage composition also plays a role (Sanson and Clanton, 1989; Goetsch et al., 1991; Matejovsky and Sanson, 1995; Stafford et al., 1996). Supplementation of low quality meadow hay with corn to 0.75% BW did not affect hay DM digestibility, while the apparent DM digestibility and total DMI of the diet were increased (Sanson and Clanton, 1989). The substitution rate for the corn-supplemented steers grazing low quality meadow hay was 0.43 kg hay per kg of corn added to the diet. Protein supplementation did not affect DMI of lambs fed medium and high quality hays, but forage DMI intake decreased linearly with increasing supplementation. Goetsch et al., (1991) found that supplementation of Holstein steer calves with concentrate often decreased forage DMI, but this effect is dependent on the forage digestibility, level of supplementation, concentrate source and characteristics, and the animals’ energy and nutritional needs.

Overall diet efficiency

Feed efficiency has been shown to increase with increasing supplementation of corn or a corn-based concentrate mixture (Woods and Scholl, 1962; Royes et al., 2001). Feed efficiency changes with alterations in dietary energy concentration (Brokken and Bywater, 1982), which is increased by energy supplementation. This effect is exaggerated as the rate of substitution increases. Along with decreasing the DMD of the forage, supplementation with a corn and soybean meal supplement could increase the energy expended by grazing animals (Gekara et al., 2001). This increase in energy expended could be caused by decreased grazing efficiency (observed as the increase in grazing time required to consume less total forage) as supplementation increases (Gekara et al., 2001).

Fiber-based supplements

It has been found that supplementation of steers fed ammoniated stargrass hay with soy hulls resulted in increased apparent ADF and NDF digestibility of the diet and fewer negative effects than grain supplementation because of the highly digestible fiber and low starch content of the soy hulls (Royes et al., 2001). Corn silage has also been observed to increase wheat pasture digestibility, while decreasing intake of wheat and bermudagrass pastures (Vogel et al., 1989; Horn et al., 2005) and, thereby, allowing higher stocking rates.
Substitution rate is a complicated issue, which involves the pasture allowance (Bargo et al., 2002), chemical and physical properties of the concentrate (Bargo et al., 2002), quality of the forage (Stafford et al., 1996), level of supplementation (Stafford et al., 1996), level of combined intake (Brokken and Bywater, 1982), nutrient ratios of feeds (Brokken and Bywater, 1982), animal breed (McCarthy et al., 2007), feeding level compared to metabolic need (Stafford et al., 1996), and stage and level of animal production (Bargo et al., 2002).
CHAPTER 3. EFFECTS OF CORN DISTILLERS DRIED GRAINS WITH SOLUBLES SUPPLEMENTATION OF AUGUST-CALVING COWS OR CALVES GRAZING STOCKPILED FORAGE ON PERFORMANCE OF COWS AND CALVES DURING THE WINTER AND SUBSEQUENT PERFORMANCE OF CALVES IN A PASTURE-BASED FINISHING SYSTEM

A paper to be submitted to Journal of Animal Science

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Abstract

Corn Distillers Dried Grains with Solubles (CDDGS) supplementation of August-calving cows or calves in a winter grazing system was evaluated. In two years, ‘Fawn’ endophyte-free tall fescue forage in six 4.04-ha pastures was stockpiled from mid-August. In mid-November, 24 pregnant, mature, August-calving Simmental x Angus cows (mean BW = 676 ± 2.6 and 669 ± 2.6 kg; mean BCS = 6.0 ± 0.05 and 6.2 ± 0.05) with calves (mean BW = 129 ± 4.8 and 137 ± 4.8 kg) were allotted by cow BW and BCS and calf sex and BW to the pastures to strip-graze stockpiled forage for 130 and 136 d. Supplementation treatments assigned to replicate pastures included: CDDGS supplementation of cows when weather prevented grazing (Minimal treatment), minimal CDDGS supplementation of cows, but ad libitum feeding of a pelleted CDDGS-soy hull creep feed to calves (Creep treatment), or CDDGS supplementation to the cows to maintain a mean BCS of 5 (9-point scale; CDDGS treatment). Over the 2 winters, calves in the Creep treatment had greater (P < 0.001) BW gains than calves in the CDDGS and Minimal treatments. Cows in the Minimal and Creep treatments had greater (P < 0.02) BW losses than cows in the CDDGS treatment. After weaning, calves were commingled in a drylot and fed tall fescue hay ad libitum with 0.91 kg/calf of the CDDGS-soy hull creep feed daily for 35 and 28 d. In April, steer calves were moved to a smooth bromegrass pasture divided into eight 2.02-ha paddocks to graze by rotational stocking as one group for 56 d. Subsequently, steers were separated by winter treatment and allotted to six of the 2.02-ha paddocks to graze by continuous stocking with a CDDGS-based supplement fed at up to 7.3 kg·hd⁻¹·d⁻¹ for 139 and 156 d in yr 1 and 2. To finish, steers were allotted to six pens in a feedlot and fed ground smooth bromegrass hay ad
libitum with the CDDGS-based supplement at 7.3 kg·hd⁻¹·d⁻¹ until harvest when a minimum of 50% of the steers in each pen achieved a choice quality grade. Post-weaning ADG of steers from the Minimal and CDDGS treatments were greater ($P<0.10$) than Creep steers. Mean live weight and carcass weights, backfat thickness, ribeye area, and marbling score at harvest did not differ between treatments. Providing August-calving cows or calves grazing stockpiled forage with minimal supplementation during winter resulted in greater net profit when calves were sold at weaning or harvest than supplementing CDDGS to either cows or calves grazing stockpiled forage during winter at equal stocking rates.

**Key Words:** beef cows, creep feed, distillers grains, stockpiled forage, winter grazing

**Introduction**

Harvested feed costs are economically significant in beef production systems as feed costs represent 45 to 50% of cow maintenance costs (Strohbehn, 1990). Grazing stockpiled forage has reduced feed costs for spring-calving beef cows by reducing the need for harvested feeds (Adams et al., 1994; Hitz and Russell, 1998; Allen et al., 2000). Similarly, August-calving cows and calves grazing stockpiled forage required 64% less hay than April-calving cows fed hay in a drylot (Janovick et al., 2004). However, adjusted weaning weights of August calves whose dams grazed stockpiled forages were 9% less than spring calves from cows with similar genetic backgrounds (Janovick et al., 2004).

Supplementation of energy or protein or both will improve BCS or BW or both of cows grazing stockpiled forage over winter (Wheeler et al., 2002; Llewellyn et al., 2006; Poore et al., 2006). Protein or fiber-based energy supplementation of lactating cows grazing dormant or summer native forages, or pea-based creep feed supplementation of calves can increase calf BW gains from birth to weaning (Gelvin et al., 2004; Llewellyn et al., 2006; Reed et al., 2006a).

Because of the ability of calves to compensate for growth restriction with greater BW gains when provided adequate dietary energy (Carstens et al., 1991; Choat et al., 2003), pre-weaning supplementation may not be an efficient use of feed resources. However, restricted growth followed by compensatory gain will increase the protein to fat ratio in cattle at harvest (Berge, 1991; Owens et al., 1995; Sainz et al., 1995) and could, alter carcass quality grade (Sainz et al., 1995).
The objective of this project was to evaluate corn distillers dried grains with solubles (CDDGS) supplementation of August-calving cows or calves grazing stockpiled forage on cow and calf BW changes during winter and BW gain and carcass characteristics of the calves finished in a pasture-based system.

Materials and Methods

All procedures for animal use in this experiment were reviewed and approved by the Institutional Animal Care and Use Committee at Iowa State University.

Winter Grazing Phase

In 2 years (2005 and 2006), two 12.1-ha pastures containing ‘Fawn’ endophyte-free tall fescue (*Festuca arundinacea* L.) at the Iowa State University Beef Nutrition Farm near Ames Iowa, were each divided into three 4.04-ha pastures. Forage from the pastures was harvested as hay on June 6 and July 28 for one block and June 15 and August 2 for the second block in 2005 and on August 7 and 14 for first and second block of pastures in 2006. After the hay was harvested in August, forage was fertilized with urea at a rate of 44.8 kg N/ha to initiate stockpiling for winter grazing. Each pasture was divided into 8 paddocks in preparation for winter grazing. On November 15 of each year, 24 pregnant, mature Simmental x Angus August-calving cows (mean initial BW = 676 ± 2.6 kg and 669 ± 2.6 kg and mean initial BCS = 6.0 ± 0.05 and 6.2 ± 0.05 in yr 1 and 2, respectively) with calves (mean initial BW = 129 ± 4.8 and 137 ± 4.8 kg and mean initial age = 79 ± 2.5 and 80 ± 2.5 d in yr 1 and 2, respectively) were blocked by cow BW and BCS and calf sex and BW and allotted to the 6 pastures to strip-graze. Pastures were assigned to 1 of 3 supplementation treatments. In the Minimal supplementation treatment, cows were fed CDDGS-based supplement (Table 1) in a bunk only when excessive snow and ice inhibited grazing or to maintain the mean BCS of cows in a pasture at 4.33 on a 9-point scale as predicted by the Cornell Net Carbohydrate and Protein System (V. 5.0, Cornell University, Ithaca, NY). Calves received no supplement. In the Creep feeding treatment, cows received the CDDGS-based supplement in a bunk at the same level as the Minimal supplementation treatment, and calves had ad libitum access to a pelleted CDDGS-soy hull creep feed (Table 1). In the CDDGS supplementation treatment, cows received the CDDGS-based supplement in a bunk to maintain a BCS of 5 on a 9-point scale, as predicted by the Cornell Net Carbohydrate and
Protein System and calves received no supplement. Cows in all treatments were offered ad
libitum access to water, limestone, and a mineral and vitamin mix (Kent Framework 365
Mineral ADE containing calcium max 18.3 min 15.3%, phosphorus 8.0%, NaCl max 16.2
min 13.5%, magnesium 1.0%, potassium 0.15%, copper 1,450 ppm, manganese 4,950 ppm,
selenium 26.4 ppm, zinc 4,750 ppm, Vitamin A 380,000 IU/lb, Vitamin D₃ 100,000 IU/lb,
and Vitamin E 375 IU/lb; Kent Feeds, Inc., Muscatine, IA).

Cow and calf BW were measured with no shrink every 28 d and cow BCS were
visually scored on a 9-point scale (Neumann and Lusby, 1986) by the same 2 experienced
individuals every 14 d until calves were weaned on March 23, 2006 and March 29, 2007.
Pasture forage was sampled by hand-clipping to a height of 2.54 cm at two 0.25-m² locations
every 28 d in each grazed and ungrazed paddock of each pasture. Two 1-m² grazing
exclosures were randomly located in each paddock at the initiation of grazing and sampled
upon conclusion of winter grazing to quantify the effects of weathering on forage mass and
composition. Grazed or ungrazed samples were composited by pasture.

Growing and Finishing Phase

After weaning, calves were commingled in a drylot and provided tall fescue hay, at an
*ad libitum* level, as large round bales with the CDDGS-soy hull creep feed at 0.91 kg
DM•calf⁻¹•d⁻¹ for 35 and 28 d backgrounding periods in yr 1 and 2. In yr 2, 3 heifers were
removed and replaced by steers of similar weight. On April 27, 2006 and April 26, 2007, 24
and 21 steer calves from the winter grazing treatments in yr 1 and 2 and the 3 replacement
steers in yr 2 were moved to a 16.2-ha smooth bromegrass (*Bromus inermis* L.) pasture
divided into eight 2.02-ha paddocks. Steers were rotationally stocked as one group with
daily movement for 30 and 28 d in yr 1 and 2. After the initial daily rotation, steers were
rotationally stocked in a first-last grazing system in which steers grazed for 20% live DM
removal, as measured with a falling plate meter (Hermann et al. 2002), followed by the
pregnant August-calving cows that removed an additional 30% of the live DM for 31 and 34
d in yr 1 and 2.

On July 13, 2006 and June 28, 2007, cows were removed from the pastures. Steers
were separated into the six pasture groups from the previous winter grazing treatments and
allotted to one of six 2.02-ha paddocks in the smooth bromegrass pastures. Steers grazed the
paddocks by continuous stocking and were supplemented with the CDDGS-based supplement (Table 1). Feeding of the CDDGS supplement was increased to 1.5% BW within 14 d with feed bunks scored daily. Because pasture forage became deficient, steers were moved to six pens in a feedlot on November 30 and December 1 of yr 1 and 2, respectively. Steers were fed tub-ground smooth bromegrass hay at an *ad libitum* level with the CDDGS-based supplement at 1.5% BW until 50% of the cattle within a pen reached a choice grade, as estimated as minimum averages of 1.02 cm backfat and 3.91% intramuscular fat using ultrasound (Wilson et al., 1998; USDA, 1997). During the growing and finishing phase, steers received no implants or ionophores.

Steers were weighed at 28-d intervals. Cow BW and BCS were also measured at 28-d intervals until removal from the experiment. After finishing, cattle were harvested at a commercial facility and carcass data including hot carcass weight, fat cover, kidney pelvic and heart fat, ribeye area, marbling score, quality grade, and yield grade were obtained by trained professionals. Forage in each 2.02-ha paddock in the smooth bromegrass pasture was sampled by hand-clipping at ten 0.25-m² locations to 2.54 cm at 28-d intervals. Pasture samples from the growing and finishing phases were composited by paddock.

**Chemical Analyses**

Pasture forage samples were frozen until they were weighed, dried in a forced-air oven (Blue M Electric Co., Blue Island, IL) at 65°C for 48 hr, weighed for determination of DM, and ground through a 1-mm screen of a Thomas-Wiley Mill (Arthur H. Thomas Co., Philadelphia, PA). Samples were analyzed for CP as Kjeldahl N × 6.25 (AOAC, 1990). Neutral detergent fiber and ADF were analyzed using an ANKOM® Fiber Analyzer (ANKOM Technology Corporation, Fairport, NY). For determination of ADIN, ADF was removed from the extraction bags, weighed, and analyzed for Kjeldahl N (Goering and Van Soest, 1970). Winter forage samples were also analyzed for IVDMD, using 48 hr incubation in rumen fluid with the NC-64 buffer and a 24 hr digestion in HCl and pepsin (Marten and Barnes, 1979).

**Statistical Analyses**

Forage, cow and calf data from the winter grazing phase were analyzed using the mixed model procedure of SAS (SAS Inst. Inc., Cary, NC) for a randomized complete block
design with pasture as the experimental unit. Forage mass and composition were analyzed using a model with main effects of year, day of grazing, pasture block, treatment, and grazing status (grazed or ungrazed) and the interaction of grazing status by treatment. Cow BW and BCS, calf BW, calf ADG, and supplement feeding were analyzed for the effects of year, block, treatment, month and the treatment by month interaction. Contrasts between the three treatments were conducted for variables with significant treatment effects, and means for treatments were calculated using the LSMeans.

Forage mass and composition, supplement and hay intake, cattle BW gain, and carcass data from the growing and finishing phase, were analyzed by month or phase using the Mixed model procedure of SAS for a randomized complete block design with effects of year, block, and treatment and winter pasture group as the experimental unit (21 steers from winter treatment groups in yr 2). Contrast statements were used to determine significance between means with significant treatment effects.

Steer ADG within a pasture group were analyzed by the regression procedure of SAS with differences analyzed using confidence limits with GLM procedure with year, block, and treatment as the effects.

**Economic Analysis**

Partial budget analyses were conducted to evaluate the net value of each treatment within this experiment and the consequences of marketing calves at weaning. The net value of steers was estimated by the income minus the expenses of the system under the following parameters. Feed consumption, steer weaning and final BW, hours of labor, days on feed, and harvest date data were used from the two years of the experiment. Land usage was estimated as 75% of the 1.01 ha of tall fescue pasture/cow-calf pair during winter grazing, and 100% of the 0.51 ha of smooth bromegrass pasture/cow-calf pair for finishing. The price of land used in the model was $165.49/ha (Edwards and Smith, 2007) which was the average annual cash rental rate for improved pasture in Iowa. Herd expenses, veterinary costs, equipment, fuel, and repairs were estimated from the 2008 Livestock Enterprises Budget for Iowa (ISU Ext. B1-21, 2008). The price of CDDGS was based on the 10-yr average of weekly prices from 1996 - 2005 ($124.70/metric ton) and the creep feed price ($185.24/metric ton) was calculated as the purchase cost of the creep feed minus the cost of
the CDDGS on the manufacturing date plus the 10-yr average cost of CDDGS (USDA-AMS, 2008). Yardage price was $0.335·hd\(^{-1}·d\(^{-1}\) (Lawrence, 2009) for both the backgrounding and feedlot periods. Labor was considered to be $12.00·hr\(^{-1}\) (Smith and Mark, 2004). Fixed and variable costs of hay production were $30.04/ha and $12.57/ metric ton (Barnhart et al., 2007). Interest for animal and operating costs was 8%. Revenues included weaned and marketed steers and cull cows, based on the average in the month of sale from 1996 to 2005 (Lawrence, 2008). Hay revenue for residual pasture forage was $92.43/metric ton (USDA-ERS, 2007). Sensitivity analyses conducted for 20% increases or decreases in the costs of labor, land, or hay cost as well as for a yardage cost increased to $0.50·hd\(^{-1}·d\(^{-1}\).

**Results and Discussion**

*Weather*

During the winter grazing phase of this study in yr 1, the average daily temperatures were higher than the 30-yr averages in October, November, January, February and March, but was lower than the 30-yr average in December (Table 2; NOAA, 2005; NOAA, 2006; NOAA, 2007). In the winter of yr 2, average daily temperatures were higher than the 30-yr averages in November, December, January and March, but colder than the 30-yr averages in October and February. In December, there were more days when the maximum temperature was below 0˚C in yr 1 (19 d) than yr 2 (4 d). In January, February and March of yr 1, there were fewer days when the maximum temperature was below 0˚ C (3, 8, and 0 d, respectively) than yr 2 (18, 19, and 6 d, respectively). A similar pattern to temperature was observed for ice pellets and snow cover, maximum snow cover on ground, and the number of days with \(\geq 2.54\) cm of snow cover with values being higher in December of yr 1 than yr 2 and greater in January, February and March of yr 2 than yr 1 (NOAA, 2005; NOAA, 2006; NOAA, 2007).

During the growing and finishing phases, average monthly temperatures were close to the 30-yr average in March through November, but differences occurred in December, January, and February as described above. Total precipitation from March through November was greater precipitation in yr 2 than yr 1. But precipitation during this period in both yr 1 (914 mm) and yr 2 (843 mm) were greater than the 30-yr average of 798 mm, respectively (NOAA, 2005; NOAA, 2006; NOAA, 2007).
Winter Grazing Phase

In spite of stratifying and randomly assigning cow-calf pairs to treatment groups, mean BW of cows in the Minimal supplementation and Creep feeding treatments were greater ($P = 0.05$) than cows in the CDDGS supplementation treatment over the two years (Table 3). At the conclusion of winter grazing, cow BW did not differ between supplementation treatments. As a result, cows in the Minimal supplementation and Creep feeding treatments had greater ($P < 0.05$) BW losses than cows in the CDDGS supplementation treatment over the winter grazing seasons. Although initial BCS of cows in the Minimal supplementation treatment tended ($P > 0.05$) to be greater than cows in the CDDGS supplementation or Creep feeding treatments, BCS of cows in the CDDGS supplementation treatment were greater ($P = 0.04$) than cows in the Minimal supplementation treatment at the conclusion of winter grazing. As a result, the seasonal loss in cow BCS tended ($P = 0.11$) to be greater for cows in the Minimal supplementation treatment than the Creep feeding or CDDGS supplementation treatments. Feeding protein supplements has been shown to improve weight gain and maintenance of BCS of cows grazing winter forage (Jordan et al., 2002). Driskill et al. (2007) also observed that while grazing stockpiled forage in winter, cows receiving a high level of corn gluten feed supplementation had greater BW gains than cows fed a lower level of supplementation.

Initial calf BW did not differ between treatments. However, BW of calves in the Creep feeding treatment were greater ($P < 0.01$) than calves in the Minimal supplementation and CDDGS supplementation treatments at the completion of winter grazing. As a result, ADG of calves in the Creep feeding treatment were greater ($P < 0.01$) than the other treatments. Also, ADG of calves in the CDDGS supplementation treatment were greater ($P < 0.01$) than the Minimal supplementation treatment, implying that cows in the CDDGS supplementation treatment had greater milk production and/or calves in the CDDGS supplementation treatment were able to consume some of the supplement from the feed bunk. Supplementation of calves for 113 d prior to weaning with either corn or soy hulls increased the weaning weight of nursing calves when fed at 1 kg/d or ad libitum over unsupplemented calves (Faulkner et al., 1994). Meyers et al. (1999) also found that ad libitum feeding of
ground corn to calves increased ADG of nursing calves by 32% above calves that received no supplementation during the last 55 d before weaning.

Because of differences in the weather conditions between years, the amounts of the CDDGS supplement fed to cows differed between years and treatments \((P < 0.01; \text{Table 4})\). Cows in the Minimal supplementation, Creep feeding, and CDDGS supplementation treatments were fed 51, 51, and 391 kg CDDGS supplement/cow and 178, 178, and 430 kg CDDGS supplement/cow during the winter grazing seasons in yr 1 and 2. Supplementation of CDDGS to cows in the Minimal and CDDGS treatments was only in response to excessive cold, snow and/or ice that impeded grazing as the mean BCS of cows in these treatments never decreased to 4.33. Creep feed consumption of calves in the Creep feeding treatment did not differ between years and averaged 405 ± 10 kg/calf.

There were no significant differences in the initial forage mass (3,634 kg DM/ha or concentrations of CP (9.2% of DM), NDF (55.1% of DM), ADF (35.8% of DM), ADIN (17.0% of total N), and IVDMD (56.1% of DM) in the stockpiled pastures between the treatments. The rates of change in forage mass (-13.61 kg ha\(^{-1}\)d\(^{-1}\)) and the concentrations of CP (0.004%/d), NDF (0.14%/d), ADF (0.11%/d), ADIN (0.038%N/d), and IVDMD (-0.112%/d) in the grazed paddocks did not differ between treatments over the winter grazing season. The lack of difference in the changes of forage mass or composition between treatments indicates that supplementation of CDDGS to cows or a CDDGS-based creep feed to calves did not alter the voluntary intake of grazing cows or calves to an extent that could be detected in this experiment. Therefore, to reduce forage intake at this level of supplementation, reduced pasture forage allowance would be necessary. Stafford et al. (1996) observed increasing forage and total DMI when CP was supplemented to steers, seemingly because of a 96% increase in forage digestibility. The resulting substitution rate was a decrease of 0.56 g forage/g supplement (Stafford et al., 1996). Feeding steers smooth bromegrass hay supplemented with CDDGS at 0, 0.5, 1.0 and 1.5% BW resulted in a substitution rate (reduction in forage DMI, kg/CDDGS DMI,kg) equal to:

\[
y = -0.0017 + 0.9812x -0.4582x^2 (r^2 = 0.76, P = 0.0001)
\]
where \( x \) was the CDDGS intake, as a percentage of BW. From this equation, it was calculated that the maximum substitution rate of 0.53 kg forage DMI/kg CDDGS DMI occurred when CDDGS were supplemented at 1.07% BW (See Chapter 4).

**Growing and finishing phase**

The ADG of steers from the winter Minimal and CDDGS supplementation treatments tended to be greater \( (P = 0.08) \) during the backgrounding period and were greater \( (P = 0.04) \) during the pasture period than the Creep feeding treatment (Table 5). In contrast, during the feedlot period, ADG of steers from the Creep feeding treatment were greater \( (P < 0.01) \) than the Minimal supplementation treatment and tended to be greater \( (P = 0.05) \) than the CDDGS treatment. As a result, ADG of steers from weaning until harvest did not differ \( (P = 0.23) \) between winter supplementation treatments. However, from the initiation of winter grazing until harvest, ADG was greater \( (P = 0.01) \) for steers in the Creep feeding treatment than the other treatments and tended to be greater \( (P = 0.06) \) for steers in the CDDGS supplementation treatments than the Minimal supplementation treatment.

Although grazing during first 56 d of the pasture period was managed by rotational stocking and first-last grazing with the August-calving cows, the limited BW gains during the pasture period may have related to forage mass or composition. Mean monthly concentrations of CP, NDF, ADF, and IVDMD of the pasture forage were 12.2 ± 0.43, 63.9 ± 0.49, 37.3 ± 0.42, and 42.3 ± 0.62% of DM in yr 1 and 12.9 ± 0.45, 59.1 ± 0.50, 35.5 ± 0.44, and 51.4 ± 0.64% of DM in yr 2 and did not differ between winter supplementation treatments in any month. Mean monthly forage masses were 2731 ± 104 and 2218 ± 108 kg DM/ha in yr 1 and 2 and did not differ \( (P > 0.10) \) between winter supplementation treatments in any month except October when the forage mass tended to be lower for CDDGS treatment steers \( (P = 0.08) \). As a result, forage allowances ranged from 11.4 to 9.3 kg/100 kg BW in July and November in yr 1 and from 11.8 to 5.4 kg/100 kg BW in July and November in yr 2 with no differences between winter supplementation treatments except in the month of October. In this month, forage allowances of pastures with the Minimal supplementation and Creep feeding treatments (11.4 kg/100 kg BW) tended \( (P = 0.08) \) to be greater than the CDDGS treatment (9.1 kg/100 kg BW). Even without CDDGS supplementation, forage allowances in every month were above the limit of 3 kg/100 kg BW (NRC, 1996) needed to
assure maximum forage intake. Although limited intake by grazing cattle may occur at forage allowances between 3 and 5 kg/100 kg BW, only the forage allowance at final sampling after cattle were removed from pastures in November approached the limiting 3 kg/100 kg BW level.

The mean amount of creep feed fed to steers in the backgrounding period over the two years was 21 kg DM/calf. During the pasture period, total intake of the CDDGS supplement did not differ between treatment groups, but was lower \((P < 0.01)\) in yr 1 than yr 2 (Table 6). During the feedlot period, total intake of the CDDGS supplement by steers in the Creep feeding treatment tended \((P = 0.09)\) be lower than the Minimal and CDDGS treatments. This difference was likely caused by a tendency for the shorter length of time (15 d) required for 50\% of the steers in the Creep feeding treatment to attain an estimated quality grade of choice than steers in the Minimal or CDDGS supplementation treatments \((P = 0.10)\).

Even with these differences, total CDDGS supplement intake from weaning through finishing did not differ between years or winter supplementation treatments. With the inclusion of CDDGS-based supplements consumed by the cows and calves pre-weaning, consumption of total CDDGS-based supplements by cow-calf pairs in the Minimal supplementation treatment (1549 kg/cow-calf pair) were lower \((P < 0.01)\) than cow-calf pairs in the Creep-feeding and CDDGS supplementation treatments (1855 kg/cow-calf pair) over the winter grazing and the growing and finishing phases.

At harvest, there were no differences \((P > 0.20)\) in steer live (603 kg/steer) or hot carcass weights (361 ± 14.4 kg/steer) between treatments. Similarly, the percentage of steers that attained a quality grade of choice (65.3 ± 17.2\%) and the yield grade (2.2 ± 0.2), kidney, pelvic, and heart fat (2.2 ± 0.1\%), ribeye area (81.1 ± 2.2 cm\(^2\)), marbling score (3.2 ± 0.3) or fat cover (1.1 ± 0.1 cm) did not differ \((P > 0.10)\) between treatments. Steers that have had decreased growth because of being on a lower plane of nutrition have been observed to have greater percentages of protein and lower percentages of fat in BW gain after realimentation than similar steers that were on a high plane of nutrition throughout growing and finishing (Rompala et al., 1985; Carstens et al., 1991; Owens et al., 1995). While it seems that the goal of harvesting pens of cattle at a similar quality grade in the experiment was achieved, the
lack of difference between treatments may be related to the low number of replicates as the mean standard error for percentage of cattle with the choice quality grade was 17.2.

**Economic Analysis**

The expenses for retained ownership included land costs for both winter and summer grazing through finishing, equipment costs (fuel and repairs included), purchased feed, herd expenses (including replacement costs, insurance, death loss, and interest), yardage cost for steers during the feedlot period, labor for feeding and watering cattle through winter and finishing, veterinary, winter feeding interest, operating interest, hay production costs, and miscellaneous expenses. Calves sold at weaning, had the same sources of expenses but did not include portions accrued after winter grazing. Calves sold at weaning also did not accrue expenses for yardage and animal interest, which were not applicable because, in both cases, those expenses were incurred following the sale of calves post-weaning. Purchased feeds (CDDGS supplement to cows, Creep feed, and CDDGS supplement to steers through finishing for retained steers) represented approximately 14, 17, and 16% of the total expenses when steers were retained through finishing and 1.5, 8 and 5% of total expenses when calves were sold at weaning. Calves retained until they were finished resulted in net returns of $190.56, $146.27, and $143.49 for the Minimal, Creep, and CDDGS treatments (Table 7).

When calves were sold at weaning, the net return for calves in the Minimal, Creep and CDDGS treatments were $198.64, $143.99, and $179.55. In both, the calves retained to finishing and calves sold at weaning, the additional weight of supplemented calves was not sufficient to compensate for the additional cost of the feeds. Additionally, the net return was greater for the Minimal supplementation treatment than the Creep feeding or CDDGS supplementation treatments regardless of 20% increases or decreases in the costs of labor, land, hay or CDDGS or yardage increased to $0.50hd⁻¹d⁻¹. However, the net return for the Minimal supplementation treatment was lower than the Creep feeding treatment when finished cattle prices of $79.08 and $79.38 • cwt⁻¹ LW basis for January and February harvest, respectively, (based on a 10 yr average LW price) were increased by 20%. If steers were retained until finished the net return of calves in the Creep feeding treatment was greater than the CDDGS supplementation treatment in the base analysis and was unaffected...
by a 20% fluctuation in land cost also if labor cost increased by 20%, CDDGS cost decreased by 20%, or yardage increased to $0.50·hd⁻¹·d⁻¹.

Bowman et al. (2004) observed that supplementation with soy hulls and soybean meal, wheat mids, or barley and soybean meal to beef cows or heifers grazing low quality winter range decreased BW losses. Heifers grazing stockpiled fescue over winter had higher BCS when supplemented with cottonseed and corn-based supplement (Poore et al., 2006). In the present experiment, supplementation of August-calving cows grazing stockpiled forages with CDDGS reduced BW losses and tended to reduce BCS losses over winter compared to the system in which cows received supplementation only if weather conditions limited grazing. While maintenance energy requirements of cows with greater subcutaneous adipose tissue may be 6% lower than thin cows in colder weather (Thompson et al., 1983), Driskill et al. (2007) found that young spring-calving cows grazing stockpiled forage in winter maintained an average BCS at or above the target (4.3 on a 9 point scale) with supplementation of corn gluten feed only if weather prevented grazing. Therefore, these cows had lower feed costs than similar cows supplemented with corn gluten feed to maintain a condition score of 5. Janovick et al. (2004) observed that August-calving cows will regain body condition lost during the winter in the subsequent summer. Similarly, in the present experiment, no differences in cow BW or BCS were observed in May, June, or July between winter treatments, although mean BCS of cows in the Minimal supplementation treatment were lower than the other treatments at weaning. Restoration of body condition in summer may be more efficient (Freetly and Nienaber, 1998) and less expensive (May et al, 1999; Freetly et al., 2000) than maintaining a higher BCS in winter.

During the winter grazing season, creep feeding of calves increased their ADG prior to weaning and the weaning weights, which has been observed by others (Faulkner et al., 1994; Meyers et al., 1999; Gelvin et al., 2004). Reed et al. (2006b) found that feeding creep feeds containing DDGS resulted in calf BW gains that were similar to creep feeds that contained SBM. Creep feeds composed of highly digestible fiber such as soybean hulls and wheat middlings increase calf BW gain (Soto-Navarro et al., 2004). The inclusion of soy hulls and wheat middlings at 49 and 43% in a creep feed did not have a negative impact on total or hay OM intake (Soto-Navarro et al., 2004).
During pasture finishing, steers that had lower ADG during the winter gained at a higher rate resulting in no difference in days required to finish or carcass characteristics between treatments. This result is in agreement with Coleman and Evans (1986) who observed no differences in carcass weight or dressing percentage of steers that had been restricted in gain during the growing phase. Sinclair et al. (2001) observed no differences in dressing percentage, ribeye area, and fat class between steers that been fed moderate and high energy diets followed by a high energy diet prior to harvest. However, steers that were fed inadequate energy early in life require more time to finish (Drouillard and Kuhl, 1999; Sainz et al., 1995; Choat et al., 2003) and had heavier carcasses weights (Lofgreen and Kiesling, 1985), lower carcass fat percentages (Carstens et al., 1991; Owens et al., 1995), and/or lower marbling scores (Sainz et al., 1995) when they were harvested. The difference in results may be caused by the diets and/or the amounts of time required for steers to finish. In the present study, because pasture finishing was used, steers were allowed sufficient time to attain comparable finish weights across treatments. It has also been observed that to maximize the benefit of compensatory gain and reduce the negative effects associated with compensation, it is important to supply adequate nutrition during the realimentation period (Bohman, 1955; Drouillard et al., 1991; Perry et al., 1972). Drouillard and Kuhl (1999) observed that there were potentially innumerable ways to reach a sufficient level of finish in beef cattle using discontinued growth patterns. Fat deposition resumes after sufficient nutrition is regained allowing steers that had previously been fed at a lower plane of nutrition to gain adequate body fat if fed enough energy prior to harvest.

The cost of harvested feeds is economically significant as feed costs represent the highest single input in cow calf operations. Harvested feed costs represent 45 to 50% of cow maintenance cost and the most profitable operations have the lowest feed costs (Strohbehn, 1990). In the economic analysis performed with the data from this experiment, the Minimal supplementation treatment was the most profitable in all, but one of the iterations of the sensitivity analysis. In that case, the steers were retained until harvest and finished cattle prices were increased by 20%. When comparing conventional and year-round grazing systems in Iowa, May et al. (2008) indicated that in most years, it was more profitable to sell weaned steers and market excess forage as hay than retaining the calves to finish, as also
observed in this experiment. When this system is used with equivalent stocking rates, the additional BW of calves resulting from CDDGS supplementation of the cows or use of the CDDGS-soy hull creep feed were inadequate to overcome the increased feed costs associated with these supplements. However, CDDGS supplementation of August-calving cows or calves may be more effective if used to increase the stocking rate of pastures grazed during winter.
### Table 1. Composition of CDDGS\(^a\) and Creep supplements

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<th>Component</th>
<th>Supplement</th>
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<td></td>
<td></td>
<td>CDDGS</td>
<td>Creep</td>
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<tr>
<td></td>
<td></td>
<td>% of DM</td>
<td></td>
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<tr>
<td>Corn Distillers Dried Grains with Solubles</td>
<td>97.72</td>
<td>45.2</td>
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<tr>
<td>Soy hulls</td>
<td>---</td>
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<tr>
<td>Molasses</td>
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<td>Limestone</td>
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<td>Salt</td>
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<tr>
<td>Vitamin A premix(^b)</td>
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<tr>
<td>Trace mineral premix(^c)</td>
<td>0.02</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td><strong>Composition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM, %</td>
<td>95.1</td>
<td>92.0</td>
<td></td>
</tr>
<tr>
<td>% of DM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP</td>
<td>25.4</td>
<td>19.5</td>
<td></td>
</tr>
<tr>
<td>NDF</td>
<td>43.6</td>
<td>55.3</td>
<td></td>
</tr>
<tr>
<td>ADF</td>
<td>17.3</td>
<td>33.9</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Fed to cows in the Minimal and Distillers Dried Grains with Solubles treatments during winter and to steers in the pasture-based finishing system.

\(^b\)35.1 IU/kg CDDGS supplement, 1000 IU/g mixed 100g in 22.7 kg SBM as carrier (Rovimix 1000).

\(^c\)Trace mineral mix (Ca 11.84, Cu 1.5, Fe 10.0, Mn 8.0, Zn 12.0% min) (Co 1000, I 2000ppm min).
Table 2. Climatic data during the winter grazing phase

<table>
<thead>
<tr>
<th>Item</th>
<th>Months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>October</td>
</tr>
<tr>
<td>Average daily temperature, °C</td>
<td></td>
</tr>
<tr>
<td>2005-2006</td>
<td>12.3</td>
</tr>
<tr>
<td>2006-2007</td>
<td>9.7</td>
</tr>
<tr>
<td>30-yr average</td>
<td>11.2</td>
</tr>
<tr>
<td>Maximum days with temperature below 0 °C</td>
<td></td>
</tr>
<tr>
<td>2005-2006</td>
<td>0</td>
</tr>
<tr>
<td>2006-2007</td>
<td>0</td>
</tr>
<tr>
<td>Ice pellets and snow, cm</td>
<td></td>
</tr>
<tr>
<td>2005-2006</td>
<td>0</td>
</tr>
<tr>
<td>2006-2007</td>
<td>0</td>
</tr>
<tr>
<td>30-yr average</td>
<td>0</td>
</tr>
<tr>
<td>Maximum snow cover, cm</td>
<td></td>
</tr>
<tr>
<td>2005-2006</td>
<td>0</td>
</tr>
<tr>
<td>2006-2007</td>
<td>0</td>
</tr>
<tr>
<td>Days with greater than 2.54 cm snow cover</td>
<td></td>
</tr>
<tr>
<td>2005-2006</td>
<td>0</td>
</tr>
<tr>
<td>2006-2007</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 3. Mean\textsuperscript{e} initial, final, and change in BW and BCS of cows and calves in Minimal, Creep, or CDDGS supplementation treatments over the winter grazing seasons in 2 yr

<table>
<thead>
<tr>
<th>Supplementation treatment</th>
<th>Cow BW, kg</th>
<th>Cow BCS\textsuperscript{a}</th>
<th>Calf BW, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>Seasonal change</td>
</tr>
<tr>
<td>Minimal</td>
<td>677\textsuperscript{b}</td>
<td>620</td>
<td>-57\textsuperscript{b}</td>
</tr>
<tr>
<td>Creep</td>
<td>681\textsuperscript{b}</td>
<td>622</td>
<td>-59\textsuperscript{b}</td>
</tr>
<tr>
<td>CDDGS</td>
<td>660\textsuperscript{c}</td>
<td>634</td>
<td>-25\textsuperscript{c}</td>
</tr>
</tbody>
</table>

\textsuperscript{a}9-point scale
\textsuperscript{b,c,d}Differences between values with different superscripts within a column are significant, $P < 0.05$.
\textsuperscript{e}Means are the LSMeans reported by the mixed procedure of SAS.

SE (n =12) 6.89 16.2 13.3 0.06 0.06 0.087 12.9 15.7 6.4 0.05
TRT, $P =$ 0.011 0.39 0.019 0.052 0.040 0.11 0.81 0.005 0.0001 0.0001
Table 4. The amounts of CDDGS-based creep feed and CDDGS supplement fed to calves and cows during winter grazing in 2 yr

<table>
<thead>
<tr>
<th>Supplement</th>
<th>Year (Yr)</th>
<th>Supplementation treatment (Trt)</th>
<th>$P =$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>SE</td>
</tr>
<tr>
<td>Creep feed, kg/calf</td>
<td>Year 1</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Year 2</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>137.9</td>
<td>132.2</td>
</tr>
<tr>
<td>CDDGS, kg/cow</td>
<td>Year 1</td>
<td>50.8$^{a}$</td>
<td>50.8$^{a}$</td>
</tr>
<tr>
<td></td>
<td>Year 2</td>
<td>177.8$^{a}$</td>
<td>177.8$^{a}$</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>164.2</td>
<td>261.8</td>
</tr>
</tbody>
</table>

$^{a/b}$Differences between values in rows with different superscripts are significant, $P < 0.05$. 
Table 5. Steer ADG during the winter grazing, backgrounding, pasture, and feedlot phases, and weaning or pre-weaning to finish.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Supplementation treatment (Trt)</th>
<th>P =</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/d</td>
<td>Year (Yr)</td>
</tr>
<tr>
<td></td>
<td>Trt</td>
<td>n = 12</td>
</tr>
<tr>
<td>Pre-weaning</td>
<td>Minimal 1.0^a 1.4^b 1.1^c SE 0.02</td>
<td>0.25 &lt;0.01 0.08</td>
</tr>
<tr>
<td></td>
<td>Creep 0.7 0.3 0.5 SE 0.09</td>
<td>&lt;0.01 0.09 0.77</td>
</tr>
<tr>
<td></td>
<td>CDDGS 1.1^a 1.0^b 1.2^a SE 0.25</td>
<td>&lt;0.01 0.04 0.46</td>
</tr>
<tr>
<td></td>
<td>n = 12</td>
<td>&lt;0.01 0.02 0.02</td>
</tr>
<tr>
<td>Background</td>
<td>Pasture 1.1^a 1.0^b 1.2^a SE 0.25</td>
<td>0.02 0.23 0.26</td>
</tr>
<tr>
<td></td>
<td>Weaning-Finished</td>
<td>1.1 1.1 1.2 SE 0.02</td>
</tr>
<tr>
<td></td>
<td>Feedlot 0.9^a 1.5^b 1.1^a SE 0.10</td>
<td>0.24 0.03 0.33</td>
</tr>
<tr>
<td></td>
<td>Pre-weaning-Finished</td>
<td>1.0^a 1.1^b 1.1^b SE 0.02</td>
</tr>
</tbody>
</table>

^abcDifferences between means in rows with different superscripts are significant, P < 0.05.
Table 6. Amounts of CDDGS-based supplements fed to calves and cows during the pre-weaning, pasture, and feedlot phases

<table>
<thead>
<tr>
<th>Supplement</th>
<th>Phase</th>
<th>Days</th>
<th>Year</th>
<th>Supplementation treatment (Trt)</th>
<th>$P =$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Year (Yr)</td>
</tr>
<tr>
<td>Creep feed, kg/calf</td>
<td>Pre-weaning</td>
<td>132</td>
<td>137.9</td>
<td>132.2</td>
<td>8.27</td>
</tr>
<tr>
<td>CDDGS, kg/steer</td>
<td>Pasture</td>
<td>221</td>
<td>916.7$^a$</td>
<td>1065.8$^b$</td>
<td>4.59</td>
</tr>
<tr>
<td></td>
<td>Feedlot</td>
<td>52</td>
<td>448.5$^a$</td>
<td>337.3$^b$</td>
<td>27.35</td>
</tr>
<tr>
<td></td>
<td>Pasture and feedlot</td>
<td></td>
<td></td>
<td></td>
<td>1365.2</td>
</tr>
<tr>
<td></td>
<td>Pre-weaning</td>
<td></td>
<td></td>
<td></td>
<td>434$^a$</td>
</tr>
<tr>
<td>CDDGS, kg/cow</td>
<td>Pre-weaning</td>
<td>164.2$^a$</td>
<td>261.8$^b$</td>
<td>0.00</td>
<td>114.3$^a$</td>
</tr>
<tr>
<td>Total creep feed</td>
<td>Pre-weaning</td>
<td></td>
<td></td>
<td></td>
<td>1684.8$^a$</td>
</tr>
<tr>
<td>CDDGS and CDDGS, kg/cow-calf pair</td>
<td>Pre-weaning</td>
<td></td>
<td></td>
<td></td>
<td>1684.8$^a$</td>
</tr>
</tbody>
</table>

$^a$Includes Pre-weaning, Drylot post weaning, Pasture, and Feedlot Phases.

$^b$Differences between year or treatments means within rows with different superscripts are significant, $P < 0.05$. 


Table 7. Net returns and sensitivity analyses of August calves from different winter supplementation treatments that were sold at weaning or finished in a pasture-based system

<table>
<thead>
<tr>
<th>Calf marketing and winter supplementation treatment</th>
<th>Steers retained through finishing</th>
<th>Calves sold at weaning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimal</td>
<td>Creep</td>
</tr>
<tr>
<td>Net Returns</td>
<td>190.56</td>
<td>146.27</td>
</tr>
<tr>
<td>Labor +20%</td>
<td>147.70</td>
<td>97.73</td>
</tr>
<tr>
<td>Labor -20%</td>
<td>231.92</td>
<td>193.31</td>
</tr>
<tr>
<td>Land +20%</td>
<td>131.47</td>
<td>87.32</td>
</tr>
<tr>
<td>Land -20%</td>
<td>249.65</td>
<td>205.21</td>
</tr>
<tr>
<td>Hay +20%</td>
<td>262.31</td>
<td>218.90</td>
</tr>
<tr>
<td>Hay -20%</td>
<td>133.59</td>
<td>84.53</td>
</tr>
<tr>
<td>CDDGS +20%</td>
<td>155.75</td>
<td>99.17</td>
</tr>
<tr>
<td>CDDGS -20%</td>
<td>225.37</td>
<td>193.36</td>
</tr>
<tr>
<td>Cattle +20%</td>
<td>400.44</td>
<td>407.53</td>
</tr>
<tr>
<td>Cattle -20%</td>
<td>-54.24</td>
<td>-78.62</td>
</tr>
<tr>
<td>Yardage at $ 0.50</td>
<td>176.43</td>
<td>134.71</td>
</tr>
</tbody>
</table>

aLabor base value $12.00·hr\(^{-1}\) (Smith et al., 2004)
bLand cash rent $165.49/ha (Edwards and Smith, 2007)
cHay base value $92.43/metric ton (USDA-ERS, 2007)
dCDDGS base price $124.70 and creep feed $185.24/metric ton (USDA-AMS, 2008)
eCattle base price average in the month of sale from 1996 to 2005 (Lawrence, 2008)
   Finished steer prices $79.08 and $79.38 Jan. and Feb. respectively
   Weaned calf prices $111.07, $107.71, and $94.61·cwt\(^{-1}\) for 249, 295, and 340 kg calves
   Cull cow prices $47.83 (July)
fYardage base price was $0.335·hd\(^{-1}\)·d\(^{-1}\) (Lawrence, 2009)
Literature Cited


Lawrence: Steers 500-600# prices, monthly average, and seasonality index

Lawrence: Steers 700-800# prices, monthly average, and seasonality index

Lawrence: Choice Steer prices, monthly average, and seasonality index

Lawrence: Cull Cow prices, monthly average, and seasonality index

Lawrence: Summary of Estimated Returns

Lawrence: Optimal marketing weight for fed cattle. Iowa Beef Center at Iowa State University


Strohbehn, D. R. 1990. Opportunities to control input costs-an Iowa perspective. pp 13-22 In: Low Input Sustainable Agriculture Beef and Forage Conference. Omaha, NE.


CHAPTER 4. EFFECTS OF CORN DISTILLERS DRIED GRAINS WITH SOLUBLES SUPPLEMENTATION OF SMOOTH BROMEGRASS HAY ON FORAGE AND TOTAL DIET INTAKE AND DIGESTIBILITY

A paper to be submitted to Animal Feed Science and Technology
P. W. Lasley and J. R. Russell

Abstract

A digestion trial was conducted to evaluate the effects of feeding increasing amounts of supplemental corn distillers dried grains with solubles (CDDGS) with smooth bromegrass (Bromus inermis L.) hay on hay and diet intake and digestibility. Three Angus steers (334 ± 7.0 kg), in metabolism stalls, were fed smooth bromegrass hay at 110 and 100% of ad libitum intake during 10-d adjustment and 5-d collection phases, respectively, with a CDDGS supplement at 0, 0.5, 1.0, and 1.5% BW in successive periods. Increasing the amount of CDDGS supplement fed increased total DM intake as a percentage of BW (y = 1.2869 + 0.4559x; r² = 0.82), and digestibility as a percentage (y = 55.202 + 18.859x - 7.43x²; r² = 0.95), but decreased hay DM intake as a percentage of BW (y = 1.2874 - 0.4963x; r² = 0.84) where x equals CDDGS supplement intake as a percentage of BW. The substitution rate of CDDGS for smooth bromegrass hay increased quadratically with CDDGS supplement intake as a percentage of BW (y = -0.0017 + 0.9812x - 0.4582x²; r² = 0.75). Mean intakes of total and undigested NDF and ADF were 0.92 ± 0.05, 0.35 ± 0.024, and 0.47 ± 0.029 % BW and did not differ significantly by treatment. The DE and ME intakes (MJ/d) increased linearly (DE = 37.527 + 48.198x, r² = 0.99; ME = 25.98 + 35.368x; r² = 0.94) with increasing CDDGS supplement inclusion in the diet from 0 to 1.5% of BW. The DE and ME concentrations (MJ/kg) in the diet increased quadratically (DE = 8.7098 + 7.9858x - 2.2709x², r² = 0.98; ME = 5.4582 + 8.820x - 3.4865x², r² = 0.94) with increasing CDDGS supplement inclusion in the diet. Crude protein digestibility increased quadratically (y = 0.411 + 0.5163x - 0.1995x², r² = 0.99) and nitrogen balance increased linearly (y = 0.0019 + 0.0422x, r² = 0.94) with increasing the amounts of CDDGS supplement fed. Supplementation of grazing cattle with CDDGS can be used to increase diet digestibility while reducing forage intake and, thereby, extend pasture acres.

Key words: Distillers dried grains with solubles, hay, digestibility, dry matter intake, substitution rate, beef cattle
Introduction

Supplementation of grazing cattle with grain has increased BW gains of beef cows during winter grazing (Llewellyn et al., 2006; Poore et al., 2006; Wheeler et al., 2002) and stocker cattle during summer grazing (Machado et al., 2006; Bodine and Purvis, 2003; Hess et al., 1998). Supplementation of maize to cattle grazing tall fescue-white clover pastures improved digestibility of the diet, but decreased forage intake and grazing time (Machado et al., 2006). The decreases in forage intake and digestibility resulting from grain supplementation may be caused by a reduction in the rate of NDF digestion associated with lower rumen pH (Bodine and Purvis, 2003; Bargo et al., 2002).

Supplementation with feedstuffs like soyhulls, wheat middlings, and corn distillers dried grains with solubles (CDDGS) that contain highly digestible fiber may reduce the negative effects associated with grain supplementation (Bowman et al., 2004; Soto-Navarro et al., 2004; Lodge et al., 1997). This increase in DM intake and digestibility is likely caused by lower decreases in ruminal pH and increased populations of cellulolytic bacteria (Grigsby et al., 1992).

Other nutrients in DDGS can affect BW gains and forage intakes of grazing animals (MacDonald et al., 2007). Distillers dried gains with solubles provide undegradable intake protein (Peter et al, 2000; MacDonald et al., 2007) and degradable intake protein (Kleinschmit et al., 2007; MacDonald et al., 2007) necessary for microbial growth and fiber digestion. The high oil content of DDGS can supply energy for BW gain (MacDonald et al., 2007), but may reduce DM, OM, and NDF digestibility (Pavan et al., 2007).

If DDGS supplementation will increase diet digestibility while reducing forage intake, DDGS supplementation may be used to increase pasture stocking rates (MacDonald et al., 2007). The objective of this study was to evaluate the effect of CDDGS supplementation of cattle fed smooth bromegrass hay on total DM and hay intake and diet digestibility.

Materials and Methods

All procedures were approved by the Iowa State University Institutional Animal Care and Use Committee. In the summer of 2006, first-harvest smooth bromegrass (*Bromus inermis* L.) was mowed at the seed head stage, sun-cured, and baled as large round bales (800
kg). Bales were stored in a fully enclosed barn and tub-ground through a 7.5 cm screen prior to feeding.

Three Angus steers (334 ± 7.0 kg) were placed in metabolism stalls and fed smooth bromegrass hay with a CDDGS supplement (Table 1) fed at 0, 0.5, 1.0 and 1.5% BW in four successive periods. Each period had 10 d for adaptation to diets and determination of ad libitum intake followed by 5 d for collection of feed, feces, and urine. During diet adaptation, steers were fed smooth bromegrass hay at approximately 110% of ad libitum intake. During collection, smooth bromegrass hay was fed at 100% of ad libitum intake, as estimated during the adjustment phase. Corn distillers dried grains with solubles supplement form a single batch were fed at the designed percentage of steer BW, based on each steer’s BW at the initiation of each period. Diets were offered in equal amounts at 0700 and 1800 hours daily. Steers had free access to water during the entire study.

During the collection phase, hay and CDDGS supplement were sampled and orts were weighed daily. Orts were less than 5.0% of feed offered during collection and, therefore, not analyzed. Total feces and urine were collected daily and measured for weight and volume, respectively. Five percent of the feces and urine were subsampled by weight and volume, respectively. Sulfuric acid was premeasured into urine collection containers at approximately 5.0% of the urine volume on the previous day to acidify urine. Samples were pooled by animal by treatment and frozen until analysis.

**Chemical Analyses**

Hay and CDDGS supplement samples and a subsample of the fecal samples were dried in a forced-air oven (Blue M Electric Co., Blue Island, IL) at 65°C for 48 hr, weighed for determination of DM, and ground through a 1-mm screen of a Thomas-Wiley Mill (Arthur H. Thomas Co., Philadelphia, PA). Dried hay and CDDGS supplement samples and thawed wet fecal and urine samples were analyzed for CP as Kjeldahl N times 6.25 (AOAC, 1990). Nitrogen balance was calculated as the sum of Kjeldahl N in urine and feces subtracted from the sum of Kjeldahl N consumed as hay and CDDGS.

Neutral detergent fiber and ADF of dried hay, CDDGS supplement, and fecal samples were analyzed using an ANKOM200 Fiber Analyzer (ANKOM Technology Corporation, Fairport, NY). Gross energy (GE) of the hay, CDDGS supplement, and fecal
samples were analyzed using a bomb calorimeter (Parr Instrument Company, Moline, Illinois). Digestible energy (DE) was calculated as the GE of the feeds consumed minus the GE excreted as feces. Metabolizable energy was calculated as the DE minus the GE excreted as urine and the calculated energy loss as methane gas. Methane gas energy loss was assumed to be 6% of GE consumed by the animal (Johnson and Johnson, 1995).

**Statistical Analysis**

Statistics were analyzed using the Mixed procedure of SAS for the determination of significance of treatment differences and to determine the standard error of means. The regression procedure of SAS was used to determine linear and quadratic effects with increasing levels of supplementation. Individual animals were used as the experimental unit in all analyses and significance was considered to be less than $P = 0.05$ and tendencies less than $P = 0.10$.

**Results and Discussion**

Increasing the amount of CDDGS supplement fed with smooth bromegrass hay (analysis in Table 2) caused a linear ($P < 0.001$) increase in total DMI (Table 3). A tendency for increased total DMI was also observed when DDGS were supplemented at 0.4% BW to heifers with chopped grass hay (Loy et al, 2007). Hay intake decreased linearly ($y = 1.2874 - 0.4963x; r^2 = 0.8449, P = 0.0002$) as the level of CDDGS supplement fed increased. Substitution of smooth bromegrass hay DMI with CDDGS supplement increased quadratically ($P = 0.01$) according to the equation:

$$\text{Substitution ration (kg decrease in hay DMI/kg CDDGS DMI) = -0.0017 + 0.9812x -0.4582x^2}$$

(r$^2 = 0.76, P = 0.0001$)

where $x$ was the CDDGS supplement intake, as a percentage of BW (Table 3). From the first derivative of this equation, the maximum substitution rate of 0.53 kg forage DM intake for every kilogram of CDDGS DMI occurred when CDDGS were supplemented at 1.07% BW. This substitution rate is similar to that found by McDonald et al. (2007) when crossbred heifers grazing smooth bromegrass pastures were supplemented with distillers dried grains (DDG) at approximately 0.6% BW.

Intake of high forage diets may be controlled by the concentrations of fiber components as they play a role in fill of the gastrointestinal tracts (Jung and Allen, 1995;
Allen, 1996; NRC, 1996). Neutral detergent fiber is highly related to gut fill and inversely correlated to intake (Mertens, 1987), but differences in particle size, ruminating behavior, robustness of particles to mechanical size reduction, passage rate of digesta from the rumen, percentage of NDF that is indigestible and rate of digestion of the digestible fraction of NDF play a role in the overall intake of the diet (Allen, 1996). In this study, mean intakes of total and undigested NDF and ADF were 0.92 ± 0.05, 0.35 ± 0.024, and 0.47 ± 0.029 % BW (Table 4). Although NDF digestibility likely differed between the smooth bromegrass hay and CDDGS supplement, as implied by the ADF:NDF ratios of 0.57 and 0.40 in the two feeds, increasing the level of CDDGS supplementation did not affect total NDF, undigested NDF, or ADF intake. While fiber content of the diet is an important factor in gut fill and overall intake (Jung and Allen 1995; Allen, 1996), there is great variability in ruminally degradable organic matter at any given level of NDF concentration (Allen, 1997).

The apparent DM digestibility of diets increased quadratically as the amounts of CDDGS fed increased ($P < 0.01$; Table 5). Apparent dietary DM digestion was predicted as:  

$$\text{Apparent DM digestion (% of DMI)} = 55.2 + 18.86x - 7.43x^2 \quad (r^2 = 0.95, P = 0.0001)$$

where x was the CDDGS supplement intake, as a percentage of BW. The first derivative of this equation implies that the maximum digestibility of 67.2% occurred when CDDGS were fed at 1.26% BW and supplementing CDDGS at a level greater did not increase DM digestibility. Similar to DM digestibility, increasing the amounts of CDDGS resulted in a quadratic increase in the apparent digestion coefficient of NDF ($y = 56.943 + 12.632x - 5.1884x^2; r^2 = 0.81; P = 0.002$) and a tendency for a linear increase in the apparent digestion coefficient of ADF ($y = 49.621 + 4.816x; r^2 = 0.53; P = 0.03$, respectively). The quadratic effects of CDDGS intake on DM and NDF digestibility may be caused by concentration of fat in the diet which was calculated to be 7.9% of DM when CDDGS were supplemented at 1.5% BW (NRC, 1996). It has been observed that supplementation of corn oil to steers grazing endophyte-free tall fescue, decreased forage and total DMI linearly, as well as, decreasing in vivo DM, OM, and NDF digestibilities (Pavan et al., 2007). Because both digestibility and intake increased with increasing CDDGS supplementation in this study, CDDGS supplementation resulted in a linear increase in total digestible DMI, as a percentage of BW, as represented by the equation:
DDMI = 0.7319 + 0.4034x (r^2 = 0.9028, P = 0.0014).

Similar to DM digestibility, the concentrations of DE and ME in the diets increased quadratically with increasing CDDGS inclusion in the diet from 0 to 1.5% of BW as:
DE (MJ/kg) = 8.7098 + 7.9858x -2.2709x^2 (r^2 = 0.98, P = 0.0001);  
ME (MJ/kg) = 5.4582 + 8.820x -3.4865x^2 (r^2 = 0.94, P = 0.0001).

As a result, both DE and ME intakes increased linearly with increasing CDDGS inclusion in the diet from 0 to 1.5% of BW as:
DE intake (MJ/d) = 37.527 + 48.198x (r^2 = 0.988, P = 0.0001);  
and  
ME intake (MJ/d) = 25.98 + 35.368x (r^2 = 0.94, P = 0.0001).

Crude protein digestibility increased quadratically with increasing amounts of CDDGS fed as:
Apparent CP digestibility (%) = 0.411 + 0.5163x -0.1995x^2  
(r^2 = 0.988, P = 0.0001).
The increase in CP digestibility may have resulted from the increased CP concentrations of the diets with increased CDDGS supplementation diluting the effects of endogenous CP sources in the feces (Willms et al., 1991). Nitrogen balance of steers also increased linearly with increasing CDDGS fed as:
N balance (kg/d) = 0.0019 +0.0422x  
(r^2 = 0.94, P = 0.0001).
The increase in N balance likely resulted from both the increased levels MP (Klopfenstein et al. 2008; MacDonald et al., 2007; Peter et al., 2000) and energy levels (El-Kadi et al., 2008) associated with DDGS supplementation. The quadratic nature of the CP digestibility may be related to the AA absorption as it relates to ME intake (El-Kadi et al., 2008).

**Implications**

Supplementation of CDDGS to steers fed smooth bromegrass hay increased total DM digestibility of consumed feed while increasing the total feed intake. Because of the substitution of CDDGS for forage intake, supplementing CDDGS at 1.0% BW should allow cattle producers to increase stocking rates approximately 20%, assuming cows are consuming pasture forage at 2.5% of body weight. Because CDDGS supplementation at 1.0% BW increased total DM digestion by 19.8%, this 20% increase would be appropriate whether the cows were fed the supplement with or without rationing of pasture forage.
### Table 1. Composition of CDDGS supplement

<table>
<thead>
<tr>
<th>Component</th>
<th>% of DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn Distillers Dried Grains with Solubles</td>
<td>97.72</td>
</tr>
<tr>
<td>Limestone</td>
<td>1.85</td>
</tr>
<tr>
<td>Salt</td>
<td>0.33</td>
</tr>
<tr>
<td>Vitamin A premix(^a)</td>
<td>0.08</td>
</tr>
<tr>
<td>Trace mineral premix(^b)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

\(^a\) 1000 IU/g mixed 100g in 22.7 kg SBM as carrier (Rovimix 1000)

\(^b\) Trace mineral mix (Ca 11.84, Cu 1.5, Fe 10.0, Mn 8.0, Zn 12.0% min) (Co 1000, I 2000ppm min)
Table 2. Composition of smooth bromegrass hay and CDDGS supplement fed in digestion trial

<table>
<thead>
<tr>
<th>Component</th>
<th>Hay</th>
<th>CDDGS supplement</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM, %</td>
<td>90.1</td>
<td>95.1</td>
</tr>
<tr>
<td>% of DM</td>
<td>90.1</td>
<td>95.1</td>
</tr>
<tr>
<td>CP</td>
<td>7.7</td>
<td>25.4</td>
</tr>
<tr>
<td>NDF</td>
<td>66.1</td>
<td>43.6</td>
</tr>
<tr>
<td>ADF</td>
<td>37.5</td>
<td>17.3</td>
</tr>
<tr>
<td>GE (kJ·g⁻¹)</td>
<td>17.0</td>
<td>23.3</td>
</tr>
</tbody>
</table>
Table 3. Effects of supplementing CDDGS on total and hay DM intake and the substitution rate^a

<table>
<thead>
<tr>
<th>CDDGS fed, %BW</th>
<th>0</th>
<th>0.5</th>
<th>1.0</th>
<th>1.5</th>
<th>P=</th>
<th>Linear</th>
<th>Quadratic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg•hd^{-1}•d^{-1}</td>
<td></td>
<td></td>
<td></td>
<td>r^2 =</td>
<td></td>
<td></td>
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<tr>
<td>CDDGS</td>
<td>0</td>
<td>1.6</td>
<td>3.3</td>
<td>5.1</td>
<td>0.0001</td>
<td>0.9962</td>
<td>0.9973</td>
</tr>
<tr>
<td>Hay</td>
<td>4.2</td>
<td>3.7</td>
<td>2.5</td>
<td>2.0</td>
<td>0.0001</td>
<td>0.8806</td>
<td>0.8807</td>
</tr>
<tr>
<td>Total DM intake</td>
<td>4.2</td>
<td>5.3</td>
<td>5.8</td>
<td>7.1</td>
<td>0.0001</td>
<td>0.9244</td>
<td>0.9297</td>
</tr>
</tbody>
</table>

| CDDGS          | 0  | 0.47 | 0.95 | 1.43 | 0.0001 | 1.0 | 1.0 |
| Hay            | 1.27 | 1.09 | 0.74 | 0.56 | 0.0002 | 0.8449 | 0.8449 |
| Total DM intake| 1.27 | 1.57 | 1.69 | 1.99 | 0.0005 | 0.8192 | 0.8192 |

Substitution rate (kg•kg^{-1})

|                | 0  | 0.37 | 0.53 | 0.44 | 0.0018 | 0.5080 | 0.7550 |

^aSubstitution rate equals the decrease in hay DMI in kg per kg CDDGS consumed
Table 4. Effects of supplementing smooth bromegrass hay with CDDGS on the intake of NDF, ADF, undigested NDF, CP, DE, and ME in the diets.

<table>
<thead>
<tr>
<th>CDDGS fed, %BW</th>
<th>0</th>
<th>0.5</th>
<th>1.0</th>
<th>1.5</th>
<th>P=</th>
<th>Linear</th>
<th>Quadratic</th>
</tr>
</thead>
<tbody>
<tr>
<td>% BW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDF intake</td>
<td>0.84</td>
<td>0.93</td>
<td>0.90</td>
<td>0.99</td>
<td>0.2297</td>
<td>0.2788</td>
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<tr>
<td>ADF</td>
<td>0.48</td>
<td>0.49</td>
<td>0.44</td>
<td>0.45</td>
<td>0.7339</td>
<td>0.0664</td>
<td>0.0665</td>
</tr>
<tr>
<td>Undigested NDF</td>
<td>0.36</td>
<td>0.35</td>
<td>0.33</td>
<td>0.36</td>
<td>0.6911</td>
<td>0.0165</td>
<td>0.0981</td>
</tr>
<tr>
<td>CP</td>
<td>0.10</td>
<td>0.15</td>
<td>0.21</td>
<td>0.30</td>
<td>0.0001</td>
<td>0.9592</td>
<td>0.9737</td>
</tr>
<tr>
<td>DE MJ•d⁻¹</td>
<td>36.74</td>
<td>64.29</td>
<td>82.75</td>
<td>110.87</td>
<td>0.0001</td>
<td>0.9880</td>
<td>0.9880</td>
</tr>
<tr>
<td>ME</td>
<td>23.11</td>
<td>47.72</td>
<td>61.86</td>
<td>77.34</td>
<td>0.0001</td>
<td>0.9432</td>
<td>0.9558</td>
</tr>
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</table>
Table 5. Effects of supplementing smooth bromegrass hay with CDDGS on the apparent digestibility of DM and its constituents, N balance, and the concentrations of DE and ME in the diet

<table>
<thead>
<tr>
<th>CDDGS fed, %BW</th>
<th>0</th>
<th>0.5</th>
<th>1.0</th>
<th>1.5</th>
<th>P=</th>
<th>Linear</th>
<th>Quadratic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Apparent digestion coefficient, %</strong></td>
<td></td>
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<tr>
<td>DM</td>
<td>54.9</td>
<td>63.6</td>
<td>65.8</td>
<td>67.0</td>
<td>0.0001</td>
<td>0.8054</td>
<td>0.9549</td>
</tr>
<tr>
<td>NDF</td>
<td>56.7</td>
<td>62.6</td>
<td>63.8</td>
<td>64.4</td>
<td>0.0014</td>
<td>0.6584</td>
<td>0.8091</td>
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<td>ADF</td>
<td>48.8</td>
<td>53.6</td>
<td>53.6</td>
<td>56.9</td>
<td>0.0305</td>
<td>0.5299</td>
<td>0.5395</td>
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<tr>
<td>CP</td>
<td>40.8</td>
<td>62.8</td>
<td>71.9</td>
<td>74.0</td>
<td>0.0001</td>
<td>0.8459</td>
<td>0.9880</td>
</tr>
<tr>
<td><strong>Nitrogen Balance, kg•d⁻¹</strong></td>
<td>-0.003</td>
<td>0.029</td>
<td>0.046</td>
<td>0.062</td>
<td>0.0001</td>
<td>0.9375</td>
<td>0.9634</td>
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<tr>
<td><strong>DE, MJ/kg</strong></td>
<td>8.67</td>
<td>12.24</td>
<td>14.31</td>
<td>15.62</td>
<td>0.0001</td>
<td>0.9358</td>
<td>0.9818</td>
</tr>
<tr>
<td><strong>ME, MJ/kg</strong></td>
<td>5.43</td>
<td>9.09</td>
<td>10.70</td>
<td>10.87</td>
<td>0.0001</td>
<td>0.7954</td>
<td>0.9454</td>
</tr>
</tbody>
</table>
Literature Cited


CHAPTER 5. GENERAL CONCLUSION

The objective of the winter grazing study was to evaluate corn distillers dried grains with solubles (CDDGS) supplementation of August-calving cows or calves grazing stockpiled forage on cow and calf BW changes during winter and BW gain and carcass characteristics of the calves finished in a pasture-based system. As expected, the results showed that over the 2 winters, calves in the Creep treatment had greater BW gains than calves in the CDDGS and Minimal treatments. However, the economic analysis showed that if calves were sold at weaning, greater net profit was achieved with the minimal supplementation regimen. The increased BW gains were not sufficient to overcome the cost of the additional supplementation. Cows supplemented with CDDGS during the winter had decreased BW losses during winter, but the additional BW losses in the Minimal and Creep treatments had no noticeable detrimental impact on the breeding or economics of the herd. Also, cows in the Minimal and Creep treatments regained BW while on pasture in the spring at a lower cost than the winter supplementation. As a result, it was overall more profitable to supplement minimally to cows and not supplement calves during winter grazing. As the economic analysis was based on not changing the stocking rates, and the metabolism trial indicated that the stocking rates could be increased by 20% with supplementation, perhaps this would alter the economics analysis.

This study also contained a pasture-based finishing portion where steers were supplemented with CDDGS. It was observed that the post-weaning ADG of steers from the Minimal and CDDGS treatments were greater than steers fed a CDDGS-based creep feed pre-weaning. The literature suggests that it is not uncommon for steers on differing nutritional planes to equilibrate as they approach finishing BW, and this phenomenon is often referred to as compensatory gain (Owens et al., 1993; Drouillard and Kuhl, 1999). This increased gain by the lighter steers at weaning resulted in mean live weight and carcass weights, backfat thickness, ribeye area, and marbling score at harvest that did not differ between treatments. While in this study we did not observe differences in the above mentioned carcass parameters, and one could argue that the lack of differences may in fact be a result of the limited number of steers in the study. While nothing can be done at the present to address this concern, it would be potentially be of value to repeat the study with more
animals to either validate the results or to refute them and provide information as to which carcass parameters are affected with such a feeding regimen. Under the circumstances above, the economic analysis indicated that providing August-calving cows or calves grazing stockpiled forage with minimal supplementation during winter resulted in greater net profit when steers were sold at harvest than supplementing CDDGS to either cows or calves during winter at equal stocking rates.

A metabolism study was conducted simultaneous to the grazing experiment to evaluate the effect of CDDGS supplementation of cattle fed smooth bromegrass hay on total DM and hay intake and diet digestibility. It was observed that increasing the amount of CDDGS supplement fed increased total DM intake as a percentage of BW and digestibility as a percentage, but decreased hay DM intake as a percentage of BW. This increase in DM intake and simultaneous decrease in hay DMI resulted in a quadratically increasing substitution rate of CDDGS for smooth bromegrass hay with increasing CDDGS supplement intake as a percentage of BW. The maximum substitution rate of 0.53 kg forage DM intake for every kilogram of CDDGS DMI occurred when CDDGS were supplemented at 1.07% BW. This substitution ratio means that at ad lib intake of forage and CDDGS fed at 1% of BW steers will replace about 0.5 kg of forage with 1 kg of CDDGS. Increasing inclusion of CDDGS in the diet resulted in quadratic increases in the digestibilities of dietary DM, NDF, and CP and the concentrations of DE and ME which may be associated with the fat content of CDDGS. But in spite of effects of CDDGS on nutrient digestion, the effects on supplementation on total DMI resulted in linear increases in the intakes of digestible DM, metabolizable energy, and crude protein. The metabolism study results imply that supplementation of grazing cattle with CDDGS can be used to increase diet digestibility while reducing forage intake. This increase in diet digestibility and reduction in intake could be valuable under several circumstances including pasture shortage for a number of reasons, decreasing cost of CDDGS making it an economical substitute for pasture forage, or when increasing stocking rates is desirable. Under conditions where it is desirable to substitute CDDGS for hay as an energy source it may be necessary to be able to limit hay or forage intake so that the supplementation results in extension of pasture acres and not simply increased overall intake of energy.
<table>
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<th>Year 2</th>
<th></th>
<th>Significance</th>
<th>Day mean</th>
<th>Intercept</th>
<th>Day mean</th>
<th>Intercept</th>
<th>Day mean (Intercept)</th>
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</thead>
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<td></td>
<td>Mass</td>
<td>Model</td>
<td>Year</td>
<td>Block</td>
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<td>Graze</td>
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<td>Ungrazed</td>
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<td>3633.8</td>
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<td></td>
<td>(3.55)</td>
<td>(521.2)</td>
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<td></td>
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<td>(1.175)</td>
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<td></td>
<td>(0.99)</td>
<td>(0.470)</td>
<td>(0.330)</td>
<td>(0.550)</td>
<td>(0.346)</td>
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<tr>
<td>Year 2</td>
<td>56.65</td>
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<td>0.0001</td>
<td>0.0343</td>
<td>0.067</td>
<td>0.006</td>
<td>0.434</td>
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<tr>
<td>Ungrazed</td>
<td>-0.134</td>
<td>56.2</td>
<td>0.470</td>
<td>(0.330)</td>
<td>(0.550)</td>
<td>(0.346)</td>
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### APPENDIX B. EFFECTS OF CDDGS SUPPLEMENTATION ON COW BW, COW BCS, AND CALF BW OVER THE WINTER GRAZING SEASON

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cow BW (kg)</th>
<th>Cow BCS</th>
<th>Calf BW</th>
<th>ADG</th>
</tr>
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<tr>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>Change</td>
<td>Initial</td>
</tr>
<tr>
<td>Min</td>
<td>677a</td>
<td>620</td>
<td>-57a</td>
<td>6.2a</td>
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<tr>
<td>Creep</td>
<td>681a</td>
<td>622</td>
<td>-59a</td>
<td>5.9b</td>
</tr>
<tr>
<td>CDDGS</td>
<td>660b</td>
<td>634</td>
<td>-25b</td>
<td>6.1ab</td>
</tr>
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<td>SE</td>
<td>6.89</td>
<td>16.2</td>
<td>13.3</td>
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<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td>0.011</td>
<td>0.39</td>
<td>0.019</td>
<td>0.052</td>
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</tbody>
</table>

| Year 1 | Min | 679.6 | 625.2 | -54.3 | 6.04 | 4.47 | -1.58 | 126.3 | 244.0 | 119.2 | 0.89 |
|        | Creep | 681.7 | 628.0 | -53.7 | 5.75 | 4.71 | -1.05 | 130.3 | 317.6 | 187.3 | 1.40 |
|        | CDDGS | 667.0 | 656.7 | -10.3 | 6.13 | 4.96 | -1.17 | 129.3 | 278.7 | 149.4 | 1.12 |
| Year 2 | Min | 673.9 | 614.2 | -73.3 | 6.33 | 4.67 | -1.69 | 138.1 | 272.0 | 133.8 | 0.99 |
|        | Creep | 679.4 | 615.6 | -63.8 | 6.08 | 4.69 | -1.65 | 129.8 | 317.9 | 188.1 | 1.39 |
|        | CDDGS | 652.2 | 611.7 | -40.5 | 6.04 | 4.81 | -1.54 | 141.8 | 283.9 | 142.1 | 1.05 |
|        | SE | 9.74 | 22.95 | 18.75 | 0.08 | 0.09 | 0.12 | 18.3 | 22.3 | 9.0 | 0.07 |

| significance | Year | 0.088 | 0.044 | 0.081 | 0.042 | 0.993 | 0.016 | 0.291 | 0.234 | 0.456 | 0.660 |
### APPENDIX C. FORAGE AVAILABLE OVER THE SUMMER GRAZING SEASON

*(kg/100kg BW)*

<table>
<thead>
<tr>
<th>Pasture</th>
<th>Trt</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Creep</td>
<td>14.9</td>
<td>9.9</td>
<td>15.0</td>
<td>12.7</td>
<td>12.0</td>
<td>6.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>CDDGS</td>
<td>7.1</td>
<td>10.4</td>
<td>13.1</td>
<td>8.0</td>
<td>9.0</td>
<td>5.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Min</td>
<td>13.0</td>
<td>14.8</td>
<td>15.9</td>
<td>14.9</td>
<td>12.4</td>
<td>8.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Min</td>
<td>16.4</td>
<td>16.1</td>
<td>15.6</td>
<td>15.2</td>
<td>6.6</td>
<td>4.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Creep</td>
<td>8.3</td>
<td>10.3</td>
<td>13.8</td>
<td>13.7</td>
<td>8.2</td>
<td>5.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>CDDGS</td>
<td>8.9</td>
<td>9.8</td>
<td>10.9</td>
<td>12.4</td>
<td>6.6</td>
<td>7.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td>14.1</td>
<td>25.4</td>
<td>21.5</td>
<td>11.4</td>
<td>11.9</td>
<td>14.0</td>
<td>12.8</td>
<td>9.1</td>
<td>6.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pasture</th>
<th>Trt</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Creep</td>
<td>15.3</td>
<td>13.3</td>
<td>10.7</td>
<td>11.2</td>
<td>7.3</td>
<td>6.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>CDDGS</td>
<td>11.3</td>
<td>8.9</td>
<td>9.2</td>
<td>9.2</td>
<td>4.6</td>
<td>4.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Min</td>
<td>9.8</td>
<td>9.1</td>
<td>8.3</td>
<td>8.5</td>
<td>5.9</td>
<td>5.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Creep</td>
<td>10.4</td>
<td>7.8</td>
<td>8.2</td>
<td>7.2</td>
<td>4.4</td>
<td>3.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>CDDGS</td>
<td>12.1</td>
<td>9.0</td>
<td>9.1</td>
<td>6.8</td>
<td>4.6</td>
<td>3.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Min</td>
<td>11.7</td>
<td>9.5</td>
<td>9.7</td>
<td>8.3</td>
<td>5.3</td>
<td>4.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td>19.0</td>
<td>19.5</td>
<td>11.8</td>
<td>9.6</td>
<td>9.2</td>
<td>8.5</td>
<td>5.4</td>
<td>4.7</td>
<td></td>
</tr>
</tbody>
</table>

*Value after steer removal from pastures*
### APPENDIX D. EFFECTS OF CDDGS SUPPLEMENTATION ON ANIMAL PERFORMANCE AND PURCHASED FEED INTAKE BY PERIOD

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>Contrasts</th>
<th>P=</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Creep</td>
</tr>
<tr>
<td>1</td>
<td>2 SE</td>
<td>Min</td>
<td>Creep</td>
</tr>
</tbody>
</table>

#### Steer ADG (kg/hd/d)
- **Pre-weaning**
  - Background: 1.2, SE 1.0, Min: 1.4, Creep: 1.1, CDDGS: 0.02, Min*Creep: 0.0001, Min*CDDGS: 0.0049, Creep*CDDGS: 0.0002, P= 0.2526, 0.0001, 0.0825
  - Pasture: 0.8, SE 0.2, Min: 0.7, Creep: 0.3, CDDGS: 0.09, Min*Creep: 0.0429, Min*CDDGS: 0.4238, Creep*CDDGS: 0.0161, P= 0.0028, 0.0874, 0.7674
  - Feedlot: 1.6, SE 0.8, Min: 0.9, Creep: 1.5, CDDGS: 1.1, Min*Creep: 0.0093, Min*CDDGS: 0.1819, Creep*CDDGS: 0.0511, P= 0.0011, 0.0242, 0.0165

#### Gain
- **Pre-weaning**
  - Background: 152.2, SE 154.7, Min: 126.6, Creep: 187.8, CDDGS: 145.9, Min*Creep: 0.0001, Min*CDDGS: 0.0053, Creep*CDDGS: 0.0002, P= 0.4862, 0.0001, 0.1014
  - Pasture: 27.2, SE 27.3, Min: 22.9, Creep: 11.7, CDDGS: 15.1, Min*Creep: 0.0357, Min*CDDGS: 0.1021, Creep*CDDGS: 0.4318, P= 0.0011, 0.0823, 0.8296
  - Feedlot: 210.3, SE 276.0, Min: 247.8, Creep: 226.6, CDDGS: 255.0, Min*Creep: 0.0443, Min*CDDGS: 0.4112, Creep*CDDGS: 0.0161, P= 0.0002, 0.0366, 0.4554

#### Creepfeed
- **Pre-weaning**
  - Background: 85.1, SE 30.7, Min: 53.2, Creep: 58.4, CDDGS: 62.2, Min*Creep: 0.0106, Min*CDDGS: 0.0642, Creep*CDDGS: 0.1682, P= 0.0001, 0.2591, 0.3044

#### CDDGS steer
- **Pre-weaning**
  - Background: 295.3, SE 306.8, Min: 301.1, Creep: 284.9, CDDGS: 317.1, Min*Creep: 0.2106, Min*CDDGS: 0.2186, Creep*CDDGS: 0.362, P= 0.2712, 0.0904, 0.9783

#### Total CDDGS + creep
- **Weaning-Finished**
  - Background: 474.4, SE 467.3, Min: 450.5, Creep: 484.3, CDDGS: 477.8, Min*Creep: 0.0331, Min*CDDGS: 0.0652, Creep*CDDGS: 0.5981, P= 0.488, 0.068, 0.629

#### Plus cow Cow CDDGS
- **Pre-weaning**
  - Background: 137.9, SE 132.2, Min: 0.0, Creep: 405.4, CDDGS: 0.0, Min*Creep: 0.001, Min*CDDGS: 1, Creep*CDDGS: 0.001, P= 0.6338, 0.0001, 0.7831

- **Pre-weaning**
  - Background: 916.7, SE 1065.8, Min: 983.1, Creep: 987.4, CDDGS: 1003.1, Min*Creep: 0.6113, Min*CDDGS: 0.0534, Creep*CDDGS: 0.1054, P= 0.0001, 0.1118, 0.1118

- **Pre-weaning**
  - Background: 448.5, SE 337.3, Min: 431.0, Creep: 316.2, CDDGS: 431.6, Min*Creep: 0.0597, Min*CDDGS: 0.917, Creep*CDDGS: 0.0589, P= 0.0348, 0.0939, 0.0945

- **Pre-weaning**
  - Background: 1365.2, SE 1403.1, Min: 1414.2, Creep: 1303.6, CDDGS: 1434.7, Min*Creep: 0.0965, Min*CDDGS: 0.7201, Creep*CDDGS: 0.06, P= 0.4301, 0.1171, 0.1178

- **Pre-weaning**
  - Background: 1520.6, SE 1560.2, Min: 1435.2, Creep: 1730.2, CDDGS: 1457.9, Min*Creep: 0.0034, Min*CDDGS: 0.7307, Creep*CDDGS: 0.046, P= 0.4292, 0.0058, 0.1615

- **Pre-weaning**
  - Background: 1684.8, SE 1822.0, Min: 1549.5, Creep: 1844.5, CDDGS: 1866.3, Min*Creep: 0.0034, Min*CDDGS: 0.0025, Creep*CDDGS: 0.7156, P= 0.0308, 0.0043, 0.0787

- **Pre-weaning**
  - Background: 164.2, SE 261.8, Min: 114.3, Creep: 114.3, CDDGS: 410.5, Min*Creep: 1, Min*CDDGS: 0.0001, Creep*CDDGS: 0.0001, P= 0.0001, 0.0001, 0.0001
### APPENDIX E. EFFECTS OF CDDGS SUPPLEMENTATION ON CARCASS CHARACTERISTICS

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>P=</th>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Min</td>
<td>DDG</td>
</tr>
<tr>
<td>Days in feed lot (d)</td>
<td>51.5</td>
<td>72.5</td>
<td>41.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>41.0</td>
<td>41.0</td>
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<tr>
<td>HCWT (kg)</td>
<td>360.8</td>
<td>340.1</td>
<td>360.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>357.1</td>
<td>371.3</td>
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<tr>
<td>FAT COVER (cm)</td>
<td>1.1</td>
<td>0.8</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>% KPH (%)</td>
<td>2.2</td>
<td>2.1</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.2</td>
<td>2.4</td>
</tr>
<tr>
<td>REA (cm²)</td>
<td>81.1</td>
<td>79.5</td>
<td>78.4</td>
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<td>80.2</td>
<td>85.2</td>
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<td>marbling score</td>
<td>3.2</td>
<td>2.8</td>
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<tr>
<td></td>
<td></td>
<td>2.9</td>
<td>3.3</td>
</tr>
<tr>
<td>% Choice (%)</td>
<td>65.3</td>
<td>58.5</td>
<td>75.0</td>
</tr>
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<td></td>
<td>50.0</td>
<td>75.0</td>
</tr>
<tr>
<td>YG plant</td>
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<td>2.0</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>6.6</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>Trt</td>
<td>0.10</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>Yr</td>
<td>0.07</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>Trt*Yr</td>
<td>0.21</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.35</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.82</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>0.89</td>
<td>0.52</td>
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</table>
APPENDIX F. NET RETURNS AND SENSITIVITY ANALYSES OF AUGUST CALVES FROM DIFFERENT WINTER SUPPLEMENTATION TREATMENTS THAT WERE SOLD AT WEANING OR FINISHED IN A PASTURE-BASED SYSTEM

<table>
<thead>
<tr>
<th>Expensess, $/steer</th>
<th>Steers retained through finishing</th>
<th>Calves sold at weaning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimal</td>
<td>Creep</td>
</tr>
<tr>
<td>Land</td>
<td>209.38</td>
<td>209.38</td>
</tr>
<tr>
<td>Equipment, fuel and repairs</td>
<td>96.40</td>
<td>96.40</td>
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<tr>
<td>Purchased feed</td>
<td>187.73</td>
<td>240.10</td>
</tr>
<tr>
<td>Herd expenses</td>
<td>293.45</td>
<td>301.29</td>
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<tr>
<td>aYardage</td>
<td>28.14</td>
<td>22.95</td>
</tr>
<tr>
<td>Labor</td>
<td>140.51</td>
<td>171.26</td>
</tr>
<tr>
<td>Veterinary</td>
<td>40.00</td>
<td>40.00</td>
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<tr>
<td>Animal Interest</td>
<td>46.54</td>
<td>51.15</td>
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<tr>
<td>Operating interest</td>
<td>16.55</td>
<td>16.17</td>
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<tr>
<td>Miscellaneous</td>
<td>79.11</td>
<td>80.28</td>
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<tr>
<td>Haying cost</td>
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<td>188.00</td>
</tr>
<tr>
<td>Expenses subtotal</td>
<td>1,325.81</td>
<td>1,416.99</td>
</tr>
<tr>
<td>Revenue, $/steer</td>
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<td></td>
</tr>
<tr>
<td>Finished steer sales</td>
<td>1,017.65</td>
<td>1,062.04</td>
</tr>
<tr>
<td>Cull cow</td>
<td>136.21</td>
<td>134.82</td>
</tr>
<tr>
<td>Hay</td>
<td>377.29</td>
<td>377.29</td>
</tr>
<tr>
<td>Weaned steers</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Revenue subtotal</td>
<td>1,531.15</td>
<td>1,574.15</td>
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<tr>
<td>Net Return</td>
<td>190.56</td>
<td>146.27</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sensitivity Analysis on Net Returns</th>
<th>Steers retained through finishing</th>
<th>Calves sold at Weaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
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<td>Creep</td>
</tr>
<tr>
<td>Labor +20%</td>
<td>147.70</td>
<td>97.73</td>
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<td>231.92</td>
<td>193.31</td>
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<tr>
<td>Land +20%</td>
<td>131.47</td>
<td>87.32</td>
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<tr>
<td>Land -20%</td>
<td>249.65</td>
<td>205.21</td>
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<tr>
<td>Hay +20%</td>
<td>262.31</td>
<td>218.90</td>
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<td>Hay -20%</td>
<td>133.59</td>
<td>84.53</td>
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<tr>
<td>CDDGS +20%</td>
<td>155.75</td>
<td>99.17</td>
</tr>
<tr>
<td>CDDGS -20%</td>
<td>225.37</td>
<td>193.36</td>
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<tr>
<td>Cattle +20%</td>
<td>400.44</td>
<td>407.53</td>
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<tr>
<td>Cattle -20%</td>
<td>-54.24</td>
<td>-78.62</td>
</tr>
<tr>
<td>aYardage at $ 0.50</td>
<td>176.43</td>
<td>134.71</td>
</tr>
</tbody>
</table>

aYardage includes drylot (average 29d) post-weaning and time in feedlot (average 51.5d)
### APPENDIX G. COMPOSITION OF FREE CHOICE TRACE MINERAL AND VITAMIN PREMIX

<table>
<thead>
<tr>
<th>Component</th>
<th>Max</th>
<th>Min</th>
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</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>18.3%</td>
<td>15.3%</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>8.0%</td>
<td></td>
</tr>
<tr>
<td>Salt (NaCl)</td>
<td>16.2%</td>
<td>13.5%</td>
</tr>
<tr>
<td>Magnesium</td>
<td>1.0%</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>0.15%</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>1,450 ppm</td>
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</tr>
<tr>
<td>Manganese</td>
<td>4,950 ppm</td>
<td></td>
</tr>
<tr>
<td>Selenium</td>
<td>26.4 ppm</td>
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</tr>
<tr>
<td>Zinc</td>
<td>4,750 ppm</td>
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</tr>
<tr>
<td>Vitamin A</td>
<td>380,000 IU/lb</td>
<td></td>
</tr>
<tr>
<td>Vitamin D₃</td>
<td>100,000 IU/lb</td>
<td></td>
</tr>
<tr>
<td>Vitamin E</td>
<td>375 IU/lb</td>
<td></td>
</tr>
</tbody>
</table>

Kent Framework 365 Mineral ADE
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The following is a quote that I came across a number of years ago, which has since that time hung on my wall.

“Let us remember that the privilege to work is a gift, that the power to work is a blessing, and that love of work is success.”

President David O. McKay