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THE EFFECT OF CALVING SEASON AND WINTERING SYSTEM ON COW AND CALF PERFORMANCE AND ECONOMICS FROM CONCEPTION THROUGH FINISHING AND THE EFFECT OF SUPPLEMENTING DRIED DISTILLERS GRAINS TO CALVES IN FORAGE BASED SYSTEMS

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By

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THE EFFECT OF CALVING SEASON AND WINTERING SYSTEM ON COW AND CALF PERFORMANCE AND ECONOMICS FROM CONCEPTION THROUGH FINISHING AND THE EFFECT OF SUPPLEMENTING DRIED DISTILLERS GRAINS TO CALVES IN FORAGE BASED SYSTEMS

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Three experiments were conducted to determine the effect of calving season and cow wintering systems on cow and calf performance and economics from conception to slaughter, the effect of supplementing steers dried distillers grains while grazing cool season dominated meadow, and a meta-analysis was conducted to determine the effect supplementing dried distillers grains to cattle in forage based growing systems. In the first experiment, cows were bred to calve in spring, summer or fall. Calves from each system were managed as calf-feds or yearlings and followed through finishing. Altering calving season impacted cow BW and BCS but did not affect re-breeding performance or the percent of cows to calve. However, fall calving cows produced fewer weaned calves compared to spring and summer calving cows. In addition, there was a significant effect of calving season on calf finishing performance and economics. Wintering system did not affect performance or profitability of cow systems. The second study evaluated dried distillers grain supplementation to steers grazing cool season meadow. Results from this

study suggest that lower levels of DDGS supplementation (0.6% BW) do not effect summer ADG or ending BW. However, when supplementation was increased (1.2% BW) ADG and ending BW were increased. In addition, supplementing dried distillers grains to calves grazing cool season meadow did not affect subsequent feedlot performance but BW at harvest was greater for steers supplemented dried distillers grains. The third study, evaluated dried distillers grains supplementation to cattle in forage based growing systems across multiple studies. Results from this study indicate that cattle supplemented dried distillers grains have greater gains during summer grazing. In addition, increasing the level of dried distillers grains supplementation results in a quadratic increase in ADG and ending BW. Supplementing dried distillers grains resulted in increased overall intake but decreased forage intake with increasing level of dried distillers grains.

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INTRODUCTION

Flexibility within the cattle industry is a very valuable resource. In Nebraska, there are multiple forage resources in abundant supply. The Nebraska Sandhills is an area that is focused on cow-calf production because of the inability to produce crops on those lands. However, during the winter, supplementation of harvested forages and purchased feedstuffs is critical in the traditional spring calving system. This is due to nutrient requirements of the cow and nutrient availability of the forage resources being out of balance. Shifting calving date can offer an opportunity to better match the nutrient requirements of the cow with the nutrient availability of the forage, ultimately reducing needs for harvested forages or purchased feeds.

In Nebraska the supply of post harvest residues, particularly cornstalks, are abundant. Cattle have the ability to utilize post harvest residues offering an opportunity to reduce the demand for winter range resources or purchased feedstuffs. This allows flexibility with in the cow-calf operation, allowing for greater ranch stocking rates or reduced forage demand from ranch resources. In addition, it offers an opportunity to maintain herd size during times of drought because of forage resources that do not utilize ranch resources.

The ability to background an animal is a very important resource in cattle production. Through the use of backgrounding, producers have more options and opportunities to use their available resources. Backgrounding programs also provide marketing flexibility by providing producers a longer time frame in which to sell their calves. Forage resources are crucial in backgrounding programs allowing producers to grow cattle to a desired weight before entering the feedlot or maintaining cattle on forage resources until market conditions improve. In addition, cost of gain while utilizing forage resources are typically lower than feedlot cost of gain.

Dried distillers grains, a product from the dry milling ethanol industry, are a great resource for forage based systems. Dried distillers grains are high in protein and energy and offer an opportunity for increased gains in forage based systems. Increased gain for cattle is critical since cattle are sold based on BW. However, level of supplementation can have a negative impact on forage digestibility due to higher fat levels in dried distiller grains. Therefore, it is critical to know the effect of dried distillers grains supplementation level on cattle performance and forage replacement.

Therefore the objectives of the research reported in this dissertation were to: 1) evaluate the impact of calving season and wintering system on cow and calf performance and economics from conception to slaughter, 2) to determine the effect of dried distillers grains supplementation on performance of calves grazing cool season meadow, and 3) to determine the effect of level of dried distillers grains supplementation on calf performance in forage based systems.

LITERATURE REVIEW

Production Systems Research.

Typically when research in cattle production is reported it is a particular phase of production not the entire system from conception to harvest. Those phases include: the production of the cow and calf from conception to weaning, cow performance through breeding, the calf in a growing system, or feedlot finishing. Rarely is the entire cattle production system followed through completion in a research project. However, following a cattle production from cow conception to calf harvest is important because of how inputs into the system at earlier phases of production can have a significant impact on the final outcome of production from an animal performance or economic return standpoint. Systems research is very complex and hard to accomplish relative to the amount of labor in data collection and the time that it takes to complete these types of projects. In addition, there are so many influences to evaluate, that could impact the overall outcome of the cattle production system. Systems influencers include but are not limited to cow nutrition status that can be influenced by calving season, wintering system and supplementation. Similarly calf management after weaning can have a profound impact on subsequent grazing or finishing performance and include nutritional status of the dam, wintering system of the dam, finishing system decisions (calf-fed vs. yearling) and supplementation practices prior to feedlot entry.

In cow production systems, forage (cellulose) is the dominant feed resource. Cellulose, the most abundant plant product on earth, can be converted to protein and energy that can be used by the ruminant through microbial fermentation (Van Soest, 1994). This unique ability makes the ruminant valuable, allowing the use of forage rather than grain for the production of beef products. Only 37% of the grains produced are fed to ruminants yet ruminants produce 61% of the human food energy from animal agriculture (Oltjen and Beckett, 1996). Ruminants also allow for the use of highly erodible land that may have no other use than for grazing (Oltjen and Beckett, 1996). Ruminants also have the ability to utilize the two hundred fifty billion Mcal of post harvest crop residues and by-products that would otherwise go to waste into a product consumable by humans (Smith, 1980; Reid and Klopfenstein, 1983). Oltjen and Beckett (1996) reported that ruminants take advantage of only 25% of the land that is viable for forage production. Therefore, beef production should continue to be a viable source for human food production. In addition, research into forage-animal interaction, further utilization of grazable forages, and efficiencies of beef production systems are needed (Hodgson, 1977). However, all of the nutrient needs cannot be met with forage grazing alone.

Meeting the cow's nutrient requirements.

Typically when supplementation is discussed energy and protein are the major topics. There are multiple ways to meet the cow's protein and energy requirements. Perhaps the best studied is providing supplemental energy and protein when range forage sources are low in nutrient availability. Earlier work focusing on protein supplementation used the crude protein system. Clanton and Zimmerman (1963) evaluated protein and energy requirements of the cow and found that beef cattle production was not impacted when adequate energy was provided, but a combination of energy and protein tended to improve reproductive performance. When evaluating just the effects of protein, Clanton and Zimmerman (1966) reported that protein supplementation (range = 0.00 to 0.45 kg of CP) in wintering cow rations resulted in increased calf BW and more calves weaned per cow. Clanton et al. (1966) reviewed protein and energy relationships in cow rations and concluded that energy and protein have to be in balance in order for cows to maintain acceptable conception rates, calf weaning BW, and cow milk production.

Over the years the idea of protein supplementation has changed from a crude protein system (measurement of nitrogen multiplied by 6.25) to a metabolizable protein (**MP**) system. With the MP system, protein is assessed as degradable intake protein (**DIP**; microbial protein) or undegradable protein (**UIP**; true protein/amino acids). In forage grazing systems for cows Clanton et al. (1969) concluded that cows had increased performance when urea (DIP) was included in a 40% CP supplement at 3 to 6%. In addition, Hollingsworth-Jenkins et al. (1996) reported that cows wintered on native range had increased gain with DIP supplementation up to 140 g/d. Lardy et al. (1996) reported that gestating cows supplemented higher levels in DIP were not deficient in MP; however, as the cow shifts into lactation both DIP and UIP are needed to meet a MP deficiency.

As a producer considers the proper supplementation strategy for their production system, cost is important. Typically purchasing feeds or harvesting feed adds considerable cost into a cattle production system (Adams et al., 1996; Clark et al., 2004; Stockton et al., 2007). Therefore ways to utilize ranch resources, in particular grazing resources, and prevent purchasing or harvesting feeds have been studied. Clanton and Jones (1970) evaluated keeping cows on winter pasture instead of placing them in drylot through winter seasons. Clanton and Jones (1970) found that keeping cows on pasture instead of drylot resulted in increased reproductive performance and BW gain for cows. Villalobos et al. (1993) supplemented cows with meadow hay instead of purchased feeds and found that it was an effective supplementation practice. However, one must consider the cost of equipment and labor for harvesting when utilizing hay.

Harvesting hay can be a significant cost to cow-calf production; therefore research at the Gudmundson Sandhills Laboratory was conducted to determine if cows could be wintered without feeding hay. Horney et al. (1996) found that grazing meadow during the winter was a suitable alternative to feeding hay. Horney et al. (1996) concluded that calves from cows wintered on meadow had increased gain performance that was maintained after weaning. Loy et al. (2004) found that grazing winter range instead of feeding hay resulted in a $7.00/hd improvement in cost and did not compromise cow gain or rebreeding performance. Given that cost increases with harvested feeds and purchased supplements it is logical to find ways to reduce supplementation. Altering calving season is a logical way to achieve a reduction in supplemental feed needs.

Effect of calving season on cow and calf performance.

Traditionally in the Nebraska Sandhills calving has occurred in spring (February, March, and April). When evaluating a spring calving season, peak lactation occurs in April and May resulting in the greatest energy requirement for spring calving animals occurring in April and May. For Range resources TDN content peaks in May (Geisert et al., 2008). Therefore, differences in BW and BCS for the cows throughout the different periods of the year are expected because of how cow requirements (NRC, 1996) and nutrients from forage resources match or do not match throughout the year. In addition, it is important to determine how the animal requirements match up with the nutrient availability since energy status is an extremely important factor that can affect cow performance (Stalker et al., 2006; Larson et al., 2009). In addition, rebreeding performance is directly related to the energy status of the cow (Randel; 1990).

Geisert et al. (2008) and Benton et al. (2006) evaluated energy and protein available in forage resources throughout the year. Geisert et al. (2008) analyzed organic matter digestibility throughout the entire year for upland native Sandhills range and found that range digestibility peaked in late February to early March. This is the time that cows in a spring calving herd would be calving. Over the next 60 d when cows would enter peak lactation and have the greatest energy requirement, native range declined in digestibility. Results from Geisert et al. (2008) would suggest that spring calving cows would need to be supplemented energy in order to maintain BCS and BW based on digestibility of forage resources when the cow's nutrient requirements are greatest. Benton et al. (2006) evaluated protein content and protein digestibility of upland range and meadows and found that protein content declined from May to September. In addition, digestibility of UIP declined and total tract indigestible protein increased from May to September. Data from Benton et al. (2006) and Geisert et al. (2008) illustrate that range resources are actually declining in quality as cow nutrient requirements are increasing in a spring calving herd. These data support the use of supplemental feeds in spring calving herds and suggest that shifting calving season could better match the cows nutrient requirements with the range nutrient availability.

When evaluating the performance data of different calving seasons, Lardy et al. (1998b) compared spring and summer calving herds in the Nebraska Sandhills. Lardy et al. (1998b) found that summer born calves had greater birth BW, but reduced weaning BW. Summer calving cows had less harvested hay input compared to spring calving cows (14 vs. 1446 kg/yr). For spring born calves, weight gain from birth to weaning was greater compared to summer born calves; however, rebreeding performance was not different when comparing spring and summer calving cows. Grings et al. (2005) compared spring and summer calving cows and found that summer calving cows had greater change in BCS throughout the production year compared to spring calving cows; however, summer calving cows had lower BW at weaning than spring calving cows.

Julien and Tess (2002) found that weaning BW decreased as calving and weaning dates were moved to later in the year and calves from each calving system were weaned at similar days of age. In addition, ADG for calves in this study were similar to results reported in previous studies (Adams et al., 2001; Grings et al., 2005; Reisenauer Leesburg et al., 2007a) who found that spring born calves had heavier weaning BW compared to summer born calves when calves were weaned at the same days of age, suggesting that ADG for spring born calves is greater than summer born calves.

Effect of calving season on subsequent calf finishing performance.

When evaluating calving season, the cow is not the only animal that should be evaluated, calf performance must also be considered. When evaluating calf performance, Phillips et al. (2006) evaluated the effect of calving season on calf feedlot performance and slight differences in feedlot ADG were observed with calves born later in the year being lighter at feedlot entry and lighter at harvest. In Phillips et al. (2006), weaning age did not consistently effect feedlot ADG. In addition, calving dates reported by Phillips et al. (2006) occurred in early February, early April and late May.

Adams et al. (2001) utilized a March and June calving season and reported that feedlot ADG was greater for June born calves compared to March born calves. Adams et al. (2001) reported lower BW at weaning and feedlot entry for June born calf-feds when compared to March born calf-feds. In addition, Adams et al. (2001) used calves from each season that were weaned at similar days of age. Lardy et al. (1998a) utilized similar treatments and found that spring born calves had greater feedlot initial BW compared to summer born calves. When comparing feedlot performance no differences were observed and returns were not different for spring or summer born calves. In addition, Lardy et al. (1998a) fed half of the summer born calves as yearlings and reported a typical yearling response compared to calf-feds with yearlings having greater final BW, DMI, G: F, HCW, and QG with fewer days on feed.

Reisenauer Leesberg et al. (2007b) evaluated a spring, summer, and fall calving system with calves weaned at similar days of age. In their study they found that calf-feds from each calving season had similar feedlot ADG. Comparing carcass characteristics, fall born calves had greater HCW, similar LM area, similar fat thickness, and a reduction in the percent of cattle grading choice or higher compared to calves from spring calving cows. Janovick Guretzky et al. (2005) reported similar feedlot ADG and G: F for fall and spring born calves. In addition, Janovick Guretzky et al. (2005), spring and fall born calves were weaned at similar days of age.

When evaluating economics of different calving seasons, later calving season resulted in lower cost per cow (May et al., 1999; Carriker et al., 2001; Payne et al., 2009). The reason for the reduction in cost was a result of feeding less harvested forage for later season calving cows compared to spring calving cows.

From the studies discussed above it is clear that calving season can have a significant impact on cow and calf performance. In addition, shifting calving data can reduce the inputs into a production system without compromising returns. Therefore, shifting calving date is an acceptable consideration when making decisions on how to reduce and manage ranch inputs in order to maximize production.

Wintering cows on cornstalks.

It has been shown that cows can maintain BW and BCS during the winter while grazing range resources. However, in Nebraska there is an abundant supply of post harvest crop residues, in particular cornstalks. For many years corn residue grazing has been used in the Nebraska cattle industry. The use of corn residue can be advantageous to beef production systems by providing low cost feed that does not compete with human food sources (Guteirrez-Ornelas, 1989). Corn residue is comprised of several plant components and quality can be quite variable. The variation in corn residue quality can be explained through the makeup of the components of the residue. The major components of the residue are stalks, cobs, leaves, husks, and grain. Stalks and cobs have the lowest nutrient content and tend to be the least consumed of the residues (Clanton, 1989). Leaves and husk are higher in nutrient content than stalks and cobs, and are readily consumed (Clanton, 1989). Grain has the highest nutrient content in the residue and is usually the first plant component to be consumed in the field (Fernandez-Rivera and Klopfenstein, 1989).

Wilson et al. (2004) reviewed cornstalk grazing from the standpoint of animal performance and crop yield. Subsequent year soybean yield after cornstalk grazing tended to be greater compared to ungrazed plots. In addition, corn yield was not impacted when comparing grazed and ungrazed plots. In Wilson et al. (2004) parts of the corn plant were evaluated to determine nutrient value. In addition, nutrient value of the cornstalks was measured over the grazing season to evaluate changes in quality over time. Wilson et al. (2004) reported that stem was the predominant forage mass in the field and the least palatable and nutrient dense. Leaf was the second largest fraction of the residue at 27% of total forage mass, and was 7.8% crude protein and 47% digestible. Husk and cob were only 12% each of the forage mass of the field. In addition, husk is the most digestible fraction (67%) and the most palatable. As the grazing season progressed from d 0 to 60, digestibility of the crop residue in the field declined from 68% to 44%. This is because as cattle grazed cornstalks they selected the more digestible material (leaf and husk) leaving more stalk and cob (least digestible) in the field.

When comparing cornstalks to native range, nutrient quality is similar from a protein standpoint. However, when cattle are first introduced to a new field digestibility of the forage material may be higher than that of native range but as the days on the field increase the digestibility of the forage in the field decreases to levels lower than the digestibility of native range. From a nutrient quality standpoint native range and cornstalks are comparable but can cornstalks fit into a cow wintering system and how does it affect cow performance and subsequent calf finishing performance?

Cow performance.

Clanton et al. (1980) evaluated traditional spring calving wintering practices of supplementing cows with hay (alfalfa) while grazing winter range to winter cornstalk grazing. Results from Clanton et al. (1980) demonstrated that wintering on cornstalks was equal to wintering on native pasture, even though cows supplemented hay on native range had a greater energy status compared to cows wintered on cornstalks. In addition, Clanton and Ford (1987) used a computer simulation to compare wintering on irrigated pasture, native upland range, and cornstalks. Cows wintered on cornstalks tended to produce greater calf BW because of better pre-calving condition for cows. In addition, when comparing cost irrigated pasture was greater compared to cornstalks and native range, even though irrigated pasture had greater carrying capacity. For the irrigated pasture and native range Clanton and Ford (1987) reported increased cost due to supplementation and that when comparing profitability cornstalks were the most profitable.

Anderson et al. (2005) found that BW and BCS prior to weaning were not different between cows wintered on cornstalks or stockpiled pasture. At weaning Anderson et al. (2005) showed that cows wintered on cornstalks had lower BW and BCS than cows wintered on pasture. However, Larson et al. (2009) reported that cows wintered on cornstalks had greater BW at weaning than cows wintered on native Sandhills range even though BCS at weaning was not different. Also, Anderson et al. (2005) and Larson et al. (2009) showed no difference in breeding performance for cows in differing wintering systems. Larson et al. (2009) reported similar calf performance from birth to weaning when cows were wintered on native Sandhills range or cornstalks.

Ultimately when choosing a wintering system, economics should be the tool used for decision making. Larson et al. (2009) reported cows wintered on cornstalks to be more profitable at weaning when compared to cows wintered on native range. However, Anderson et al. (2005) reported lower cost when cows were wintered on cornstalks but reported no significant difference in returns per cow when calves were sold at weaning.

Subsequent calf-performance.

When evaluating systems research it is important to consider the effect that previous treatments have on performance of other phases of the system. when comparing maternal wintering systems it is important to consider the impact that this may have on future calf performance since maternal influences can have a significant effect on calf-performance.

Larson et al. (2009) concluded that steer calves from cows wintered on native range or cornstalks presented no difference in feedlot performance or carcass characteristics. Anderson et al. (2005) reported differences in performance of calves from cows wintered on range or cornstalks; however in Anderson et al. (2005) calves from cows wintered on cornstalks were finished as yearlings and calves from cows wintered on pasture were finished as calf-feds. Based on data from Larson et al. (2009) and because there were no differences in cow performance when comparing wintering systems, it strengthens the argument that cornstalks are a suitable alternative to wintering on native range. In addition, because of no difference in calf performance after weaning it is reasonable to believe that differences in economics observed after calf finishing would be a carryover effect of the maternal wintering system.

Calf age at weaning.

Within a production system the inputs from each system can effect the optimal weaning time for calves. When utilizing a cornstalk wintering system in the Nebraska Sandhills, location of cornstalks from the ranch can be a challenge. At the Gudmundson Sandhills Laboratory located in Whitman, NE, cornstalks are 84 km away from the ranch. The time that cattle can graze cornstalks in the winter is from mid-November until the first of March. In order to wean calves at similar days of age in later calving season cows and calves would have to be transported back to the ranch and weaned. This is increased cost to the system because of hauling cattle to and from the ranch and cornstalks. Therefore, weaning age affects on the cow and the calf become an important factor that needs to be reviewed.

Stalker et al. (2007) evaluated a spring calving system in which calves were weaned in August or November. Stalker et al. (2007) reported cows that were in the early weaning treatment had increased BCS compared to late wean cows. Calf BW gain from birth to weaning was reduced with later weaning dates; however, late weaned calves had greater weaning BW compared to early weaned calves. Stalker et al. (2007) followed calf performance through finishing and found that early weaned calves had lower initial BW, required more days on feed to finish at similar BW as late weaned calves, reduced DMI, reduced ADG, and increased fat thickness compared to late weaned calves. In addition, QG was not different when comparing weaning treatments. Economic returns reported by Stalker et al. (2007) were equal at weaning but were greater for later weaned calves at finishing.

Myers et al. (1999) compared cow and subsequent calf performance when calves were weaned at 90, 152, and 215 d of age. Myers et al. (1999) concluded that early weaning increased cow BCS due to an improvement in energy status of the cow. In addition, pregnancy rate tended to improve (12%) with cows in early weaning treatment. When comparing subsequent calf finishing performance, early weaning resulted in improved G: F but no differences in carcass quality were reported.

Grings et al. (2005) evaluated the effect of calf weaning age in a February, April, and June calving seasons. Weaning ages reported by Grings et al. (2005) were 190 and 240 d in February and April calving systems and 140 and 190 d in the June calving system. When compared at 190 d of age, calves from June calving cows were lighter than February and April born calves. When comparing weaning age of February and April calving systems, no difference in calf BW gain or cow BCS and BW were observed when all calves and cows were weighed at 190 d of calf age. However, when compared at different weaning ages, early weaned calves had reduced weaning BW, and cow BCS decreased with increasing weaning age.

Story et al. (2000) evaluated the effect of different weaning times on cow and calf performance in a spring calving herd. Weaning ages evaluated were 150, 210, and 270 d. Story et al. (2000) reported that weaning early resulted in increased BCS for cows at weaning but did not affect pregnancy rates. Calves were followed through finishing and early weaned calves had increased feedlot ADG and reduced DMI. In addition early weaned calves had greater 12^{th} rib fat thickness when compared to later weaned calves. When compared at equal fat thickness, carcass quality was not different. Economic results from Story et al. (2000) resulted in increased profitability for earlier weaned calves with calves weaned at 150 d of age returning $73.26/hd, calves weaned at 210 d of age returning $62.16/hd, and calves weaned at 270 d of age returning $10.09/hd.

Results from the studies discussed above illustrate that age of the calf at weaning can have a large impact on the performance of the cow and the calves. The differences in performance between early and late weaned systems are due to difference in energy balance of the cow as milk production decreases (NRC, 1996) and shifting lighter calves form milk and forage to high grain finishing diets. Therefore, weaning age is an important consideration when comparing different cow-calf production systems.

Calf-fed vs. yearling finishing systems.

When determining what finishing system calves enter, calf type should be evaluated. In addition, the finishing system selected can have a significant impact on the economics of the entire production system from conception to harvest. There are two major beef production systems in the United States: an intensive system where calves are placed into the feedlot after weaning and fed a high concentrate diet until finished and an extensive system were cattle are backgrounded after weaning on crop residue or harvested/grazed forages prior to feedlot entry. Both systems have merit in the United States and warrant investigation.

Feedlot Performance and Carcass Characteristics

In order to properly manage different cattle types, we must be aware of the production potential of animals and understand the biological differences that exist in cattle that are intensively or extensively managed. Harris et al. (1997) completed a study utilizing two groups of cloned Brangus steers to evaluate performance, carcass traits, and meat palatability of steers fed as calf-feds or yearlings. Calf-feds were started in the feedlot directly after weaning, while yearling cattle were allowed to graze bermudagrass pasture for 123 d in experiment 1 and native range for 120 d in experiment 2. The first group was fed to a constant age endpoint of 16 mo of age, and the second group was fed to a constant weight endpoint of 530 kg. When calf-feds and yearlings were finished to the same age endpoint there was not a difference in feedlot ADG. However, the calf-fed steers were heavier and had a higher dressing percentage. Yearling cattle displayed lower

YG and had lower marbling scores than calf-feds. When steers were fed to a constant weight endpoint, yearlings gained more rapidly in the feedlot, and had lower yield grades. However, there was no difference in meat palatability. These studies illustrate the importance of knowing the cattle type and then managing accordingly. Perhaps, the differences in these cattle are not completely accurate when comparing them at equal days or at equal body weights. When comparing cattle of different types it is more important to compare at equal fat endpoints (Tedeschi et al., 2004).

Schoonmaker et al. (2002) evaluated performance of cattle at 3 different ages of placement into the feedlot: 1) 111 days (early weaned), 2) 202 days, and 3) 371 days (yearling). Steers were harvested at an ultrasound estimated fat thickness of 1.27 cm. While in the feedlot, yearlings gained 0.26 and 0.20 kg/d more than calves placed in the feedlot at either 111 or 202 days of age, respectively. The younger calves spent the most number of days in the feedlot. Dry matter intake in the feedlot was not significantly different among age groups; however, DMI was numerically highest for yearlings. Even though the yearlings were least efficient, they showed the greatest advantage in final weight of 100 and 165 kg, when compared with cattle 202 and 111 days of age, respectively. This increase in final weight was due to a 55 and 99 kg increase in hot carcass weight compared with cattle that were 202 and 111 days of age, respectively. When comparing carcass characteristics, yearlings had a larger LM area, lower YG, and more cattle grading select than calves 202 and 111 days of age.

Carcass quality is a very important aspect of production and can often be a major goal of an operation. This is an important consideration because there seems to be a perception in the industry that calf-feds are more likely to produce a carcass that has increased marbling and is more palatable compared with yearling fed cattle. Myers et al. (1999) conducted a 2-year study that evaluated steers fed high concentrate diets after weaning and steers grown on pasture for 82 d before entering the feedlot. Steers entering the feedlot directly after weaning had higher ADG, lower DMI, and were more efficient than steers backgrounded on pasture. However, there was no difference in carcass characteristics of steers placed on a high concentrate diet or steers backgrounded for 82 d and then placed on feed.

Camfield et al. (1999) conducted a 9-year study with steers in either feedlot or pasture development treatments. Four different growth types were used: 1) large framed-late maturing, 2) intermediate framed-intermediate maturing, 3) intermediate framed early maturing, and 4) small framed-early maturing. Maturing rate and frame size were determined by the breed type of the animal. Among feedlot and pasture developed steers, the early maturing steers had greater marbling scores, quality grades, and yield grades. Between both systems the larger framed-late maturing steers had larger LM area, heavier BW, and hot carcass weights. In conclusion, the authors stated that this study was not designed to compare systems. However, it does demonstrate the variation that exists in carcass traits for growth types. Even though backgrounded cattle can be less efficient than calf-feds, quality carcasses can be produced in both production systems. These studies illustrate again the importance of understanding cattle type and managing cattle based on their type. When cattle are managed according to type, animal performance and carcass characteristics are improved, leading to an improvement in production efficiency and profitability.

Griffin et al. (2007) utilized eight years of data to compare performance of calf-feds and yearlings. Griffin et al. (2007) reported that initial BW for yearlings at receiving was lighter, feedlot initial BW was greater, and final BW was greater compared to calf-feds. In addition, yearlings had greater feedlot ADG, fewer days fed, greater DMI, and reduced G: F compared to calf-feds. In addition, QG did not differ for yearlings compared to calf-feds. Calf-feds produced more YG 4 carcasses while yearlings produced more overweight carcasses. When comparing cattle at similar fat endpoints, yearlings had greater percent choice compared to calf-feds.

Profitability

Griffin et al. (2007) reported that yearlings were more profitable than calf-feds due to increased weight sold and lower cost of gain throughout the entire production system. Lewis et al. (1990) conducted a sensitivity analysis of several production costs for extensive and intensive beef production system. The added carcass weight from the extensive production system was important to the profitability of the system because interest rates affected extensive systems more than intensive systems. This increase in cost was due to the fact that calf-fed steers have more efficient feed conversion and were owned fewer days than yearling cattle; however, total feed consumption for calf-feds is higher than that of yearlings leading to increased feeding cost. These authors also suggest that winter and summer inputs must be minimized in order to maximize profitability.

Steer and heifer finishing performance.

In cow-calf production both males and females are produced. Typically when finishing system performance is discussed steers are the animal used but heifers not used for breeding must enter a terminal system. When comparing steers and heifers, significant biological differences exist when evaluating performance. When determining how to manage steers and heifers in a terminal system it is important to consider differences in performance since they can have a profound effect on the economic outcome of a production system.

Tanner et al. (1970) and Zinn et al. (1970) compared steer and heifer performance in finishing studies and concluded that steers produced greater HCW and had greater ADG compared to heifers. Taylor et al. (2008) reported that heifers had lower DMI, lower ADG and similar G: F when compared to steers. When comparing carcass characteristics, carcass quality results have been mixed with Tanner et al. (1970) reporting no difference in QG, Zinn et al. (1970) reporting increased QG in steers, and Taylor et al. (2008) reporting greater marbling scores for heifers when fed a similar number of days. When evaluating economic differences Taylor et al. (2008) reported that steers were $20.00/hd more profitable than heifers.

Dried distillers grains supplementation in forge based systems.

Dried distillers grains plus solubles is a byproduct from the dry milling industry. In the dry milling process starch is removed from the grain, primarily corn, to produce ethanol and the remaining nutrients are recovered, dried and marketed as dried distillers grains (Stock et al., 2000). During the dry milling process, approximately two thirds of corn grain is removed (starch), therefore, concentrations of protein, fat, fiber, and P in dried distillers grains are increased approximately three fold when compared to corn. Growing cattle in summer grazing systems can be deficient in MP. This suggests that supplemental MP form dried distillers grains could increase ADG during the grazing season (Loy et al., 2008; MacDonald et al., 2007). In addition, cattle in summer grazing systems can benefit from additional energy provided from DDGS supplementation (Loy et al., 2008; Morris et al., 2005).

In the past, grazing supplementation has been accomplished with corn grain; however, because of increasing ethanol production, corn prices have increased compromising cost of gain in traditional supplementation practices and have led to increased finishing cost of cattle. This increase in finishing cost has caused producers to evaluate opportunities to increase cattle BW prior to feedlot entry using lower priced feed resources. Dried distillers grains plus solubles is typically priced lower than corn grain (approximately 70 to 90% the price of corn on a DM basis) and because of increased supply and competitive price of DDGS relative to corn, DDGS have become a viable resource for supplementing growing cattle consuming forage based diets prior to feedlot entry.

Klopfenstein (1996) reviewed supplementation studies for growing cattle and found that UIP supplementation increased gain by meeting a MP deficiency and that increased energy from supplemental feeds increased ADG as well. The dynamics between energy and protein supplementation and the observed responses can be very difficult to differentiate as an energy or MP response in the ruminant animal because the addition of energy can increase microbial protein synthesis. In addition, other considerations must be made when considering protein degradation within the rumen

When evaluating UIP from dried distillers grains supplementation, MacDonald et al. (2007) reported UIP content of dried distiller grains and meeting an MP deficiency to be a major contributing factor to increased ADG accounting for up to one-third of the increase in ADG. In addition, MacDonald et al. (2007) reported a 0.06 kg increase in

ADG for each 0.1% of BW increase in DDGS supplementation. Lomas and Moyer (2008) reported a quadratic gain response to DDGS supplementation when steers grazed cool season grasses. In Lomas and Moyer (2008), steers supplemented 0.5% BW of DDGS exhibited a 53% increase in ADG; however, when supplementation increased to 1.0% of BW, gain was only improved by 50% compared to nonsupplemented steers.

Corrigan et al. (2007) reported a quadratic ADG response when level of dried distillers grains supplementation was increased up to 1.0% of BW in a high forage diet. Another possible explanation for quadratic responses observed with dried distiller grains can be due to the fat intake of cattle at higher levels of dried distillers grains supplementation. Fat intake of cattle with higher levels of dried distillers grains supplementation is enough to potentially inhibit fiber digestion (Hess et al., 2008). However, the fat level may not be of any concern until fat intake is $\geq$ 6% of the total diet (Doreau and Chilliard, 1997).

Rolfe et al. (2011) reported that steers supplemented while grazing native Sandhills range had a 49% improvement in gain when supplemented modified distillers grains at a rate 0.6% of BW daily. The increase in ADG during summer grazing resulted in a 47 kg increase in BW at feedlot entry. Rolfe et al. (2011) evaluated modified distillers grains which is a product that is 40 to 50% DM compared to dry distillers grains that is 90% DM. However, DM may not matter in growing diets and grazing programs as moisture has not been shown to have an impact on distillers grains energy values when compared to corn in forage based diets (Ahern et al., 2011; Nuttelman et al., 2008).

Morris et al. (2006) reported an increase in ADG of 16 and 33 % when steers were supplemented dried distillers grains at a rate of 0.6 and 1.2% BW while grazing native range. In addition, Morris et al. (2006) reported a linear increase in ADG with increased level of supplementation. Morris et al. (2005) also evaluated dried distillers grains supplementation to heifers consuming low and high quality forage and reported that heifers supplemented 0.6 and 1.2% of BW and fed low quality hay gained 40 and 76 kg more during the 84 d feeding period respectively, compared to heifers not supplemented dried distillers grains. In addition, Morris et al. (2005) reported heifers consuming high quality hay and supplemented dried distillers grains at a rate of 0.6 and 1.2% BW gained 31 and 58 kg more during the 84 d feeding period, respectively, compared to heifers not supplemented DDGS.

Watson et al. (2011) concluded that steers supplemented dried distillers grains at a rate 0.6% BW daily gained an additional 40 kg over a 156 d grazing period which is consistent with Greenquist et al. (2009) in which cattle gained 37 kg (35% improvement in ADG) more BW over a 160 d grazing period when supplemented dried distillers grains at a rate of 0.6% BW. Watson et al. (2011) reported that with 2.3 kg/d of DDGS intake, supplemented steers consumed 5.8 kg/d forage compared to nonsupplemented cattle that consumed 8.6 kg/d forage. This suggests that with increased gain from dried distillers grains supplementation forage intake can also be reduced allowing for increased stocking rates on pasture or stockpiling forage resources during time of drought.

Funston et al. (2007) reported a 44% improvement in ADG when dried distillers grains were fed to calves free choice. In Funston et al. (2007), it was determined that calves consumed 1.5% BW dried distillers grains daily. In addition, Gustad et al. (2008) reported a 0.68 kg/d increase, a 150% improvement in ADG when growing cattle were supplemented 1.0% BW dried distillers grains daily. When compared to previous dried distillers grains research, the response to dried distillers grains supplementation observed by Gustad et al. (2008) was the greatest because she utilized calves that were lighter and would have had greater MP requirements per kg of BW.

It is important to consider the length of the grazing season and time of year that grazing is occurring. Changes in forage quality can have a large impact on ADG response to dried distillers grains supplementation. This perhaps explains some of the differences observed in the different studies. In Watson et al. (2011) TDN was 68% at the beginning of the grazing season and 53% at the conclusion of the grazing season. The change in forage quality caused the gain response from dried distillers grains supplementation to increase from 0.2 to 0.4 kg/d as the grazing season progressed. The increase in ADG throughout the grazing season occurs due to increased protein and energy from dried distillers grains supplementation while forage protein and energy content are declining. Most grazing studies occur during the forage growing season. During the growing season forage quality would be the greatest (Geisert et al., 2008; Benton et al., 2006). However, some grazing studies are conducted through the forage growing season and continue well past the growing season (Rolfe et al., 2011; Watson et al.; 2011, Gustad et al., 2008; Lomas and Moyer, 2008) and needs to be considered when evaluating supplementation work since forage quality changes over time and cattle energy and protein requirements change with BW changes.

Subsequent feedlot performance.

Watson et al. (2010), Greenquist et al. (2009), and Funston et al. (2007) concluded no difference in feedlot performance and marbling scores between calves supplemented dried distillers grains and nonsupplemented calves. However, Greenquist et al. (2009) reported increased BW after finishing for supplemented steers; however the difference in BW after finishing and at the end of summer grazing were similar suggesting that supplementation of DDGS during summer grazing did not affect subsequent feedlot gain. Data from Watson et al. (2010), Greenquist et al. (2009), and Funston et al. (2007) suggest that there is no compensatory gain for nonsupplemented cattle during the finishing period. However, Lomas and Moyer (2008) reported a 0.12 kg/d increase in feedlot ADG for nonsupplemented calves compared to calves supplemented dried distillers grains during summer grazing, suggesting that nonsupplemented calves do exhibit compensatory gain. In the largest supplementation study, Rolfe et al. (2011) used 240 steers/yr (120 steers/treatment) and followed treatments through harvest for 3 yr. From this study, Rolfe et al. (2011) reported no difference in feedlot ADG for steers that were supplemented 0.6% BW dried distillers grains or nonsupplemented during summer grazing. Unlike Watson et al. (2010), Greenquist et al. (2009), and Funston et al. (2007), Rolfe et al. (2011) fed supplemented steers fewer days than nonsupplemented steers and reported lower marbling scores compared to nonsupplemented steers.

Conclusions

It is obvious that decisions relative to management of productions systems can have a significant impact on the biological and economic responses observed. When evaluating cow-calf production systems, the energy and protein status of the cow is critical to efficient cost effective performance of the system. In addition, the relationship of energetics between the cow and calf can impact the overall production of the system. In addition, matching the cow requirements with the nutrient availability of the forage resources is critical to reducing purchased feed and harvested forage inputs into the production system.

Opportunities to utilize multiple forage resources are an important part to Nebraska cattle production. Nebraska is abundant in post harvest residue and post harvest residue is an excellent feed resource for cattle. Utilization of post harvest residue offers flexibility to cow calf producers from the standpoint of cost and managing ranch forage resources. This is critically important from the standpoint of sustainability of cow-calf production and can help cattle production maintain or improve in the future.

Increasing calf BW gain prior to feedlot entry helps reduce time in the feedlot and can decrease the cost of production for cattle. Nebraska has a large supply of distillers grains that when used with forage growing systems are an ideal supplement relative to meeting and exceeding energy and protein requirements for cattle in forage based systems. In current market situations increased BW without utilization of high priced grain resources is advantageous and can produce greater returns in finishing cattle systems.

Therefore the objectives of the research reported in this dissertation were to: 1) evaluate the impact of calving season and wintering system on cow and calf performance and economics from conception to slaughter, 2) to determine the effect of dried distillers grains supplementation on performance of calves grazing cool season meadow, and 3) to determine the effect of level of dried distillers grains supplementation on calf performance in forage based systems.

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Effect of calving season and wintering system

The Effect of Calving Season and Wintering System on Cow and Calf Performance: A Systems Approach to Cattle Production in the Nebraska Sandhills[1]

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ABSTRACT

A four year study using two hundred seventeen cows/year (5/8 Red Angus, 3/8 Continental) was conducted to evaluate effects of calving season and wintering system on cow and calf performance from birth to harvest. Cows were assigned to one of five treatments: 1) spring calving (**SP**) wintered on native range, 2) SP wintered on cornstalks, 3) summer calving **(SU)** wintered on native range, 4) SU wintered on cornstalks, and 5) fall calving (**FA**) wintered on cornstalks. Steers from SP entered the feedlot at weaning (calf-fed). At weaning, half of SU and FA calves from each treatment were fed as calf-feds and the other half grazed cool season meadow prior to feedlot entry. Data were analyzed as a completely randomized design with binomial measurements analyzed using GLIMMIX. Across calving season, pre-breeding BW was lowest for SP (480 kg) and greatest for FA (589 kg; $P < 0.01$). At weaning, BW was lower for SP compared to SU ($P = 0.03$) and FA ($P = 0.14$), which were similar ($P = 0.64$). At pre-calving, BW was greatest for FA (629 kg; $P < 0.01$) and lowest for SP (533 kg; $P < 0.01$). Rebreeding performance was similar across calving seasons ($P = 0.22$). When comparing calf-feds from each system, G: F for SP (0.174) and SU (0.162) calves were different ($P < 0.01$) and FA (0.169) was intermediate. In the current study, wintering system did not influence cow or subsequent calf performance. Calving season significantly affected cow BW and BCS at certain times of the year, and influenced calf performance from birth to harvest.

Keywords: calving season, feedlot, system, wintering

INTRODUCTION

Cellulose, the most abundant plant product on earth, can be converted to protein and energy that can be used by the ruminant through microbial fermentation (Van Soest, 1994). There are many sources of cellulose available for use. Typically in cow-calf production, the focus has been on native range or pasture; however, the use of corn residue can be advantageous to beef production systems by providing low cost feed that does not compete with grain demand (Guteirrez-Ornelas, 1989). The use of cornstalk grazing could result in reduced needs for harvested forages. This is important to cow-calf production since the amount of harvested feed required to maintain cows in the Nebraska Sandhills can be a significant cost input for ranches (Adams et al., 1996; Clark et al., 2004; Stockton et al., 2007). In addition, the amount of harvested forage needed is directly related to calving date (Adams et al., 1996; Clark et al., 2004).

In the Sandhills of Nebraska, cows are traditionally bred to calve in February, March, and April which leads to lactation occurring in early spring. In early spring, range forages are dormant and low in protein and energy (Geisert et al., 2008). To meet nutrient requirements of the cows, producers feed hay and other purchased feeds that can lead to increased cost for spring calving cows (Stockton et al., 2007). However, changing calving date and utilization of crop residues could decrease the use of harvested forages and purchased feed resources by matching the cow's requirements with the time of year that forage resources are greater in protein and energy, potentially decreasing cost for cow-calf producers in both the cow herd and the calf crop. However, in any production system, changing inputs could alter subsequent breeding performance of the cows or calf feeding performance.

Therefore, the objectives of this study were to determine the effect of calving season and wintering program on cow and subsequent calf performance from conception to slaughter.

MATERIALS AND METHODS

Cow Management

A four year study was conducted using an average of two hundred seventeen cows (5/8 Red Angus, 3/8 Continental) per year from the Gudmundsen Sandhills Laboratory (Whitman, NE). Cows were assigned to one of five treatments. Treatments were: 1) spring calving cows (**SP**) wintered on native range, 2) SP wintered on cornstalks, 3) summer calving cows (**SU**) wintered on native range, 4) SU wintered on cornstalks, or 5) fall calving cows (**FA**) wintered on cornstalks. Calving data were collected from 2005 through 2008. Average calving dates for SP were March 24th, March 25th, March 26th, and March 23th, for yr 1, 2, 3, and 4, respectively. Average calving dates for SU were June 14th, June 17th, June 16th, and June 12th, for yrs 1, 2, 3, and 4, respectively. Average calving dates for FA were August 8th, August 4th, August 10th, and July 31st, for yrs 1, 2, 3, and 4, respectively. Overall average calving dates were March 24th, June 15th, and August 5th for SP, SU, and FA, respectively. Prior to data collection, all cows were allocated to their respective calving season and wintering treatment for one year. Therefore, data collection began in the second year after implementation of each cow system.

Cows were exposed to fertile bulls for a 45 d breeding season with a 1:25 bull to cow ratio. Cows that did not calve within a 45 d window were removed from the data set. For SP, 0, 6, 5, and 6 cows were removed in yr 1, 2, 3, and 4. For SU, 7, 4, 1, and 4 cows were removed in yr 1, 2, 3, and 4. For FA, 4, 1, 2, and 0 cows were removed in yr 1, 2, 3, and 4. For all calving groups, cows were given a pre-calving vaccination for *Clostridium perfringens C, Escherichia coli*, *Rotavirus,* and *Coronavirus* (Scourguard 3 (K)/ C (Pfizer Animal Health, New York, NY). At pre-breeding cows were vaccinated for *infectious bovine rhinotracheitis, parainfluenza-3 virus, bovine viral diarrhea* (killed), *Leptospirosis*, and *Vibriosis* (Bovishield Gold 3 and Staybred VL 5, Pfizer Animal Health). At branding, which occurred approximately 75 d post calving, all bulls were castrated and all calves were vaccinated for *Mannheimia hemolytica* type *A1* (One Shot, Pfizer Animal Heatlth) and given a 7-way clostridial vaccine (Vision 7, Intervet-Schering Plough, Desoto, KS).

Spring calving cows wintered on native range were allowed to graze native Sandhills range from May until the end of February. On March 1st, SP were placed in drylot and fed meadow hay until May 1st. Spring calving cows wintered on cornstalks were allowed to graze native Sandhills range from May 1st until November 10th when cows were transported approximately 84 km to cornstalks in the Platte river valley. At the end of February, SP wintered on cornstalks were returned to the ranch and placed in drylots with SP wintered on native range. While in the drylots, SP were only fed hay harvested from cool season dominated meadows. Prior to drylot entry (January 15th to March 1st), SP cows in both wintering systems were supplemented 0.45 kg daily of a 28% CP dried distillers grains cube (Table 1) to meet protein requirements.

Summer calving cows wintered on native range were allowed to graze native Sandhills range for the entire year. Summer calving cows wintered on cornstalks were allowed to graze native Sandhills range from March 1st until November 10th when cows were shipped to cornstalks. Similar to SP wintered on cornstalks, SU wintered on cornstalks returned to the ranch March 1st. From August 1st until the end of April, SU wintered on cornstalks and range were supplemented 0.45 and 1.14 kg daily of a 28% CP dried distillers based cube, respectively. During the production year SU cows were not fed hay unless snow cover did not allow for grazing.

Fall calving cows were wintered on cornstalks from November until March 1st and grazed range resources during the remainder of the year. However supplementation dates differed from SU wintered on cornstalks with FA cows supplemented 0.45 kg daily with a 28% CP dried distillers grains cube beginning October 1st and ending on May 30th. Similar to SU, FA cows were not fed hay unless snow cover did not allow for grazing.

At calving, calves were assigned a calving difficulty score from 1 to 5 (1= no assistance, 2= minor assistance; 3=difficult assistance, 4 = caesarean section, 5 = abnormal presentation) and a calf vigor score from 1 to 5 (1=nursed unassisted, 3 = nursed with assistance, and 5 = dead at birth). Calves from SP cows were weaned on October 31st (221 d of age). Spring born calves were preconditioned for 19 d on cool season dominated meadow with supplementation of 0.45 kg daily of 28% CP dried distillers grains cube. Calves from SU and FA were weaned on April 10th, when calves were 298 and 247 d of age, respectively. For SU and FA, weaning date was planned to occur after cows on cornstalk wintering treatments were returned to the ranch and to increase weaning BW of the calf by not separating calves from their dam (Stalker et al., 2007). After weaning, SU and FA calves, were preconditioned on cool season dominated meadow for 30 d. During preconditioning calves were supplemented 0.45 kg daily of a 28% CP dried distillers grains cube.

For each system, cow BW and BCS were recorded at three different periods during the year: 21-d before calving (pre-calving), 59-d post calving (pre-breeding), and at weaning. Calf BW was recorded at birth, dam pre-breeding, and weaning.

Calf Management

After preconditioning, SP heifers were retained as replacements and SP steers entered the feedlot as calf-feds. Summer born and FA steers and heifers were stratified by BW and assigned randomly to 1 of 2 treatments: enter the feedlot as calf-feds or summer graze cool season dominated meadow prior to feedlot entry (yearling fed). During summer grazing, all yearlings were managed as one group and supplemented 0.6% of BW dried distillers grains plus soluble to meet protein requirements (NRC, 1996). For finishing, all cattle were shipped 200 km to the West Central Research and Extension Center (North Platte, NE) where they were placed in feedlot pens and fed until finished. Prior to feedlot entry, all cattle were limit fed 5 d at 2% of BW and then weighed 2 consecutive days to determine feedlot initial BW. At feedlot arrival, all cattle were dewormed (Dectomax Pour On, Pfizer Animal Heatlh) and vaccinated with a killed vaccine for clostridial diseases (Vision 7/Somnus with Spur, Intervet Schering-Plough) and *Hemophilus sominus* (Vision 7/Somnus with Spur, Intervet Intervet Schering-Plough). Additionally, cattle were vaccinated with a modified live vaccine for respiratory viruses (BoviShield Gold 4, Pfizer Animal Heatlh). All cattle were finished using a common finishing diet. Calves entering the feedlot as calf-feds were adapted to the final finishing diet in 54 d using 3 step-up diets containing 37, 27, and 14% roughage, fed for 7, 7, and 40 d. Cattle entering the feedlot as yearlings were fed similar step-up diets compared to calf-feds; however, yearlings were adapted to the finishing diet in 21 d with

7 d on each adaptation diet. The final finishing diet for all cattle in the feedlot contained 40% wet corn gluten feed (Sweet Bran, Cargill Inc., Blair, NE), 48% dry-rolled corn, 7% alfalfa hay, 5% supplement, and a minimum of 12% CP, 0.7% Ca, 0.35% P, 0.6% K, 30 mg/kg monensin (Elanco Animal Health, Indianapolis, IN) and 11 mg/kg Tylosin (Elanco Animal Health). Cattle in this study were determined as ready for slaughter when 12th rib fat thickness (**FT**) was estimated to be 1.27 cm.

All finished cattle in this study were slaughtered at a commercial packing plant. On the day of slaughter, carcass weights (**HCW**) were collected. After a 24-h chill, QG, KPH, FT, and LM area were measured. Yield grade was calculated as 2.5 + 6.35 × FT (cm) + 0.0017 × HCW (kg) + 0.2 × KPH (%) − 2.06 × LM area (cm^2; Boggs and Merkel, 1993). In addition, final BW for all cattle was calculated by adjusting HCW to a common dressing percentage (63%).

Spring Born Calves. At feedlot entry, SP steers were implanted with Synovex-S (Fort Dodge Animal Health; Overland Park, KS). Approximately 100 d pre-slaughter, SP calves were reimplanted with Revalor-S (Intervet Schering-Plough). At feedlot entry, SP steers were sorted by maternal wintering treatment (cornstalks vs. range) and fed in separate pens. In yr 1, there was 1 pen/treatment and in yrs 2, 3, and 4, there were 2 pens/treatment. In yr 1, 2, 3, and 4 steers entered the feedlot on November 10th, November 21st, November 9th, and December 4th, respectively. Steers were harvested on June 16th, July 2nd, June 19th, and June 25th, in yrs 1, 2, 3, and 4, respectively. Within year SP steers from each treatment were fed an equal number of days. For yrs 1, 2, 3, and 4 SP steers were fed 218, 223, 223, and 204 d.

Summer Born Calves. After preconditioning, SU calves were assigned randomly to a calf-fed or yearling-fed finishing system. At feedlot entry, SU calf-feds and yearlings were sorted by cow wintering treatment and sex and fed in individual pens resulting in 8 pens of SU calves fed per year.

Summer born calves fed as calf-feds entered the feedlot on May 12th, May 9th, May 8th, and May 7th in yrs 1, 2, 3, and 4, respectively. At feedlot entry, SU calf-feds were implanted with Synovex-S for steers and Synovex-H (Fort Dodge Animal Health) for heifers. Approximately 100 d pre-harvest, SU calf-feds were implanted with Revelor-S for steers and Revelor-H (Intervet) for heifers. Calf-feds from SU were fed for 200, 203, 222, and 221 d in yrs 1, 2, 3, and 4, respectively. Summer born calf-feds were marketed on November 28th, November 28th, December 15th, and December 14th in yrs 1, 2, 3, and 4.

At feedlot entry for calf-feds, calves assigned to the yearling system began grazing cool season dominated meadow. Days grazing were determined based on the time needed to achieve similar BW for yearling steers and heifers at feedlot entry. Since steers were heavier at treatment assignment, heifers were allowed to graze cool season dominated meadow more days. Summer born yearling steers grazed for 56, 105, 104, and 102 d in yrs 1, 2, 3, and 4, respectively. Summer born yearling steers entered the feedlot on July 7th, August 22nd, August 20th, and August 22nd for yrs 1, 2, 3, and 4, respectively. Summer born heifers grazed for 75, 126, 131, and 126 d in yrs 1, 2, 3, and 4, respectively. Summer born heifers entered the feedlot on July 26th, September 12th, September 16th, and September 10th in yrs 1, 2, 3, and 4, respectively. At feedlot entry, yearlings were implanted with Ralgro (Shering-Plough Animal Health, Union, NJ).

Approximately 100 d pre-harvest yearling steers were re-implanted with Revelor-S and yearling heifers were re-implanted with Revelor-H. Yearling steers were fed for 144, 147, 167, and 160 d in yrs 1, 2, 3, and 4, respectively. Yearling heifers were fed for 125, 126, 140, and 136 d in yrs 1, 2, 3, and 4, respectively. All SU yearlings were marketed on November 28th, January 16th, February 3rd, and January 24th, in yrs 1, 2, 3, and 4, respectively.

Fall Born Calves. After preconditioning, FA calves were assigned randomly to a calf-fed or yearling fed finishing system. At feedlot entry, FA calf-feds and yearlings were sorted by sex and fed in individual pens resulting in 4 pens of FA calves fed per year.

Fall born calves fed as calf-feds entered the feedlot on May 12th, May 9th, May 8th, and May 7th in yrs 1, 2, 3, and 4, respectively. At feedlot entry, FA calf-feds were implanted with Synovex-S for steers and Synovex-H for heifers. Approximately 100 d pre-harvest, FA calf-feds were implanted with Revelor-S for steers and Revelor-H for heifers. Calf-feds from FA were fed for 200, 203, 222, and 221 d in yrs 1, 2, 3, and 4, respectively. Fall born calf-feds were marketed on December 19th, November 28th, December 15th, and December 14th in yrs 1, 2, 3, and 4.

At feedlot entry for calf-feds, calves assigned to the yearling were handled similar to yearling from SU. Fall born yearling steers grazed for 75, 126, 131, and 126 d in yrs 1, 2, 3, and 4, respectively. Days grazing for FA yearling steers were similar to SU yearling heifers since they were similar in BW at the beginning of summer grazing. Fall born yearling steers entered the feedlot on July 26th, September 12th, September 16th, and September 10th for yrs 1, 2, 3, and 4, respectively. Fall born heifers grazed for 130, 153, 155, and 153 d in yrs 1, 2, 3, and 4, respectively. Fall born heifers entered the feedlot on September 19th, October 9th, October 9th, and October 7th in yrs 1, 2, 3, and 4, respectively. At feedlot entry, yearlings were implanted with Ralgro. Approximately 100 d pre-harvest yearling steers were re-implanted with Revelor-S and yearling heifers were re-implanted with Revelor-H. Yearling steers were fed for 146, 126, 140, and 136 d in yrs 1, 2, 3, and 4, respectively. Yearling heifers were fed for 146, 148, 167, and 169 d in yrs 1, 2, 3, and 4, respectively. In yrs 1, 2, 3, and 4 yearling steers were marketed on December 19th, January 16th, February 3rd, and January 24th, respectively. Yearling heifers were marketed on February 12th, March 5th, March 25th, and March 25th in yrs 1, 2, 3, and 4, respectively.

Calf comparison at Equal Fat Endpoints. When comparing different types of cattle it is important to compare cattle at equal fat endpoints (Tedeschi et al., 2004). To compare cattle from this study at similar fat endpoints, the procedure described by Griffin et al. (2007) was used. In Griffin et al. (2007), serial slaughter data for calf-feds (May et al., 1992) and yearlings (Bruns et al., 2004) were used to determine FT and marbling score at feedlot entry. The initial fat thickness was subtracted from the final fat thickness and divided by days fed to determine a fattening rate for each group of cattle. Using the calculated fattening rate, days on feed were adjusted by subtracting the initial fat thickness from a fat thickness of 1.27 cm to determine the number of days it would take an animal to achieve a fat thickness of 1.27 cm. The initial feedlot carcass weight of each animal was determined using the initial feedlot BW of each animal and adjusting to a 55% dressing percent (May et al., 1992; Bruns et al., 2004). Initial carcass weight was subtracted from the actual carcass weight of the animal and divided by the number of days fed to determine the daily carcass gain of each animal. This procedure was used by MacDonald et al. (2007) who demonstrated that daily carcass gain remains constant over the entire finishing period. Adjusted carcass weight was calculated by multiplying the adjusted days fed by the carcass rate of gain and adding the initial carcass weight of the animal at feedlot entry.

Initial marbling score was subtracted from the final marbling score and divided by days fed to determine the marbling rate of each pen of cattle. To determine the percent of cattle that graded choice, marbling score was regressed on percent choice of a pen of cattle. Using the proc REG function of SAS (SAS Inst. Inc, Cary, NC) it was determined that slopes were similar across treatment (P = 0.36) so data from all treatments were combined to determine the regression equation for percent choice at a given marbling score. The percent of carcasses over 455 kg was calculated by regressing the observed % of carcasses over 455 kg to days fed. Using proc REG it was determined that slope was different (P < 0.01) for sex and finishing systems therefore four different equations (calf-fed steers, calf-fed heifers, yearling steers, and yearling heifers) were used to determine the percent of overweight carcasses in a pen at a given number of days fed.

Statistical Analysis

Cow data from this study were analyzed as a completely randomized design using the MIXED procedure of SAS. All binomial data including rebreeding performance, calf vigor score, and calving data were analyzed using the GLIMMIX procedure. Experimental unit for this study was group of cows within treatment. Data from SP and SU were analyzed for interactions between calving season and wintering system. There were no interactions (P > 0.29), therefore the interaction statement was removed from the model. To determine the effect of calving season on cow performance the model included calving season with year as a random effect. Spring calving cows and SU were used to determine the difference between wintering on cornstalks and wintering on native Sandhills range, since FA were only wintered on cornstalks. The model to test for differences between wintering systems included wintering system with year included as a random effect.

Calf data were analyzed as a completely randomized design using the MIXED procedure of SAS. Binomial data including USDA QG, calculated YG, and the percent of carcasses over 455 kg were analyzed using the GLIMMIX procedure. For calving season analysis only, calf-fed steers were used to determine calf performance since SP heifers were not terminal and steers from SP did not enter a yearling fed system. For maternal wintering effect on calf performance, SP and SU born calves were used since FA calves were only wintered on cornstalks. All calf models for wintering and calving season included yr as a random effect and treatment in the model statement. Since steers and heifers were finished as calf-feds and yearlings from SU and FA, the effect of sex and calf finishing system were analyzed. The model included sex, finishing system, and sex*finishing system interaction. Data are presented as least squares means with differences considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

Cow Calving Season Performance

There were no interactions between calving season and wintering system ($P >$ 0.29). Main effects of calving season on cow performance are presented in Table 2. Calving difficulty ($P = 0.14$) and calf vigor ($P = 0.73$) were not different among calving seasons. Pre-calving BW was greatest for FA (629 kg), intermediate for SU (569 kg), and lowest for SP (533 kg; $P < 0.01$). Body weight at pre-breeding was greater for FA compared to SP ($P < 0.01$) and SU ($P < 0.01$). Additionally, SU were 90 kg heavier ($P < 0.01$) than SP. Cow BW at weaning tended to be lower for SP compared to FA ($P = 0.14$) and was lower than SU ($P = 0.03$); however, FA and SU were not different from each other ($P = 0.64$). Along with cow BW, pre-calving BCS differed ($P < 0.01$) among calving seasons with FA having the greatest followed by SU and SP. At pre-breeding, SP had the lowest BCS ($P < 0.01$) compared to SU and FA which were not different ($P = 0.82$). There was no difference ($P > 0.22$) in BCS at weaning among cows within different calving seasons.

There was no difference in calf BW at birth among the different calving seasons ($P > 0.26$; Table 2). Calf weaning BW was similar ($P = 0.36$) for SP and FA calves; however, because of increased days of age, SU calves were 20 kg and 16 kg heavier than FA ($P < 0.01$) and SP ($P < 0.01$) calves, respectively. Calf ADG from birth to weaning was 0.18 and 0.12 kg/d greater for SP calves ($P < 0.01$) compared to SU and FA calves, respectively, In addition, FA calves had greater ADG from birth to weaning compared to SU calves (0.79 vs. 0.73 kg/d; $P < 0.01$). Adjusted 205 d weaning BW for calves was greatest for SP calves ($P < 0.01$); intermediate for FA calves and lowest for SU calves ($P < 0.01$).

At weaning time each year cows were determined to be bred or open. Of the cows determined to be bred at weaning time the percent of cows to actually calve was not different across calving season ($P > 0.16$). In addition, calving season did not impact cow rebreeding performance ($P = 0.22$). However, when evaluating the number of calves weaned per cow, FA produced fewer calves per cow than SP (P = 0.05) and tended to produce fewer calves per cow than SU (P = 0.08). However, when comparing the number of calves weaned per cow for SU and SP there was not a difference (P = 0.67).

Differences in BW and BCS for the cows throughout the different periods of the year were expected because of how cow requirements (NRC, 1996) and nutrients from forage resources match or do not match throughout the year. In this study, protein requirements for the cows were met using supplementation of a 28% CP distillers grains cube. Therefore, differences in BW and BCS presumably were due to differences in energy supply from the forage and energy demand of the cows during the production year. Energy status is an extremely important factor that can affect cow performance (Stalker et al., 2006; Larson et al., 2009). During peak lactation which is in April and May for SP, energy requirements would be the greatest. Range TDN content peaks in May (Geisert et al., 2008). When comparing SU and FA, energy requirements are greatest during July and August for SU and September and October for FA. In the months of September and October, range nutrient value has declined to dormant season nutrient levels.

Grings et al. (2005) found similar results in BCS for SP and SU calving cows, reporting that SU had greater change in BCS throughout the production year compared to SP; however, SU had lower BW at weaning than SP which does not agree with the current study. When comparing the two studies, the current study was conducted using Nebraska feed resources and Grings et al. (2005) was conducted using Montana feed resources.

Rebreeding performance is directly related to the energy status of the cow (Randel; 1990). In this study, FA did not have reduced rebreeding performance but there were differences in calves weaned per cow when comparing FA to SU and SP. In this study, the reduced number of calves weaned per cow in FA was a result of a slight numerical reduction in rebreeding performance and percent of cows to calve from FA. In addition, energy status of the cows across calving season is evident from differences in BCS throughout the production year. For SP, BCS remained relatively constant with a change in BCS from 5.3 at pre-calving to a BCS of 5.1 at weaning. For SU and FA, there was a larger difference from pre-calving to weaning with a 1.0 and 1.6 unit change in BCS for SU and FA, respectively, throughout the production year.

Calf performance from birth to weaning was different when comparing the different calving seasons. Results for ADG are consistent with Julien and Tess (2002) who found that weaning BW decreased as calving and weaning dates were moved to later in the year and calves from each calving system were weaned at similar days of age. In addition, ADG for calves in this study were similar to results reported in previous studies (Adams et al., 2001; Grings et al., 2005; Reisenauer Leesburg et al., 2007a) who found that SP calves had heavier weaning BW compared to SU when calves were weaned at the same days of age, suggesting that ADG for SP is greater than SU.

Cow winter feeding system

Main effects of cow winter feeding system on cow performance are presented in Table 3. Calf vigor ($P = 0.57$) and calving difficulty ($P = 0.91$) were not different between cows wintered on Sandhills native range or cornstalks. Additionally, cow BW and BCS at pre-calving (*P* > 0.57), pre-breeding (*P* > 0.70), and weaning (*P* > 0.61) were not different between winter feeding systems.

Winter feeding system did not influence calf BW at birth (*P* = 0.64) or at weaning (*P* = 0.63). Additionally, calf ADG (*P* = 0.72) from birth to weaning and adjusted 205 d weaning BW (*P* = 0.77) were not different between wintering systems. Neither percent of cows to calve nor number of calves weaned per cow were influenced by wintering system (P > 0.65). In addition, there were no differences in cow rebreeding performance (*P* = 0.86) when comparing wintering system.

Body weight and BCS for cows grazing cornstalks in the winter was similar when compared to cows grazing native Sandhills range. Similar results were presented by Anderson et al. (2005) who found that BW and BCS prior to weaning were not different between cows wintered on cornstalks or stockpiled pasture. At weaning, Anderson et al. (2005) showed that cows wintered on cornstalks had lower BW and BCS than cows wintered on pasture. However, Larson et al. (2009) reported that cows wintered on cornstalks had greater BW at weaning than cows wintered on native Sandhills range even though BCS at weaning was not different. Also, Anderson et al. (2005) and Larson et al. (2009) showed no difference in breeding performance for cows in differing wintering systems. Larson et al. (2009) reported similar calf performance from birth to weaning when cows were wintered on native Sandhills range or cornstalks. When compared to the current study, Larson et al. (2009) had similar supplementation practices for both wintering systems where in the current study supplementation practices for each wintering system were different. In the current study, cows wintered on range were supplemented 1.14 kg/hd daily of 28% CP dried distillers grain cube to meet protein requirements and cows wintered on cornstalks were supplemented 0.45 kg/hd daily of the same supplement. The supplement used contained monensin, therefore cows wintered on cornstalks would have been fed 80 mg/cow daily and cows wintered on range would have been fed 200 mg/cow daily. Previous results suggest that there are no differences in performance for cows fed different levels of monensin when evaluating cow BW and BCS (Lemenager et al., 1978; Walker et al., 1980b; Clanton et al., 1981). In addition breeding performance is not affected (Walker et al., 1980a).

Using the 1996 NRC model, metabolizable protein (**MP)** and energy were evaluated to determine MP balance and energy supply with supplementation. For SP, MP balance was 64 and 59 g/d deficient for cows wintered on native range and cornstalks, respectively. In addition, when evaluating energy balance it was estimated that it would take 654 d to increase BCS one unit which is a similar rate to BCS change observed throughout the production year. During the time that cows were supplemented, MP balance for SU was 153 and 31 g/d deficient for cows wintered on cornstalks and native range, respectively. When evaluating energy, it would take 152 and 244 d for SU and SP cows, respectively, to lose a body condition score which is similar to results observed. During supplementation for FA, cows were 190 g/d deficient in MP and it was estimated that cows would lose a BCS in 125 d which is similar to observed performance.

Hollingsworth-Jenkins et al. (1996) reported that cows wintered on native range had increased gain and BCS with DIP supplementation up to 140 g/d. In the current study, degradable protein balance ranged from negative 50 to negative 114 g/d within the cow groups and suggests that cows in general would have met a deficiency with degradable protein supplementation. However, increasing degradable protein would not have met the MP requirement. In retrospect, cattle needed to be supplemented a higher level of MP in order to meet requirements. Based on reported forage protein digestibilities that are older (NRC, 1996), it is conceivable that protein estimations demonstrated an adequate MP availability with the supplementation practices used in this study. However, newer protein estimation techniques (Haugen et al., 2006) and better values for protein digestibility of native range (Benton et al., 2006; Geisert et al., 2008) and cornstalks (Gigax et al., 2011) are available and supplementation practices need to be re-evaluated to ensure that MP requirements are met.

Calf Performance

Initial BW at finishing system entry was greatest for SU steers regardless of wintering systems ($P < 0.01$) and lowest for FA calves regardless of sex ($P < 0.01$). When evaluating feedlot entry BW, yearlings had greater BW which was similar by design regardless of sex, wintering system, and calving season. Similarities in yearling feedlot initial BW were achieved by adjusting days grazing. However, grazing yearling heifers gained less per day than yearling steers ($P < 0.01$). When evaluating calf-feds, SU steers were heaviest, followed by SU heifers, SP steers and FA steers. Calf-fed heifers from FA were lightest at feedlot entry ($P < 0.01$).

Feedlot performance was different based on all treatments (calving season, wintering system, sex, and finishing system) and will be discussed as main effects of treatments. When evaluating carcass characteristics, FT was not statistically different when comparing all calf treatments ($P = 0.13$); however, FT ranged from 1.09 to 1.42 cm, therefore, all cattle were adjusted to a common FT endpoint of 1.27 cm. With the observed fat endpoints, calculated YG, USDA marbling score, KPH, and LM area were not different ($P > 0.14$). Without adjustment the percent of cattle to grade choice or greater FA and SU yearling steers and SU calf-fed heifers wintered on cornstalks had fewer cattle grading choice than other calf treatments ($P < 0.01$). However, when compared at an equal fat endpoint the percent of cattle grading choice or better did not differ among treatments. In addition, carcasses over 455 kg did not differ across treatments ($P = 0.77$).

Effect of Calving Season on Calf Performance. The effect of calving season on calf performance is presented in Table 4. To determine the effect of calving season on calf performance, only the calf-fed steers from each calving season were used since SP calves were only finished as calf-feds and SP heifers were not terminal. In addition, since there were no differences in maternal wintering system on calf-performance ($P > 0.24$; Table 5), performance data from cornstalk and winter range wintering systems were combined.

At feedlot entry, SU calves (269 kg) were heavier ($P < 0.01$) than FA (241 kg) and SU (244 kg) calves. Final adjusted BW for SU calves was 53 and 26 kg greater than SP and FA calves ($P < 0.01$). In addition, FA had greater final adjusted BW compared to SP ($P < 0.01$). The difference in final BW is due to greater ADG ($P < 0.01$) for SU and FA calves compared to SP since days fed were not different ($P = 0.40$). Dry matter intake was greatest for SU, intermediate for FA, and lowest for SP calves ($P < 0.01$). Conversely, SP calves had the greatest G:F and SU calves had the lowest G:F ($P < 0.01$). Carcass weight for SU calves was greatest, followed by FA calves, and SP calves which had the lowest HCW ($P < 0.01$). Quality Grade ($P = 0.15$) and FT ($P = 0.48$) did not differ across calving season. However, KPH ($P = 0.09$), LM area ($P =0.06$), and YG ($P =$

0.10) were numerically different when comparing calving seasons. When comparing the percent of calves to grade choice or greater, SP (86.1%) and SU (84.9%) calves were similar and FA was lowest (P = 0.01) with 72.6 % of cattle grading choice or better. In addition, there were no differences in the percent of cattle with carcasses over 455 kg (P = 0.99).

When compared at an equal fat endpoint, rate of 12th rib fat accretion (P = 0.33), days fed to achieve 1.27cm FT (P = 0.33), marbling score (P = 0.22), HCW (P = 0.22), percent choice (P = 0.36), and carcasses over 455 kg (P = 0.99) were not different across treatments. However, carcass ADG was lowest (P < 0.01) for SP calves compared to SU and FA calves which were not different from each other. In addition, marbling rate was lowest for FA calves, intermediate for SP calves, and greatest for SU calves (P = 0.08).

Phillips et al. (2006) evaluated the effect of calving season on calf feedlot performance and slight differences in feedlot ADG were observed with calves born later in the year being lighter at feedlot entry and lighter at harvest. When compared to the current study, Phillips et al. (2006) had calves that were weaned at the same days of age within each calving season and calves that were late weaned within each calving season. In Phillips et al. (2006), weaning age did not consistently affect feedlot ADG. In addition, calving dates reported by Phillips et al. (2006) were slightly different with calving occurring in early February, early April and late May, whereas in the current study calves were weaned at different days of age with SU the oldest at weaning and SP the youngest at weaning, and calving occurring in late March, mid June, and early August.

Adams et al. (2001) utilized a March and June calving season similar to the current study and reported that feedlot ADG was greater for June born calves compared to March born calves, which agrees with data reported in the current study. Contrary to the current study, Adams et al. (2001) reported lower BW at weaning and feedlot entry for June born calf-feds when compared to March born calf-feds. Differences between results from Adams et al. (2001) and the current study are perhaps due to differences in age at weaning for calves. Adams et al. (2001) used calves from each season that were weaned at similar days of age whereas in the current study, SU were 77 d older at weaning compared to SP. Reisenauer-Leesberg et al. (2007b) evaluated a spring, summer, and fall calving system with calves weaned at similar days of age. In their study they found that calf-feds from each calving season had similar feedlot ADG. Comparing carcass characteristics, FA had greater HCW, similar LM area, similar FT, and a reduction in the percent of cattle grading choice or higher compared to SP. Janovick-Guretzky et al. (2005) reported similar results when comparing fall calving cows and spring calving cows. Conversely, Janovick-Guretzky et al. (2005) reported similar feedlot ADG and G:F for fall born calves and spring born calves whereas in the current study FA had lower feedlot ADG and G:F compared to SP. In Janovick-Guretzky et al. (2005), spring and fall born calves were weaned at similar days of age where in the current study, calves were weaned at different days of age with FA older than SP.

Comparing the current study findings to previous research suggests that age at weaning could be major factor in the differences observed in calf post weaning performance. When comparing FA and SU to SP BCS was greater for SU and FA at pre-breeding and pre-calving compared to SP. This allowed calves from SU and FA to be weaned at greater ages and cows still have similar BCS to SP at weaning. Stalker et al. (2007) illustrated that calf efficiency of gain is improved with later weaning dates and that it is more economical to allow the calf to have milk if it does not compromise cow BCS or rebreeding performance.

Effect of Maternal Wintering on Calf Performance. All SU and SP calves were used to determine the effect of maternal wintering system on calf performance. There were no interactions (*P* > 0.10) between sex and wintering system or calving season and wintering system, therefore main effects of maternal wintering system on calf performance are presented in Table 5.

Maternal wintering system had no effect on calf feedlot initial BW (*P* = 0.80) or adjusted final BW (*P* = 0.99). In addition, feedlot performance including days fed (*P* = 1.00), DMI (*P* = 0.81), ADG (*P* = 0.60), and G: F (*P* =0.64) were not different when comparing effect of maternal wintering system on calf performance. Carcass weight (*P* = 0.99), marbling score (*P* = 0.84), YG (*P* = 0.71), FT (*P* = 0.28), KPH (*P* = 0.34), LM area (*P* = 0.77), percent of cattle grading USDA choice or greater (*P* = 0.24), and the percent of carcasses 455 kg or greater (*P* = 0.31) were not affected by maternal wintering system. In addition, when evaluating data adjusted to a common FT end point, no differences in calf performance were observed as an effect of maternal wintering systems (*P* > 0.38).

Larson et al. (2009) presented similar results in which steer calves from cows wintered on native range or cornstalks presented no difference in feedlot performance or carcass characteristics. Anderson et al. (2005) reported differences in performance of calves from cows wintered on range or cornstalks; however, in Anderson et al. (2005) calves from cows wintered on cornstalks were finished as yearlings and calves from cows wintered on pasture were finished as calf-feds. Based on data from Larson et al. (2009) and because there were no differences in cow performance when comparing wintering systems, we conclude that cornstalks are a suitable alternative to wintering on native range. However, the economics of each system should be evaluated before making a final decision on management system.

Calf Finishing System and Sex. To determine the effect of calf finishing system and sex on feedlot performance, calves from SU and FA were used. Calves from SP were excluded since only steers were fed only as calf-feds. There were no three way interactions for finishing system, sex, or wintering system in the SU calf performance. However, two way interactions for sex and finishing system were present in HCW, YG and FT. Therefore, the simple means of sex and finishing system are presented in Table 6. Because there were no differences in maternal wintering on calf feedlot performance data from the two wintering systems in SU calves were combined.

When evaluating finishing system, initial BW at feedlot entry ($P < 0.01$) was less for calf-feds; however, final BW ($P = 0.30$) was similar for calf-feds and yearlings. However, days fed was 69 d greater for calf-feds compared to yearlings ($P < 0.01$). Feedlot ADG ($P < 0.01$) and DMI ($P < 0.01$) were greater for yearlings; however, G:F was 7.4% greater for calf-feds compared to yearlings ($P < 0.01$). Marbling score ($P = 0.88$), KPH ($P = 0.28$), LM area ($P = 0.26$), the percent of cattle grading choice or better ($P = 0.31$) and the percent of cattle with carcasses over 455 kg ($P = 0.61$) were not affected by finishing system.

Interactions for sex and finishing system were observed in feedlot initial BW ($P = 0.02$), YG ($P = 0.04$), and FT ($P = 0.02$). For feedlot initial BW, the general trend was for yearlings to be heavier at feedlot entry compared to calf-feds; however, by design yearling heifers gained more weight during summer grazing and had a larger difference in BW at feedlot entry compared to steer calf-feds and yearlings. This was due to differences in days grazing for steer and heifer yearlings with the goal of steer and heifer yearlings having similar feedlot initial BW. Calculated YG and FT followed similar trends with yearling heifers exhibiting greater FT and YG compared to their calf-fed counterparts and yearling steers having less FT and lower YG compared to their calf-fed counter parts.

When compared at equal fat endpoints, there were no differences in marbling score (P = 0.20) or percent choice (P = 0.72). Carcass ADG was 14% greater for yearlings compared to calf-feds (P < 0.01). Carcass weight was 27 kg heavier (P = 0.01) for yearlings and yearlings produced more carcasses greater than 455 kg (P = 0.01). Interactions were observed between sex and finishing system for rate of FT accretion (P = 0.02), marbling rate (P = 0.08) and days fed (P = 0.02). However, when comparing yearlings and calf-feds, fattening rate and marbling rate were greater for yearlings and days fed were greater for calf-feds.

The reason for the interactions has to do with the differences in biology for steers and heifers. When comparing calf-fed and yearling fattening rate, marbling score and days fed the direction of the differences in rates agrees with results presented by Vieselmeyer et al. (1995) and Griffin et al. (2007). However, in this study, heifers exhibited greater change across production system in fattening rates and days fed compared to steers.

Several reports have shown that backgrounded steers produce heavier carcasses (Jordon, 2000; Krehbiel et al., 2000; Sainz and Vernazza Paganini, 2004) compared with cattle placed directly on feed after weaning. When cattle of similar type are placed into different production systems, yearlings tend to be leaner and have lesser quality carcasses at harvest when compared with calf-feds (Schoonmaker et al., 2002; Anderson et al., 2005). However, similar to the current study, Adams et al. (2010) reported no differences in QG or FT when cattle were assigned randomly to calf-fed or yearling finishing systems. When comparing HCW, Adams et al. (2010) reported a 37 kg increase in HCW for summer yearlings compared to calf-feds. In the current study, measured HCW was 7 kg greater for yearlings compared to calf-feds; however when adjusted to a common fat endpoint yearlings were 27 kg heavier than calf-feds.

When evaluating the effect of calf sex on calf performance, initial BW ($P < 0.01$) and adjusted final BW ($P < 0.01$) were 16 and 61 kg greater respectively, for steers compared to heifers. Days fed ($P = 0.71$) were similar for steers and heifers; however, DMI ($P < 0.01$), feedlot ADG ($P < 0.01$), and G: F ($P < 0.01$) were greater for steers compared to heifers. Steers had 42 kg greater HCW and lower marbling scores ($P = 0.04$) compared to heifers. Greater marbling scores for heifers led to more carcasses grading choice or better compared to steers (86.1 vs. 72.4%; $P < 0.01$). There was no difference when comparing steer and heifer KPH ($P = 0.54$) or LM area ($P = 0.24$). In addition, steers produced more carcasses that were over 455 kg compared to heifers (0.4 vs. 3.8%; $P < 0.01$). When comparing steer and heifer performance at an equal fat endpoint, steers had greater carcass ADG ($P < 0.01$) leading to a 47 kg increase ($P < 0.01$) in HCW for steers compared to heifers. The percent of heifers grading choice was numerically 7.4 percentage units greater than steers ($P = 0.15$). However, steers produced more carcasses over 455 kg.

Results from the current study are consistent with previous results in which steers produced greater HCW and had greater ADG compared to heifers (Tanner et al., 1970; Zinn et al., 1970). Taylor et al. (2008) reported that heifers had lower DMI, lower ADG and similar G:F when compared to steers. Results from Taylor et al. (2008) are consistent with the current study in which heifers had lower ADG and DMI. However, in the current study heifers had lower G:F compared to steers. When comparing carcass characteristics, carcass quality results have been mixed with Tanner et al. (1970) reporting no difference in QG, Zinn et al. (1970) reporting increased QG in steers, and Taylor et al. (2008) reporting greater marbling scores for heifers when fed a similar number of days. Similar to Taylor et al. (2008) results from the current study showed heifers had greater marbling scores leading to an increase in the number of heifers grading choice compared to steers; however, when compared at equal fat endpoints marbling score and the percent of animals grading choice were not different between heifers and steers.

IMPLICATIONS

Calving season impacts cow performance and subsequent calf performance from conception to slaughter. Wintering feeding programs involving cornstalks or native range do not affect cow or subsequent calf performance regardless of SP or SU calving seasons. When evaluating calf performance there are differences in performance based on sex of the calf and whether fed as calf-feds or yearlings. However, when making decisions for cow calf production and retention of calves through harvest, producers must not base decisions on performance of the animals alone.

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Table 1. Composition of 28% CP distillers grain cube[1].

Item	% DM-basis
Dried distillers grains	62
Wheat midds	11
Cottonseed meal	9
Corn gluten meal	5
Molasses	5
Urea	2
Calcium carbonate	3
Binder	3

[1]Formulated to contain 22000 IU/kg of Vitamin A and 176 mg/kg monensin (Elanco Animal Health Greenfield, IN)

Table 2. Effect of three calving season systems on cow and pre-weaning calf performance.

					P-value[1]			
Item	SP[2]	SU[3]	FA[4]	SEM	F-test	SP vs. SU	SP vs. FA	SU vs. FA
n	88	74	55	---	---	---	---	---
Cow BW								
Pre-calving, kg	533	569	629	10	< 0.01	< 0.01	< 0.01	< 0.01
Pre-breeding, kg	480	570	589	5	< 0.01	< 0.01	< 0.01	< 0.01
Weaning, kg	501	525	519	11	0.07	0.03	0.14	0.64
Cow BCS								
Pre-calving	5.3	5.9	6.6	0.1	< 0.01	< 0.01	< 0.01	< 0.01
Pre-breeding	5.3	6.1	6.0	0.1	< 0.01	< 0.01	< 0.01	0.82
Weaning	5.1	5.1	5.0	0.1	0.37	0.28	0.22	0.72
Calf BW								
Birth, kg	37	38	38	1	0.48	0.42	0.26	0.63
Weaning, kg	238	254	234	4	< 0.01	< 0.01	0.36	< 0.01
Adj. weaning[5], kg	223	186	200	3	< 0.01	< 0.01	< 0.01	< 0.01
Calf ADG[6], kg	0.91	0.73	0.79	0.01	< 0.01	< 0.01	< 0.01	< 0.01
Calved, %	98.4	97.1	94.4	2.7	0.36	0.57	0.16	0.33
Calves/ cow[7]	0.96	0.95	0.86	0.05	0.18	0.67	0.05	0.08
Rebreeding, %	93.2	94.3	90.2	---	---	0.22	0.22	0.22

[1]*P* value = differences across treatments determined using contrast statements except for rebreeding % which chi square distribution was used.
[2]SP = spring calving cows (average calving date = March 24th).
[3]SU = summer calving cows (average calving date = June 15th).
[4]FA = fall calving cows (average calving date = August 5th).
[5]Adj. weaning = calf weaning weight adjusted to 205 d.
[6]Calf ADG = ADG for the calf from birth to weaning.
[7]Calves/ cow = calves weaned per cow.

Table 3. Effect of winter feeding program on cow performance for spring and summer calving system.

Item	Cornstalks	Range	SEM	*P*-value
n	82	81	---	---
Cow BW				
Pre-calving, kg	546	555	12	0.57
Pre-breeding, kg	527	522	19	0.86
Weaning, kg	516	510	9	0.61
Cow BCS				
Pre-calving	5.5	5.6	0.2	0.61
Pre-breeding	5.6	5.7	0.2	0.70
Weaning	5.1	5.1	0.1	0.80
Calf BW				
Birth, kg	37	37	1	0.64
Weaning, kg	244	247	5	0.63
Adj. weaning[1], kg	203	205	7	0.77
Calf ADG[2], kg	0.80	0.82	0.04	0.72
Calved, %	97.8	97.7	1.6	0.94
Calves/ cow[3]	0.95	0.96	0.1	0.65
Rebreeding, %	93.8	93.5	---	0.86

[1]Adj. weaning = calf weaning weight adjusted to 205 d.
[2]Calf ADG = ADG for the calf from birth to weaning.
[3]Calves/ cow = calves weaned per cow.

Table 4. Effect of calving season on subsequent calf-fed steer finishing performance.

Item	SP[1]	SU[1]	FA[1]	SEM	*P*-value
Feedlot initial, kg	244^{b}	269^{a}	241^{b}	7	< 0.01
Final BW, kg	597^{c}	650^{a}	623^{b}	12	< 0.01
Days fed	217	212	217	5	0.40
DMI, kg/d	9.39^{c}	11.15^{a}	10.51^{b}	0.37	< 0.01
ADG, kg/d	1.63^{b}	1.80^{a}	1.77^{a}	0.05	< 0.01
G: F	0.174^{a}	0.162^{b}	0.169^{ab}	0.006	0.01
Carcass Weight	376^{c}	409^{a}	393^{b}	7	< 0.01
Fat thickness, cm	1.32	1.40	1.35	0.08	0.48
Yield Grade[2]	2.8^{b}	3.1^{a}	2.9^{ab}	0.2	0.10
Marbling[3]	590	600	557	19	0.15
LM area, cm^2	89.68^{b}	93.55^{a}	92.90^{ab}	2.58	0.06
Choice, %	86.1^{a}	84.9^{a}	72.6^{b}	7.4	0.01
Carcasses > 455 kg, %	0.5^{b}	7.9^{a}	2.2^{b}	2.2	< 0.01
Fat adjusted[4]					
Days fed	214	195	208	14	0.33
Marbling[3]	583	578	547	18	0.22
Carcass weight	371	388	381	11	0.22
Choice, %	80.6	76.7	70.6	6.4	0.36
Carcasses > 455 kg, %	3.1	3.4	3.1	2.4	0.99

[a, b, c] Means with different superscripts differ $P < 0.05$.

[1] SP = spring born, SU = summer born, FA = fall born.

[2] Yield grade is calculated USDA yield grade.

[3] Marbling = 400 = $slight^{00}$, 500 = $small^{00}$, etc.

[4] Fat adjusted = data adjusted to a common fat thickness (1.27 cm).

Table 5. Effect of maternal winter feeding program on subsequent spring and summer born calf performance.

Item	Cornstalks	Range	SEM	*P*-value
Feedlot initial, kg	273	277	10	0.80
Final BW, kg	605	605	10	0.99
Days fed	197	197	7	1.00
DMI, kg/d	10.36	10.30	0.27	0.81
ADG, kg/d	1.70	1.67	0.04	0.60
G: F	0.165	0.164	0.006	0.64
Carcass Weight	381	381	7	0.99
Fat thickness, cm	1.35	1.30	0.05	0.28
Yield Grade[1]	2.9	2.8	0.1	0.71
Marbling[2]	596	594	25	0.84
LM area, cm^2	90.64	90.32	1.48	0.77
Choice, %	87.6	83.2	6.4	0.24
Carcasses > 455 kg, %	2.6	4.4	1.7	0.31
Fat adjusted[3]				
Days fed	189	199	9	0.42
Marbling[2]	585	596	28	0.59
Carcass weight	370	381	12	0.38
Choice, %	80.4	80.9	2.7	0.88
Carcasses > 455 kg, %	3.1	3.6	1.3	0.78

[1]Yield grade is calculated USDA yield grade.
[2] Marbling = 400 = slight^{00}, 500 = small^{00}, etc.
[3]Fat adjusted = data adjusted to a common fat thickness (1.27 cm).

Table 6. The effect of sex and finishing system on finishing performance of summer and fall born calves.

	Heifer		Steer			*P*-value		
Item	Calf-fed	Yearling	Calf-fed	Yearlings	SEM	Sex	Finish	Sex*Finish
Feedlot initial, kg	237	355	255	353	7	0.09	< 0.01	0.02
Final BW, kg	565	583	636	632	8	< 0.01	0.30	0.12
Days fed	214	145	214	146	5	0.71	< 0.01	0.71
DMI, kg/d	9.88	11.33	10.83	12.17	0.18	< 0.01	< 0.01	0.60
ADG, kg/d	1.53	1.59	1.79	1.92	0.05	< 0.01	< 0.01	0.19
G: F	0.155	0.140	0.165	0.158	0.006	< 0.01	< 0.01	0.19
Carcass Weight	355	367	401	399	5	< 0.01	0.30	0.13
Fat thickness, cm	1.30	1.32	1.37	1.17	0.05	0.27	0.03	0.02
Yield Grade[1]	2.6	2.8	3.0	2.8	0.1	0.03	0.67	0.04
Marbling[2]	592	604	579	562	28	0.04	0.88	0.28
LM area, cm^2	91.48	89.61	93.10	91.61	2.06	0.24	0.26	0.90
Choice, %	85.1	87.2	77.7	67.1	8.0	< 0.01	0.31	0.13
Carcasses > 455 kg, %	0.0	0.8	5.0	5.8	1.8	< 0.01	0.61	1.00
Fat adjusted[3]								
Days fed	211	141	201	165	10	0.29	< 0.01	0.02
Marbling[2]	586	600	562	595	36	0.44	0.20	0.62
Carcass weight	351	364	384	425	12	< 0.01	0.01	0.15
Choice, %	82.0	84.7	74.7	77.3	9.0	0.15	0.72	0.49
Carcasses > 455 kg, %	1.5	1.1	3.3	5.8	2.2	< 0.01	< 0.01	0.18

[1]Yield grade is calculated USDA yield grade

[2] Marbling = 400 = $slight^{00}$, 500 = $small^{00}$, etc.

[3]Fat adjusted = data adjusted to a common fat thickness (1.27 cm).

Effect of calving season and wintering system economics

The Effect of Calving Season and Wintering System on Cow and Calf Performance: Economic Analysis[1]

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ABSTRACT

Four years of data (217 cows/year; 5/8 Red Angus, 3/8 Continental) were used to evaluate cow and calf production system profitability. Cow systems included: 1) spring calving (**SP**) wintered on native range, 2) SP wintered on cornstalks, 3) summer calving **(SU)** wintered on native range, 4) SU wintered on cornstalks, and 5) fall calving (**FA**) wintered on cornstalks. Steers from SP entered the feedlot at weaning (calf-fed). At weaning half of SU and FA calves from each treatment were fed as calf-feds and the other half grazed cool season meadow prior to feedlot entry. Data were analyzed as a completely randomized design and tested for interactions with calving season, sex, and finishing system. For economic analysis average prices (2007-2010) were used for the month that feed ingredients were used and cattle were sold. Profitability across the different calving systems at weaning was not different (P = 0.46) and no interactions (P = 0.29) were observed for wintering system and calving season when comparing SU and SP. Retaining calf-fed steers through finishing did not result in profit differences when comparing production systems (P = 0.12). There were no differences in profitability of SP when comparing wintering system (P = 0.21). However, SU wintered on cornstalks were more profitable than SU wintered on range (P = 0.04). Yearling and calf-fed profit was equal (P = 0.13) but steers were more profitable than heifers (P < 0.01). Profitability of a production system is influenced by retaining ownership through finishing, calving season, wintering system, finishing system, and calf sex.

Keywords: calving season, production system, profitability, wintering system

INTRODUCTION

In the Nebraska Sandhills cows are traditionally bred to calve in February, March, and April which leads to lactation occurring in early spring. In early spring, range forage is dormant and low in protein and energy (Geisert et al., 2008). To meet nutrient requirements of the cows, hay and other purchased feeds are fed which can add to cost of production for spring calving (**SP;** Stockton et al., 2007). Harvested or purchased feeds required to sustain the cow herd is related to calving date (Adams et al., 1996; Clark et al., 2004). Changing calving season can reduce needs for harvested or purchased feeds by matching the cow's requirements with the time of year that forage resources are greater in protein and energy, potentially leading to decreased cost per cow.

Typically, cow-calf production has used native range for grazing resources; however, in Nebraska crop residues are abundant. The use of corn residue can be advantageous to beef production systems by providing low cost feed that does not compete with grain demand (Guteirrez-Ornelas, 1989). Larson et al. (2009) reported no difference in cow weaning BCS or breeding performance when comparing wintering systems utilizing native range or cornstalks. In addition, cost for cattle grazing cornstalks are less than utilizing winter range or harvested forages and dry lot (Anderson et al., 2005; Griffin et al., 2008).

Time of year that calves are marketed is another factor to consider when making decisions on production systems. In spring calving seasons, calves and culls are marketed when average seasonal prices are lowest. Altering calving season would result in different marketing times. In addition, the decision to feed calves as calf-feds (calves that enter the feedlot at weaning) or yearlings (calves that enter the feedlot after a growing period) offers flexibility in the marketing times allowing producers to sell calves when markets are at seasonal highs.

Therefore, the objective of this experiment was to determine the effect of calving season, wintering system and decisions on calf management (sell at weaning, feed as calf-feds, or enter a yearling finishing system) on the economics of cow-calf systems.

MATERIALS AND METHODS

Experiment

Four years of data (Griffin et al., 2011) were collected from the Gudmundsen Sandhills Laboratory (Whitman, NE) in which cows were assigned to one of five treatments. Treatments were: 1) spring calving cows wintered on native range, 2) SP wintered on cornstalks, 3) summer calving cows (**SU**) wintered on native range, 4) SU wintered on cornstalks, or 5) fall calving cows (**FA**) wintered on cornstalks. Average calving dates were March 24th, June 15th, and August 5th for SP, SU, and FA, respectively.

Spring calving cows wintered on native range were allowed to graze native Sandhills range from May until the end of February. On March 1^{st,} SP were placed in drylot and fed meadow hay until May 1st. Spring calving cows wintered on cornstalks were allowed to graze native Sandhills range from May 1st until November 10th when cows were transported approximately 84 km to cornstalks in the Platte river valley. At the end of February, SP wintered on cornstalks were returned to the ranch and placed in drylot with SP wintered on native range. While in drylot SP, were only fed hay harvested from cool season grass dominated meadows. Prior to drylot entry (January 15th to March

1^{st}), SP cows in both wintering systems were supplemented 0.45 kg daily of a 28% CP supplement.

Summer calving cows wintered on native range were allowed to graze native Sandhills range for the entire year. Summer calving cows wintered on cornstalks were transported to cornstalks on November 10^{th} and returned to the ranch at the end of February. Summer calving cows wintered on cornstalks were allowed to graze native Sandhills range from March 1^{st} until November 10^{th} when cows were shipped to cornstalks. Similar to SP cows wintered on cornstalks, SU cows wintered on cornstalks returned to the ranch March 1^{st}. From August 1^{st} until the end of April, SU cows wintered on cornstalks and range were supplemented 0.45 and 1.14 kg daily of a 28% CP supplement, respectively. Similar to SU cows wintered on cornstalks, all FA cows were wintered on cornstalks from November 10^{th} until March 1^{st} and grazed range resources during the remainder of the year. Supplementation dates for FA were October 1^{st} thru May 30^{th} and supplement was delivered at a rate of 0.45 kg/hd daily.

Calves from SP cows were weaned on October 31^{st}. Calves from SU and FA cows were weaned on April 10^{th}. For SU and FA, weaning date was planned to occur after cows on cornstalk wintering treatments were returned to the ranch. After weaning, SU and FA calves were preconditioned on cool season grass dominated meadow for 30 d. During preconditioning calves were supplemented 0.45 kg daily of a 28% CP supplement. Spring born calves were preconditioned for 19 d on cool season dominated meadow with supplementation of 0.45 kg daily of 28% CP supplement.

After preconditioning, SP heifers were retained as replacements and SP steers entered the feedlot as calf-feds. Summer born and FA steers and heifers were stratified by BW and assigned randomly to 1 of 2 treatments: enter the feedlot as calf-feds or summer graze cool season grass dominated meadow prior to feedlot entry (yearling fed). During summer grazing all yearlings were managed as one group and supplemented 0.6% of BW dried distillers grains plus solubles. For finishing, all calves were shipped 200 km to the West Central Research and Extension Center (North Platte, NE) where they were placed in feedlot pens and fed until finished. Prior to feedlot entry all calves were limit fed 5 d at 2% of BW and then weighed 2 consecutive days to determine feedlot initial BW. All calves were finished using a common finishing diet.

Average arrival date to the feedlot for SP steer calf-feds was November 19th and average harvest date was June 23rd. Average arrival date to the feedlot for SU calf-feds, SU yearling steers, and SU yearling heifers was May 9th, August 11th, and September 1st, respectively. Average harvest date for SU calf-feds, SU yearling steers, and SU yearling heifers was December 6th, January 10th, and January 10th, respectively. The average feedlot entry date for FA calf-feds, FA yearling steers, and FA yearling heifers was May 9th, September 1st, and October 3rd, respectively. The average harvest date for FA calf-feds, FA yearling steers, and FA yearling heifers was December 10th, January 15th, and February 10th, respectively.

When cattle were harvested, fat thicknesses ranged from 1.09 cm to 1.42 cm. Griffin et al. (2011) reported calf performance from this study as observed and as adjusted to a common fat thickness. When comparing cattle of different types, it is important to compare at similar fat endpoints (Tedeschi et al., 2004). Therefore, data used for the economic analysis are adjusted to a common fat endpoint so that cattle are compared appropriately at an equal endpoint of 1.27 cm fat thickness.

Economic Analysis

The returns for each system were examined at different phases in each production system. Returns for each system were evaluated at calf weaning, the end of summer grazing for yearlings and at harvest for calf-feds and yearlings. The purpose of this economic analysis was to determine the dollars per cow returned to the producer; therefore, all profit and losses are represented as dollars returned per exposed cow. In addition, the seasonal trends of commodity prices can have a large impact on the profitability of each system. Therefore, all prices for feedstuffs and cattle are a 2007 to 2010 average for the month that feedstuffs were utilized by the cattle and the month cattle were marketed.

Cow inputs. This analysis assumes that all cows are owned free and clear by the producer therefore this is a partial budget approach to determining relative differences in production systems economics. Range cost was calculated by taking the average land rent cost per hectare of the Northern region of Nebraska (Johnson et al., 2010) and determining the number of acres that it would take to maintain a 454 kg cow (**AU**) using 1.5 AU/hectare (Volesky, 2010). To adjust for cow and calf BW greater than 454 kg, BW of the cow at weaning time and the average BW of the calf from birth to weaning was divided by 454 kg to determine AU equivalents for each system. One AU is equal to 454 kg (Meyer et al., 2008). Dividing hectare rent by range production is the cost of range needed to manage a 454 kg cow for one month (**AUM)**. Animal unit equivelants was then multiplied by the number of days on grass divided by 30 to get the total AUM needed for each animal. The total AUM's used were then multiplied by the average 2007 to 2010 calculated AUM price. During the forage growing season (May 1st thru October

31^{st}) when range resources were in the growing season, cost per AUM was $25.42. To determine the cost for winter grazing (November 1^{st} thru April 30^{th}), range value was estimated as half the value of summer range ($12.71/AUM). While grazing forage resources, a cost was charged to the cow ($0.10/cow daily) to factor in labor and equipment cost while maintaining cows on grass. During the time that cows were supplemented on native range, an additional cost of $0.05/cow daily was charged to account for added equipment cost and added time associated with cow supplementation. In addition, supplement cost was the average price paid by the ranch for supplement from 2007 through 2010 ($289.60/tonne on a DM-basis).

During the time that cows were grazing cornstalks, a daily rate of $0.50 per cow was assessed for SP which were dry cows during wintering. This is the actual price that was paid to rent cornstalks from 2007 to 2010. Cows from SU and FA were in milk and had a calf by their side therefore daily rates for cornstalk grazing was adjusted for SU and FA to account for intake of the calf. The adjustment for SU and FA wintering cost on cornstalks was done similar to AUM calculations in which average BW of the SU and FA cows with calves was divided by SP BW and multiplied by $0.50/cow daily. The cost for grazing cornstalks included management of the cattle; therefore added daily charges were not included in the cost of grazing cornstalks. In addition, cattle had to be shipped 84 km to cornstalks. Trucking was charged at a rate of $2.48 per loaded km. In addition, 35 SP cows could be loaded on a truck, based on hauling 24,090 kg per load. For SU and FA, cows and calves were shipped together and it was estimated that 25 and 26 pairs could fit on each load, respectively, based on hauling 24,090 kg per load.

During calving, SP were placed in drylot and fed hay. Hay intake was determined using AUM calculations (Meyer et al., 2008). Cost of hay during the drylot period was \$106.18/tonne (DM-basis; USDA, 2010a). During drylot cows were charged \$0.25/cow daily to account for labor and facilities needed.

Replacement cows from this study were all produced from the SP heifers and no other system. In addition, replacement heifers were not followed after weaning, therefore; cost to produce replacement heifers from each system cannot be assessed. Replacement rate for each system was assumed to be 15%. To determine replacement cow cost for each system, bred cows were purchased into each system. For all herds, bred cow prices were obtained for 2007 through 2010 (Cattle Fax, Centennial, CO) . In each system bred cows were introduced into the system at weaning and cull cows were sold at weaning. For SP, SU, and FA, bred cow price was \$947.46 (October), \$1025.06 (April), and \$1025.06 (April), respectively.

For SP, SU, and FA, cull cow price (USDA, 2010a) was \$46.66/45 kg (October), \$53.28/45 kg (April), and \$53.28/45 kg (April), respectively.

Calves were preconditioned prior to finishing system entry. In the economic analysis, the calf preconditioning costs are added to the cow cost. During the preconditioning period, calves grazed sub-irrigated cool season meadow and were supplemented 0.45 kg/d supplement. Forage cost for calves during preconditioning was calculated using the same method as the cows. In addition, during preconditioning \$0.15/calf daily was assessed to account for labor and equipment.

Other costs per cow included in this analysis are bull cost, calving labor, and vaccination cost. The cost of bulls for each system included: purchasing the bull for

$3000.00/bull, adding feeding cost of $571.56/bull, and subtracting slaughter value of $1264.60 (USDA, 2010a). Therefore, costs of $461.39/bull yearly if the bulls are retained for 5 yr. In this study the bull to cow ratio was 1:25; therefore, cost per year was divided by 25 to determine the bull cost per cow. Labor during calving was recorded and a cost for labor of $15.00/hr was assessed to account for increased labor with different calving seasons. In addition, a cost of $11.50/cow was used for the vaccination program cost up to calf weaning.

To determine returns from calf sales at weaning, it was assumed that half of the calves sold were heifers and half of the calves sold were steers. Returns to each system at weaning assumed that all calves from a system were sold as feeder cattle. Calf BW at weaning was different when comparing calving season, therefore, the 4-yr average price slide ($3.66/45 kg; USDA, 2010a) was used to determine calf values at different BW. The use of a price slide decreases the dollars/45 kg received for heavier calves and increases the dollars/45 kg for lighter calves. For SP, SU, and FA, average price per 45 kg received for calves was $108.61 (238 kg; November), $121.24 (254 kg; May), and $122.85 (234 kg; May), respectively.

Finishing system inputs. To assess the costs for calves during the yearling finishing system, forage cost was estimated using the same procedure as the cow forage cost. In addition, during summer grazing, $0.15/calf daily was assessed to account for labor and equipment. During summer grazing, calves were supplemented dried distillers grains at a rate of 0.6% BW. Distillers grains were priced at 84% (USDA/AMS, 2010) the price of corn when corn was $0.19/kg (DM-basis). Returns per cow exposed were evaluated at the end of summer grazing. Feeder calf price reported by USDA (2010a) for

SU steers, FA steers, SU heifers and FA heifers at the end of summer grazing was $115.57 (August), $112.83 (September), $105.77 (September), and $101.43/45 kg (October).

Calves from each finishing system were shipped 200 km from the ranch to the feedlot where they were finished. Hauling cost for cattle was $2.48/loaded km. However, because BW was greater for yearlings compared to calf-feds, 70 yearlings and 90 calf-feds could be hauled in one load. At feedlot entry, yearlings and calf-feds were vaccinated similarly. Since receiving was similar for all cattle a health charge of $23.85 was used which would account for vaccination cost and assumed one medical treatment for each animal.

Yardage during finishing was assessed at $0.45/calf daily (Jensen and Mark, 2010). Ration cost for SU calf-feds and FA calf-feds was $0.129/kg. Ration ingredient prices are from USDA (2010a). Sweet Bran (Cargill; Blair, NE) was priced into the ration at 90% the price of corn (Erickson et al., 2005). Ration cost for SP calf-feds, SU yearling steers, and FA yearling steers was $0.128, $0.127, and $0.126/kg, respectively. Ration cost for SU yearling heifers and FA yearling heifers was $0.126 and $0.125/kg, respectively. Differences in diet cost are due to differences in the time of year that cattle where fed. Interest was assessed at a rate of 7.5% and was calculated for supplemental dried distillers grains in the yearling system and half of the diet cost and yardage charges during feedlot finishing. Death loss was added to yearlings by multiplying value of the animal by 0.75%. To account for death loss of yearlings during the finishing period total cost of the animal was multiplied by 1.25%. For calf-feds, total cost of the animal was multiplied by 2.00%. Therefore, in each finishing systems death loss was assessed as

2.00% of the cattle produced; however, some of the death loss cost in yearlings is assessed during summer grazing, where in the calf-feds it is all accounted for in the feedlot.

Calf value after finishing was calculated 2 ways, first using the 2007 through 2010 average live price and subtracting the total cost of production from the value of the animal. Second, profit was calculated by selling the cattle in the beef using the average premiums and discounts received for carcass QG and carcass over 455 kg (Table 1; USDA, 2010b). Price received for cattle on the grid was determined by dividing live cattle price by 0.63 (dressing percentage) and adding/subtracting premiums and discounts. Live price received ($/45 kg) for steers in SP calf-feds, SU calf-feds, SU yearlings, FA calf-feds, and FA yearlings were $88.92 (June), $84.98 (December), $85.03 (January), $84.98 (December), and $85.03 (January), respectively. Live price received ($/45 kg) for heifers in SU calf-feds, SU yearlings, FA calf-feds and FA yearlings were $85.58 (December), $85.64 (January), $85.58 (December), and $85.64 (February), respectively.

Statistical Analysis

All data from this study were analyzed as a completely randomized design using the MIXED procedure of SAS. Economics up to weaning and calf-fed steer harvest were analyzed with a 2 (SP or SU) x 2 (wintered on range or cornstalks) + 1 (FA wintered on cornstalks) factorial arrangement of treatments. Experimental unit for this study was group of cows and calves within treatment by yr. Data from SP and SU were analyzed for interactions between calving season (SP and SU) and wintering system (range vs. cornstalks).

Calf economics were analyzed as a completely randomized design using the MIXED procedure of SAS. Treatments were separated by calving season, therefore experimental unit was maternal wintering system, calf sex, and finishing system which were analyzed independently of other calving seasons. For calving season analysis only, calf-fed steers were used to determine calf economics since SP heifers were not terminal and steers from SP did not enter a yearling system. All models included yr as a random effect and treatment in the model statement. Since steers and heifers were finished as calf-feds and yearlings from SU and FA, the effect of sex and calf finishing system were analyzed. The model included sex, finishing system, and sex*finishing system interaction. Data are presented as least squares means with differences considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

Conception to weaning. Results of the economic analysis for each production system from conception to weaning are presented in Table 2. Wintering system by calving season interactions for calf range cost ($P < 0.01$), cow supplement cost ($P < 0.01$), and total cost ($P = 0.02$) were observed between SU and SP cows. For calf range cost, SU wintered on range had greater cost compared to SU wintered on cornstalks; however, calf range cost for SP were not different when comparing wintering systems. For cow supplement cost, SU wintered on range (supplemented 1.14 kg/d) had greater supplement cost compared to SU wintered on cornstalks (supplemented 0.45 kg/d); however, SP supplement cost were not different when comparing wintering systems because supplement practices were similar. Total cost for SU on cornstalks was less compared to SU wintered on range; however, total cost was not different when comparing wintering systems in SP.

Fall calving range costs were comparable to SU wintered on cornstalks. Cost of range for cows was greatest for SU wintered on native range ($P < 0.01$) and least for SP wintered on cornstalks ($P < 0.01$). In addition, calf range costs were greatest ($P < 0.01$) for SU wintered on range and least for FA ($P < 0.01$). Hauling cost for cows wintered on cornstalks was $11.89, $16.64, and $16.00 for SP, SU, and FA respectively, because SU and FA had calves by their side and SP were dry cows. In addition, the cost of wintering on cornstalks for 110 d was $55.00, $78.21, and $73.47/cow for SP, SU, and FA, respectively. Supplement cost was greatest ($P < 0.01$) for SU wintered on range and lowest for SP ($P < 0.01$). However, the cost associated with placing SP in dry lot increased cost per cow by $99.22 and $100.01, for SP wintered on cornstalks and range, respectively. In addition, labor for calving was greatest for SP ($63.00 vs. $22.50 vs. $19.50) compared to SU and FA. Because of the seasonality of bred cow prices, SP had lower replacement cow prices ($P < 0.01$) compared to SU and FA. In addition, because of reduced days in a preconditioning program, SP had lower preconditioning cost compared to SU and FA ($P < 0.01$). When comparing total cost of production from conception to weaning, SU wintered on range had the greatest cost/cow ($P < 0.01$) and FA had the lowest cost/cow ($P < 0.01$).

Returns for each system were a combination of cull cow value and calf value. Profitability is reported as dollars returned per exposed cow. Cull cow value, on a per cow basis, was greatest ($P < 0.01$) for SU and FA which were not different ($P > 0.23$) from each other. There were no differences in calf value ($P = 0.14$) among systems. In addition, total returns for each system where not different (*P* = 0.13). Profit was not different (*P* = 0.46) among system even though the range in profitability was $23.24 to $84.09 per cow exposed.

Larson et al. (2009) reported cows wintered on cornstalks to be more profitable at weaning when compared to cows wintered on native range. However, Anderson et al. (2005) reported lower cost when cows were wintered on cornstalks and no significant difference in profit per cow when calves were sold at weaning. Similar results were observed in the current study, where no differences in system profitability were observed when comparing cow wintering system.

Later calving seasons have resulted in lower cost per cow (May et al., 1999; Carriker et al., 2001; Payne et al., 2009). The reason for the reduction in cost was a result of having to feed less harvested forage for later season calving cows compared to spring calving cows. In the current study, calving season had no effect on profitably even though total costs were reduced with later calving seasons in part by a reduction in the need to feed harvested feeds.

A major factor that influences profitability of a calving system is the number of calves weaned per cow. In yr 1 of FA, calves weaned/cow exposed were 0.73, making the average calves weaned/cow over the 4 yr study 0.89. When 0.73 for yr 1 is removed the number of calves weaned/cow is 0.94. In yr 2 for SU wintered on cornstalks, calves weaned per cow was 0.86 making the average number of calves weaned per cow 0.94. When 0.86 is removed the number of calves weaned per cow becomes 0.97. Changes in calves weaned/cow have a large impact on overall profitability and the amount of variation in profitability. When adjusting calves weaned/cow by removing the potential outliers, differences in profitability exist ($P < 0.01$). In addition, profitability for SU wintered on cornstalks and FA increases $17.50 and $32.12/cow exposed, respectively. When measuring variation, removing the data for FA and SU wintered on cornstalks that are low, reduced SEM from 24.94 to 16.49 increasing the ability to detect significance. The other consideration with potential outliers in the data set is the possibility of committing a type II statistical error in which we conclude that no differences exist when in fact there is a statistical difference in the means. Given the range in profitability and the high SEM with the potential outliers included in the data set, we conclude that in fact differences exist and that SU wintered on cornstalks is the most profitable system compared to SP and FA systems.

Finishing system economics. Profitability for each system is presented as $/exposed cow. In addition, each economic scenario assumes retained ownership through each phase of production. The fat adjusted data were used to evaluate economics for finishing cattle so that cattle were evaluated at equal endpoints. When determining carcass value, it is assumed that at 1.27 cm of fat (adjusted endpoint) cattle would all be YG 3. Therefore premiums and discounts for YG were not assessed for each group of cattle since there is no premium or discount for YG 3 carcasses.

Calving system on subsequent calf-feeding performance. The calf-fed steers from each system were compared to determine the effect of calving system on the economics of finishing cattle from each system. The effect of calving system on calf-fed economics is presented in Table 3.

Interactions between SU and SP wintered on cornstalks and native range were observed for calf live value ($P = 0.04$), calf carcass value ($P = 0.05$), live profit ($P =$

0.01), and a tendency for grid profit (P = 0.06). For calf live value, calves from SP wintered on cornstalks were less than SP wintered on range (P = 0.05); however calves from SU wintered on cornstalks had greater calf live value than SU wintered on range (P = 0.04). Carcass value followed a similar pattern as calf live value. When evaluating live profit, SP wintered on cornstalks had $39.09 lower returns than SP wintered on range (P < 0.01). Conversely, SU wintered on cornstalks had $46.57 greater profit than SU wintered on range (P < 0.01). Similar trends were observed for grid profit when comparing SU and SP wintered on cornstalks or range.

When comparing all treatment means including FA, no differences were observed for feedlot yardage (P = 0.40), diet cost (P = 0.26), interest (P = 0.76), total cost of finishing (P = 0.66), feedlot cost of gain (P = 0.52), live calf value (P = 0.35), calf carcass value (P = 0.36), live profit (P = 0.12), or grid profit (P = 0.23).

Stockton et al. (2007) reported that June born calves were more profitable than March born calves when retained through a calf-fed system due to higher returns and lower cost related to the entire production system from conception to weaning. In both Stockton et al. (2007) and the current study, differences represented after calf-feeding are not because of the finishing system alone but are a cumulative effect of reduced production cost from conception to weaning and increased returns due to season of marketing and increased BW sold.

Summer born calf economics. Summer born calf economics are presented in Table 4 and statistics presented in Table 5. There were no 3 way interactions for wintering system, sex or finishing system (P > 0.13). However, interactions for wintering system and finishing system were observed for feedlot yardage (P = 0.04), diet cost (*P* = 0.05), interest (*P* = 0.03), and a trend was observed for total feedlot cost (*P* = 0.08). In addition, interactions for sex and finishing systems were observed for feedlot yardage (*P* = 0.03), diet cost (*P* = 0.05), interest (*P* = 0.05), and a trend was observed for feedlot cost of gain (*P* = 0.09).

When evaluating interactions for wintering and finishing systems, yearlings had less feedlot yardage cost compared to calf-feds. However, steer yearlings wintered on range had feedlot yardage cost that was similar to steer calf-feds in both wintering systems resulting in less difference between calf-fed and yearling yardage in calves from cows wintered on range compared to calves from cows wintered on cornstalks. In addition, diet cost for yearlings from cows wintered on range were closer in cost to calf-feds from cows wintered on range compared to calf-feds and yearlings from cows wintered on cornstalks. Similar trends were observed for interest cost. However, total feed costs were similar when comparing calf-feds and yearlings from cows wintered on cornstalks but when comparing yearlings and calf-feds wintered on range, calf-feds had lower total feedlot cost compared to yearlings.

When evaluating interactions for sex and finishing system, yearling steers and calf-feds had less difference in yardage cost compared to yearling and calf-fed heifers. Similar trends were observed in diet cost and interest cost. When comparing feedlot cost of gain, steer calf-feds and yearlings had similar cost of gain, but heifer yearlings had greater feedlot cost of gain compared to their calf-fed counterparts.

Live and carcass value were affected by sex (*P* < 0.01) of the calf and finishing system (*P* = 0.03), with steers having greater live value compared to heifers and yearlings having greater live value than calf-feds. Profit ($/cow exposed) are presented after grazing for yearlings, live, and carcass basis. When evaluating yearling profit after summer grazing, heifers were less profitable than steers ($P < 0.01$) and calves from cows wintered on cornstalks were more profitable ($P = 0.04$) than calves from cows wintered on range. After finishing, heifers were less profitable than steers ($P < 0.01$) for live and grid profit, and calves from cows wintered on cornstalks were more profitable than calves from cows wintered on range ($P = 0.01$). When marketed using the grid, profit tended to be different between calf-feds and yearlings ($P = 0.07$) with yearlings being more profitable than calf-feds.

Fall born calf economics. Fall born calf economics are presented in Table 6. Interactions between sex and finishing system were observed for feedlot yardage ($P = 0.04$). In addition, trends were observed for feedlot cost of gain ($P = 0.09$), calf carcass value ($P = 0.07$), and grid profit ($P = 0.06$). Numerically, feedlot yardage was lower for calf-fed steers compared to feedlot heifers; however, when comparing heifer and steer yearling feedlot yardage, steers had greater cost. Yearling heifer feedlot cost of gain was greater than feedlot cost of gain for all calf-feds and yearling steers. Carcass value was greatest for yearling steers compared to calf-fed steers and heifers and yearling heifers due to increased weight sold from yearling steers. In addition, the difference between profits when marketed on the grid is greater between steer and heifer yearlings compared to steer and heifer calf-feds.

When comparing steers and heifers, diet cost was lower for heifers ($P = 0.03$), live value was greater for steers ($P < 0.01$), and live profit was greater for steers ($P < 0.01$). When comparing calf-feds and yearlings, yearlings had lower feed cost ($P < 0.01$), lower interest cost ($P < 0.01$), greater total cost ($P < 0.01$), and greater live value ($P < 0.01$).

Finishing system and sex. To evaluate the effect of sex and finishing system, FA and SU calves were combined to determine profitability of steers, heifers, calf-feds and yearlings (Table 7). Interactions between finishing system and sex were observed for feedlot yardage cost ($P = 0.01$), ration cost ($P = 0.02$), interest ($P = 0.02$), and feedlot cost of gain ($P = 0.02$). Feedlot yardage cost was greatest for heifer and steer calf-feds, intermediate for steer yearlings, and lowest for heifer yearlings due to differences in days fed to achieve a fat thickness of 1.27 cm. The difference in feedlot yardage between calf-feds and yearlings was greater for heifers compared to steers. The trend for interest and diet cost were similar to that for feedlot yardage. However, when comparing feedlot cost of gain, heifers had greater cost of gain compared to steers with yearling heifers having the greatest cost of gain, calf-fed heifers were intermediate, and all steer calves had the lowest cost of gain due to greater G:F for steers compared to heifers. In addition, calf-fed and yearling costs of gain were not different when comparing steers.

When evaluating the effect of calf sex, steers had greater feedlot cost ($P = 0.05$), greater live value ($P < 0.01$), greater carcass value ($P < 0.01$), and greater profit whether marketed live ($P < 0.01$) or with grid marketing ($P < 0.01$) compared to heifers. When evaluating finishing system, yearlings had greater cost ($P < 0.01$), greater live value ($P < 0.01$), and greater carcass value ($P = 0.01$).

Taylor et al. (2008) reported that steers had $20.00/hd greater profit compared to heifers. In Taylor et al. (2008) steers had greater final BW compared to heifers which resulted in greater profitability for steers compared to heifers. The major reason for difference in returns for steers and heifers in the current study is differences in BW because weight is a major driver of the value of an animal (Shain et al., 2005; Owens et al., 1993). In the current analysis, steers were heavier at marketing and had lower cost of gain resulting in greater returns per steer compared to heifers. However, when comparing profitability change from live to grid marketing, heifers benefited more from grid marketing compared to live since they produced fewer overweight carcasses and graded similar to or better than steers when fed to an equal fat endpoint.

In all marketing scenarios, heifers were less profitable than steers. Average 2007 to 2010 prices (USDA, 2010a) showed that heifer prices per 45 kg of carcass were \$3.01 greater than steers. However, heifers were less profitable than steers because of less BW sold. In the current grid marketing scenario heifers would need to be reduced \$94.29 per heifer in original cost or receive \$11.85/45 kg more at harvest compared to steers in order to be at similar profit.

When comparing calf-feds and yearlings, total costs were greater for yearlings. In addition, yearlings were more profitable than calf-feds. Griffin et al. (2007) reported similar results with yearlings having greater total costs of production but greater profits compared to calf-feds. However, in Griffin et al. (2007) calves were sorted by BW into each finishing system. In the current study calves were assigned randomly to finishing system. Adams et al. (2010) utilized cattle that were assigned randomly into calf production systems and reported that yearlings had greater cost compared to calf-feds and profitability was lower for yearlings compared to calf-feds. Adams et al. (2010) concluded that poor yearling economic responses were due to low pasture gains suggesting that summer gains for yearlings on grass affect subsequent feedlot economics.

Weight is a major driver for economics in cattle production (Shain et al., 2005; Owens et al., 1993). In the current study, more weight was sold with yearlings compared to calf-feds but did not result in significantly greater returns. In addition, QG was not different when comparing calf-feds and yearlings but the number of carcasses over 454 kg was greater for yearlings. However, because of increased weight sold for yearlings, discounts from overweight carcasses were offset.

Profit from each phase. Profitability from each phase of production and marketing scenario are presented in Table 8. Selling cattle on the grid increased profit for each finishing system (ave. = $34.31/hd) compared with selling cattle live. In addition, retaining ownership of yearlings through finishing increased profit of each system except SU steers from dams wintered on cornstalks. When evaluating steer marketing times the most profit could be realized at weaning. When evaluating heifers, profit was increased as heifers were retained through finishing. These results illustrate the importance of producing steers in terminal systems. Profitability of SP steers, regardless of maternal wintering system, was decreased with retaining ownership through finishing as calf-feds. Retaining calves from SU dams wintered on range through calf-feeding reduced profitability; however, when marketed as yearlings profitability was improved compared to calf-feds. Heifer calves regardless of production system were not as profitable as steers. In addition, changes in profitability were variable when shifting production from calf-feeding to yearling production systems.

Profits from each cow system at weaning time were numerically different for SU and SP with SP wintered on range having greater profit than SP wintered on cornstalks. Conversely, SU wintered on cornstalks were more profitable than SU wintered on range.

Results from this study illustrate that inputs into each system and the economic impact of the inputs are dependent on the biology of the system whether it be season of calving, wintering system, or subsequent calf management.

IMPLICATIONS

Production of a calf per cow is critical to profitability of production systems since the calf is the marketed entity from the cow. In addition, production system inputs relative to harvested feeds and labor have a large influence on the profitability of a production system. Seasonal trends in market price have an impact on cost and returns relative to each system and marketing strategy. Results from this study indicate profitability of retaining ownership of steers through finishing can maintain or increase returns/cow exposed. However, finishing heifers may not increase profit after weaning. Ultimately, the profitability of a production system is dependent on the amount of weight sold from each cow and the cost of adding that weight to each marketed animal.

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Table 1. Grid premiums and discounts.[1]

Month[2]	Choice-Select Spread	Carcass over 455 kg
January	7.41	19.52
February	3.05	19.27
June	4.49	19.25
December	7.20	19.80

[1]Prices reported are from USDA (2007-2010) and are $/45 kg carcass weight.
[2]Sping born calves marketed in June. Summer and fall born calf-feds marketed in December. Summer born yearlings and fall born steers marketed in January. Fall born yearling heifers marketed in February.

Table 2. Effect of calving season and wintering system on economic performance from conception to weaning.[1]

	Cornstalks			Range				
Item	Spring	Summer	Fall	Spring	Summer	SEM	F-test	S x W[2]
Cornstalks[3]	55.00	78.21	73.47	0.00	0.00	---	---	---
Cow range[4]	176.12[d]	218.59[bc]	212.77[c]	228.90[b]	263.84[a]	4.57	< 0.01	0.43
Calf range[5]	49.39[b]	44.07[c]	28.11[d]	49.93[b]	59.47[a]	0.82	< 0.01	< 0.01
Yardage[6]	19.40	33.60	32.10	32.60	50.10	---	---	---
Supplement	5.79	35.80	31.86	5.79	89.51	---	---	< 0.01
Drylot cost	99.22	---	---	100.01	---	---	---	---
Labor[7]	63.00	22.50	19.50	63.00	22.50	---	---	---
Replacement[8]	142.12[b]	153.76[a]	153.76[a]	141.12[b]	153.76[a]	0.00	< 0.01	1.00
Precondition[9]	12.81[b]	21.22[a]	20.06[a]	12.92[b]	21.42[a]	0.29	< 0.01	0.86
Total cost	663.71[b]	652.68[b]	616.02[c]	664.21[b]	688.67[a]	6.19	< 0.01	0.02
Cull value	76.78[b]	93.73[a]	91.23[a]	77.50[b]	90.67	1.77	< 0.01	0.30
Calf value	610.16	643.04	561.87	621.74	657.22	27.04	0.14	0.94
Returns	686.94	736.77	653.10	699.23	747.89	28.06	0.13	0.97
Profit[10]	23.24	84.09	37.08	35.03	59.01	24.94	0.46	0.29

[abcd]Means with different superscripts differ ($P < 0.05$).
[1]All values represented as $/cow.
[2]S x W = *P*-value for interaction between calving season and maternal wintering system (summer and spring cows).
[3]Cost of grazing cornstalks ($0.50/cow daily).
[4]Cow range cost.
[5]Calf range cost.
[6]Yardage cost assessed while grazing range ($0.10/cow daily during grazing, additional $0.05/cow daily during supplementation).
[7]Labor cost during calving assessed at a rate of $15.00/hr.
[8]Replacement cow cost.
[9]Cost for pre-conditioning calves.
[10] $/cow exposed.

Table 3. Effect of calving season and wintering system on profitability of calf-feds.[1]

	Cornstalks			Range				
Item	Spring	Summer	Fall	Spring	Summer	SEM	F-test	S x W[2]
Yardage[3]	92.70	88.88	93.38	100.58	86.29	5.19	0.40	0.34
Diet cost	245.21	285.13	282.81	263.80	275.22	15.24	0.26	0.21
Interest[4]	8.74	9.16	9.62	10.07	8.60	0.90	0.76	0.28
Total cost[5]	387.88	424.94	425.95	415.67	412.17	20.40	0.66	0.25
Feedlot COG[6]	1.17	1.19	1.17	1.14	1.21	0.04	0.52	0.45
Live value	1118.56	1167.43	1129.98	1182.43	1135.05	24.31	0.35	0.04
Carcass value	1141.58	1212.93	1168.87	1208.88	1176.64	26.96	0.36	0.05
Live profit[7]	34.66	46.59	5.10	73.75	0.02	20.14	0.12	0.05
Grid profit[7]	56.66	89.54	39.66	99.18	39.72	21.95	0.23	0.06

[1]All values represented as $/calf.
[2]S x W = *P*-value for interaction between calving season and maternal wintering system (summer and spring calves).
[3]Charged at a rate of $0.45/calf daily.
[4]Interest rate = 7.5%.
[5]Total cost = total feedlot cost.
[6]Feedlot COG = feedlot cost of gain ($/kg).
[7]Profit represented as $/exposed cow.

Table 4. Effect of wintering system, sex, and finishing system on summer born calf economics.[1]

	Cornstalks				Range			
	Calf-fed		Yearling		Calf-fed		Yearling	
Item	Heifer	Steer	Heifer	Steer	Heifer	Steer	Heifer	Steer
Grazing cost[2]	---	---	115.70	94.72	---	---	115.40	95.67
Grazing COG[3]	---	---	1.10	1.10	---	---	1.21	1.08
Yardage[4]	96.08[a]	88.88[ab]	58.16[d]	68.51[cd]	85.73[ab]	86.29[ab]	64.35[d]	80.33[bc]
Diet cost	274.74[ab]	285.13[a]	190.22[d]	238.62[bc]	250.33[ab]	275.22[ab]	204.98[cd]	275.15[ab]
Interest[5]	9.88[a]	9.16[a]	4.44[c]	6.11[bc]	8.04[ab]	8.60[ab]	5.23[c]	8.53[ab]
Total cost[6]	422.47[bc]	424.94[bc]	422.35[bc]	461.34[ab]	386.15[c]	412.17[bc]	443.71[bc]	513.38[a]
Feedlot COG[7]	1.28[bc]	1.19[c]	1.34[ab]	1.21[bc]	1.30[bc]	1.21[bc]	1.43[a]	1.19[c]
Live value	1082.73[cd]	1167.43[bc]	1098.82[bcd]	1214.16[ab]	1031.11[d]	1135.05[bcd]	1084.89[cd]	1322.81[a]
Carcass value	1130.33[bc]	1212.93[b]	1145.80[bc]	1253.72[ab]	1074.56[c]	1176.64[bc]	1135.56[bc]	1349.45[a]
Grazing returns[8]	---	---	16.38[b]	106.03[a]	---	---	-23.89[c]	86.85[a]
Live profit[9]	-31.30[cd]	46.59[ab]	-7.99[bc]	61.64[a]	-74.72[d]	-0.02[bc]	-71.91[c]	88.35[a]
Grid profit[9]	-13.71[de]	89.54[abc]	36.24[cde]	99.08[ab]	-33.27[f]	39.72[bcd]	-23.98[ef]	113.62[a]

[abcd]Means with different superscripts differ (*P* < 0.05).
[1]Cost are represented as $/hd.
[2]Grazing cost = cost of summer grazing for yearlings.
[3]Grazing COG = Cost of gain ($/kg) during summer grazing.
[4]Charged at a rate of $0.45/calf daily.
[5] Interest rate = 7.5%.
[6]Total cost = total cost of production post weaning.
[7]Feedlot COG = Cost of gain ($/kg) during finishing.
[8]Grazing returns = $/cow exposed returned if calves were sold after summer grazing.
[9] $/exposed cow.

Table 5. Statistical *P*-values for the economics presented in Table 4.

Item	SEM	Winter[1]	Sex[2]	Finish[3]	W x S[4]	W x F[5]	S x F[6]	W x F x S[7]
Grazing cost[8]	---	---	---	---	---	---	---	---
Grazing COG	---	---	---	---	---	---	---	---
Yardage[9]	6.68	0.72	0.17	< 0.01	0.34	0.04	0.03	0.88
Diet cost	23.15	0.68	< 0.01	< 0.01	0.38	0.05	0.05	0.86
Interest[10]	1.20	0.74	0.06	< 0.01	0.24	0.03	0.05	0.88
Total cost[11]	37.63	0.72	0.05	< 0.01	0.42	0.08	0.24	0.91
Feedlot COG[12]	0.02	0.48	< 0.01	0.15	0.33	0.95	0.09	0.23
Live value	57.34	0.93	< 0.01	0.02	0.26	0.16	0.19	0.41
Carcass value	58.61	0.96	< 0.01	0.03	0.31	0.16	0.27	0.48
Grazing returns[13]	12.71	0.08	< 0.01	---	0.53	---	---	---
Live profit[14]	25.27	0.04	< 0.01	0.04	0.15	0.38	0.21	0.13
Grid profit[14]	25.92	0.03	< 0.01	0.07	0.24	0.40	0.39	0.21

[1]Effect of maternal wintering system.
[2]Effect of calf sex.
[3]Effect of finishing system.
[4]Maternal wintering system by calf sex.
[5]Maternal wintering system by finishing system.
[6]Calf sex by finishing system.
[7]Maternal wintering system by calf finishing system by calf sex.
[8] Cost of gain during summer grazing.
[9]Yardage charged during the finishing period.
[10]Interest charged during the finishing period.
[11]Total cost of calf finishing post weaning.
[12]Feedlot cost of gain.
[13]$/cow exposed returned if calves were sold after summer grazing.
[14] $/exposed cow.

Table 6. Effect of sex and finishing system on fall born calf economics.[1]

Item	Calf-fed Heifer	Calf-fed Steer	Yearling Heifer	Yearling Steer	SEM	*P*-value Sex[2]	*P*-value Finish[3]	*P*-value Sex x Finish[4]
Grazing cost[5]	---	---	145.70	112.95	---	---	---	---
Grazing COG[6]	---	---	1.15	1.03	---	---	---	---
Yardage[7]	98.55[a]	93.38[a]	65.81[b]	74.36[b]	4.40	0.57	< 0.01	0.04
Diet cost	272.85[a]	282.81[a]	204.72[b]	253.81[a]	17.77	0.03	< 0.01	0.13
Interest[8]	10.00[a]	9.62[a]	5.22[b]	6.97[b]	0.86	0.28	< 0.01	0.11
Total cost[9]	421.55[b]	425.95[b]	476.29[a]	501.61[a]	23.83	0.31	< 0.01	0.48
Feedlot COG[10]	1.30[b]	1.17[b]	1.50[a]	1.19[b]	0.09	< 0.01	0.04	0.09
Live value	1043.80[c]	1129.98[b]	1081.15[bc]	1257.19[a]	41.99	< 0.01	< 0.01	0.11
Carcass value	1088.52[b]	1168.87[b]	1099.31[b]	1288.40[a]	42.77	< 0.01	0.03	0.07
Grazing returns[11]	---	---	-37.66[b]	53.68[a]	25.24	0.06	---	---
Live profit[12]	-68.07[b]	5.10[a]	-73.72[b]	58.29[a]	27.17	< 0.01	0.21	0.13
Grid profit[12]	-28.29[b]	39.66[a]	-57.47[b]	86.69[a]	29.89	< 0.01	0.63	0.06

[abc]Means with different superscripts differ ($P < 0.05$).
[1]Cost are represented as $/hd.
[2]Effect of calf sex.
[3]Effect of finishing system.
[4] Calf sex by finishing system.
[5]Grazing cost = cost of summer grazing for yearlings.
[6]Grazing COG = Cost of gain ($/kg) during summer grazing.
[7]Charged at a rate of $0.45/calf daily.
[8] Interest rate = 7.5%.
[9]Total cost = total cost of production post weaning.
[10]Feedlot COG = Cost of gain ($/kg) during finishing.
[11]Grazing returns = $/cow exposed returned if calves were sold after summer grazing.
[12]$/exposed cow.

Table 7. Effect of sex and finishing system on calf economics.[1]

	Heifer		Steer			*P*-value		
Item	Calf-fed	Yearling	Calf-fed	Yearling	SEM	Sex[2]	Finish[3]	Sex x Finish[4]
Grazing cost[5]	---	125.60	---	101.12	---	---	---	---
Grazing COG[6]	---	1.15[a]	---	1.07[b]	0.02	0.05	---	---
Yardage[7]	93.45[a]	62.78[c]	89.51[a]	74.40[b]	4.50	0.19	< 0.01	0.01
Diet cost	265.98[ab]	199.97[c]	281.05[a]	255.86[b]	17.22	< 0.01	< 0.01	0.02
Interest[8]	9.31[a]	4.96[c]	9.13[a]	7.20[b]	0.84	0.05	< 0.01	0.02
Total cost[9]	410.06[b]	447.45[b]	421.02[b]	492.11[a]	21.42	0.05	< 0.01	0.22
Feedlot COG[10]	1.30[b]	1.43[a]	1.19[c]	1.19[c]	0.04	< 0.01	0.02	0.02
Live value	1052.55[c]	1088.29[bc]	1144.15[b]	1264.72[a]	33.80	< 0.01	< 0.01	0.12
Carcass value	1097.80[c]	1126.89[bc]	1186.15[b]	1297.19[a]	35.61	< 0.01	0.01	0.13
Grazing returns[11]	---	-15.06[b]	---	82.19[a]	11.28	< 0.01	---	---
Live profit[12]	-58.03[c]	-51.21[c]	17.24[b]	69.43[a]	16.49	< 0.01	0.13	0.12
Grid profit[12]	-15.95[b]	-15.07[b]	56.31[a]	99.80[a]	18.55	< 0.01	0.15	0.17

[abc]Means with different superscripts differ ($P < 0.05$).
[1]Data from fall and summer born calves combined; cost are represented as $/hd.
[2]Effect of calf sex.
[3]Effect of finishing system.
[4] Calf sex by finishing system.
[5]Grazing cost = cost of summer grazing for yearlings.
[6]Grazing COG = Cost of gain ($/kg) during summer grazing.
[7]Charged at a rate of $0.45/calf daily.
[8] Interest rate = 7.5%.
[9]Total cost = total cost of production post weaning.
[10]Feedlot COG = Cost of gain ($/kg) during finishing.
[11]Grazing returns = $/cow exposed returned if calves were sold after summer grazing.
[12]$/exposed cow.

Table 8. Profitability of system by phase of production.[1]

System	Weaning	Summer Grazing[2]	Live Profit	Grid Profit
Cow System				
Spring Stalks	23.24	---	---	---
Spring Range	35.03	---	---	---
Summer Stalks	84.09	---	---	---
Summer Range	59.01	---	---	---
Fall Stalks	37.08	---	---	---
Steer Calf-feds				
Spring Stalks	111.67	---	34.66	56.66
Spring Range	144.55	---	73.75	99.18
Summer Stalks	201.30	---	46.59	89.54
Summer Range	206.45	---	0.02	39.72
Fall	118.91	---	5.10	39.66
Steer Yearlings				
Summer Stalks	201.30	106.03	61.64	99.08
Summer Range	206.45	86.85	88.35	113.62
Fall	118.91	53.68	58.29	86.89
Heifer Calf-feds				
Summer Stalks	-33.12	---	-31.30	13.71
Summer Range	-50.19	---	-74.72	-33.27
Fall	-30.59	---	-68.07	-28.29
Heifer Yearlings				
Summer Stalks	-33.12	16.38	-7.99	36.24
Summer Range	-50.19	-23.89	-71.91	-23.98
Fall	-30.59	-37.66	-73.72	-57.47

[1]Values are cumulative profit per cow exposed.

2Cumulative profit if calves were marketed after summer grazing.

The Effects of Supplementing Dried Distillers Grains to Steers Grazing Cool Season Meadow[1]

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ABSTRACT

Two summer experiments were conducted year 1 and 2 respectively, with 28 (BW = 291 ± 22 kg; Exp. 1) and 48 (BW = 280 ± 22 kg; Exp. 2) steers to determine the effect of supplementing dried distillers grains plus solubles (**DDGS**) on growth when grazing sub-irrigated Sandhills meadow. Steers were stratified by BW and assigned randomly to treatment. In Exp. 1, there were 2 treatments: nonsupplemented or DDGS supplemented 0.6% BW (1.75 kg) daily. In Exp. 2, there were 3 treatments: 0, 0.6 (1.68 kg), or 1.2% BW (3.36 kg) DDGS supplementation daily. In both experiments, steers were individually supplemented for the duration of the study (Exp. 1 = 92 d; Exp. 2 = 91 d). Both experiments were analyzed as completely randomized designs with individual steer as the experimental unit. In Exp.1, ending BW ($P = 0.52$) and ADG ($P = 0.16$) were not different. In Exp. 2, ADG ($P < 0.01$) and ending BW ($P = 0.02$) increased linearly with increased level of DDGS supplementation. In Exp.1, feedlot performance was not affected by previous supplementation ($P > 0.06$). However, in Exp. 2, supplementing DDGS to steers grazing sub-irrigated Sandhills meadow increased carcass weight ($P = 0.02$) with increasing level of DDGS supplementation. In Exp. 2, supplementing DDGS during summer grazing did not affect QG or YG. Results from these studies indicate that supplementing DDGS at levels greater than 0.6% BW during summer meadow grazing increases ADG, with BW maintained through finishing.

Keywords: dried distillers grains plus solubles, summer grazing, supplementation

INTRODUCTION

Dried distillers grains plus solubles (**DDGS)** is a byproduct from the dry milling industry. In the dry milling process, starch is removed from the grain, to produce ethanol and the remaining nutrients are recovered, dried and marketed as DDGS (Stock et al., 2000). During the dry milling process, approximately two thirds of corn DM is removed (starch), therefore, concentrations of protein, fat, fiber, and P in DDGS are increased approximately three fold when compared to corn (Stock et al., 2000). Growing cattle in summer grazing systems can be deficient in metabolizable protein (**MP**; MacDonald et al., 2007). This suggests that supplemental MP from DDGS increases ADG during the grazing season (Loy et al., 2008; MacDonald et al., 2007). In addition, cattle in summer grazing systems benefit from additional energy provided from DDGS supplementation (Loy et al., 2008; Morris et al., 2005).

Supplementation has historically been accomplished with corn grain; however, because of increasing ethanol production, DDGS is often more economical for supplementation. Dried distillers grains plus solubles is typically priced lower than corn grain (approximately 70 to 90% the price of corn on a DM basis). Likewise corn prices have increased due to greater demand (USDA, 2010) leading to increased cost of finishing cattle. This increase in finishing cost has caused producers to evaluate opportunities to increase cattle BW prior to feedlot entry with supplements other than corn grain. Because of increased supply and competitive price of DDGS relative to corn, DDGS should be evaluated as a supplement for growing cattle consuming forage based diets prior to feedlot entry.

Supplementation with DDGS has been well studied in grazing programs using native warm season (Morris et al., 2006; Gustad et al., 2008; Taylor et al., 2008) pastures and cool season monocultures (MacDonald et al., 2004; MacDonald et al., 2007; Greenquist et al., 2009). However, data on supplementation of DDGS to cattle grazing cool season sub-irrigated meadow in the Nebraska Sandhills is not available. Therefore, the objectives of these studies were to evaluate the performance response of supplementing DDGS to steers grazing sub-irrigated cool season dominated meadows and to determine whether or not the performance response is due to increased MP or energy intake.

MATERIALS AND METHODS

Experiment 1.

Twenty-eight spring born steer calves (291 ± 22 kg) located at the Gudmundsen Sandhills Laboratory (Whitman, NE) were used in a study to determine effects of supplemental DDGS while grazing sub-irrigated meadow dominated by cool season grasses, and the impact of summer supplementation on feedlot performance and carcass characteristics. Prior to trial initiation, steers were wintered on native range and retained as yearlings for summer grazing. For BW collection, steers were limit fed meadow hay at 2 % BW (6 kg) for 5 d and weighed 3 consecutive d to determine initial BW. Steers were stratified by initial BW and assigned randomly to 1 of 2 treatments: nonsupplemented or supplemented DDGS at 0.6% of BW during the summer grazing season. Steers were allowed to graze 92 d (May 16th thru August 15th) and managed as one group during the summer grazing period. The amount of DDGS supplemented per steer was determined by multiplying the initial BW by 0.6% (range = 1.45 to 2.00 kg of

DDGS/steer daily). Supplementation was offered to each steer 6 d/wk. Steers receiving DDGS were individually penned each morning (0700 hr) and not turned out until DDGS was consumed (approximately 1 h). Each d of supplementation, nonsupplemented steers were penned as a group and not allowed to graze until supplemented steers had consumed all of their DDGS. At the end of the grazing period, steers were limit fed meadow hay 5 d at 2% BW (7.5 kg). After limit feeding, steer BW were collected 3 consecutive d to determine ending grazing BW.

The amount of DDGS that supplemented steers were allowed was not adjusted for BW gain over the summer grazing period. Therefore, the amount of supplementation delivered was 0.6% BW based on initial BW at the beginning of summer grazing. Taking the amount of supplementation during the grazing period and dividing by average BW over the supplementation period shows that steers were at 0.6% BW DDGS supplementation at the beginning of summer grazing and at 0.5% BW DDGS supplementation at the end of the summer grazing period.

***Experiment 2*.**

Forty-eight spring born steer calves (280 ± 22 kg) located at the Gudmundsen Sandhills Laboratory (Whitman, NE) were used in a study to determine the effect of supplemental DDGS at two different levels while grazing sub-irrigated meadow dominated by cool season grasses and the impact of summer supplementation on feedlot performance and carcass characteristics. Prior to trial initiation, steers were managed similar to Exp. 1. For BW collection, steers were limit fed meadow hay at 2 % BW (6 kg) for 5 d and weighed 3 consecutive d to determine initial BW. Steers were stratified by initial BW and assigned randomly to 1 of 3 treatments: nonsupplemented, low supplement (0.6% of BW), or high supplement (1.2% of BW). Steers were allowed to graze 91 d (May 21st thru August 20th) during the summer grazing period and managed as one group. Amount of DDGS supplemented per steer was determined by multiplying the initial BW by 0.6% (range = 1.36 to 2.05 kg of DDGS/steer) or 1.2% (range = 2.77 to 3.86 kg of DDGS/steer) and delivered to each steer 6 days/wk. Steers receiving DDGS were individually penned each morning (0700 hr) and not turned out until DDGS was consumed. Each day of supplementation, nonsupplemented steers were penned as a group and not allowed to graze until supplemented steers had consumed all of their DDGS. At the end of the grazing period steers were limit fed meadow hay 5 d at 2% BW (7 kg). After limit feeding, steer BW were collected 3 consecutive d to determine final grazing BW.

The amount of DDGS that supplemented steers were allowed was not adjusted for BW gain over the summer grazing period. Therefore, the amount of supplementation delivered was 0.6 and 1.2% BW based on initial BW at the beginning of summer grazing. Taking the amount of supplementation during the grazing period and dividing by average BW over the supplementation period shows that steers were at 0.6 and 1.2% BW DDGS supplementation at the beginning of summer grazing and at 0.4 and 0.9% BW DDGS supplementation at the end of the summer grazing period.

***Estimation of forage quality*.**

Meadow species included slender wheatgrass [*Elymus trachycaulus* (Link) Matte], redtop bent (*Agrostis stolenifera* L.), Timothy (*Phelum pretense* L.), Kentucky bluegrass (*Poa pratensis* L.), smooth bromegrass (*Bromus inermus* Leyss.), Woolly sedge (*Carex lanuginose* Michx.), spike rush (*Eleocharis* spp.), white clover (*Trifolium repens*

L.), alsike clover (*Trifolium hybridium* L.), red clover (*Trifolium pretense* L.), prairie cordgrass (*Spartina pectinata* L.), and big bluestem (*Andropogon gerardii* Vitman; Volesky et al., 2004). During the grazing period, diet samples were collected weekly using 4 esophageally cannulated cows. After sample collection, samples were freeze dried and ground through a 2-mm screen using a Wiley mill (Thomas Scientific, Swedesboro, NJ) for undegradable intake protein and IVDMD analysis. In addition, a sub sample was ground through a 1-mm screen for CP analysis.

Diet samples were used to determine steer diet quality, including IVDMD and CP (Table 1). In vitro DM disappearance was measured using the Tilley and Terry method (Tilley and Terry, 1963) with the addition of 1 g/L of urea to McDougall's buffer (Weiss, 1994). For this procedure, rumen fluid was composited from 2 ruminally fistulated steers that were allowed ad libitum access to smooth bromegrass hay and water. All IVDMD tests had 5 feed standards of varying quality in which in vivo DM digestibility was known (Geisert et al. 2007). The IVDMD values of these standards were then regressed based on in vivo DM digestibility in order to develop regression equations for each tests to calculate total tract DM digestibility (Geisert et al. 2007). Crude protein was measured using a combustion (AOAC; 1996) N analyzer (Leco FP-528, St. Joseph, MI).

Diet samples were also used to determine the undegradable protein (**UIP**) fraction of the steers' diet. Two ruminally fistulated steers were used for incubation of the samples to determine UIP. The animals were individually penned and allowed ad libitum access to brome hay and water. Dacron bags (Ankom, Fairport, NY) that were 5 by 10 cm with a pore size of 50 µm were used. Sample was weighed (1.25 g) into each Dacron bag and placed inside mesh bags and then inside the rumen at 3 different time points that corresponded with IVDMD of the samples. Samples of lower quality were incubated for a longer time in order to ensure adequate degradation. The time points were chosen based on calculation of rate of passage with the following equation: Rate of passage (**K_p**) = 0.07 * IVDMD (%) – 0.20 (Klopfenstein, et al., 2001), followed by determination of 75 % total mean retention time with the following equation with a 10 h passage lag (Broderick, 1994): $((1/k_p) + 10) * 0.75$. The bags were inserted into the rumen sequentially starting with the longest incubation time and finishing with the shortest incubation time so that all bags were removed at the same time. The mesh bags were then removed and Dacron bags rinsed using a washing machine (Whittet et al., 2003). Rinsing consisted of 5 rinse cycles with each having 1 minute of agitation and 2 minutes of spin. All bags were then bulk refluxed in neutral detergent solution (Midland Scientific, Omaha, NE) to remove microbial contamination, dried at 60°C for 48 h, weighed , allowed to air equilibrate for 3 h, and then weighed again. Samples were taken from the bags to determine neutral detergent insoluble nitrogen (Mass et al., 1999). Neutral detergent insoluble nitrogen, average steer BW for the grazing period, and steer ADG were used to determine animal intake and MP balance using the 1996 NRC model (Table 2). To determine UIP utilization from steers grazing the meadow, UIP digestibility's from Benton et al. (2006) were used with observed UIP values from the current study to determine the amount of UIP available.

Finishing phase for Exp. 1 and 2.

After summer grazing, steers were shipped approximately 200 km to the West Central Research and Extension Center (North Platte, NE) where they were placed in the feedlot for 153 and 154 d for Exp. 1 and 2, respectively. At feedlot entry, all calves were dewormed (Dectomax Pour On, Pfizer Animal Health, New York, NY) and vaccinated with a killed vaccine for clostridial diseases (Vision 7/Somnus with Spur, Intervet Schering-Plough, Desoto, KS) and *Hemophilus sominus* (Vision 7/Somnus with Spur, Intervet Schering-Plough). Additionally, cattle were vaccinated with a modified live vaccine for respiratory viruses (BoviShield Gold 4, Pfizer Animal Health). At feedlot entry steers were sorted and penned by treatment. All calves were finished using a common finishing diet consisting of 40% wet corn gluten feed (Sweet Bran, Cargill Inc., Blair, NE), 48% dry-rolled corn, 7% meadow hay, 5% supplement, and a minimum of 12% CP, 0.7% Ca, 0.35% P, 0.6% K, 31 mg/kg Rumensin (Elanco Animal Health, Indianapolis, IN) and 11 mg/kg Tylan (Elanco Animal Health). Steers were adapted to the final finishing diet in 21 d using 3 adaptation diets containing 37, 27, and 14% roughage, fed for 7, 7, and 7 d. Steers were implanted 30 d after feedlot arrival with Revalor-S (Intervet Schering-Plough).

Steers in both studies were slaughtered at a commercial packing plant. On the d of slaughter, carcass weight (**HCW**) was collected. After a 24-h chill, QG, KPH, fat thickness (**FT)**, and LM area were measured. Yield grade was calculated as 2.5 + 6.35 × FT (cm) + 0.0017 × HCW (kg) + 0.2 × KPH (%) − 2.06 × LM area (cm^2; Boggs and Merkel, 1993). In addition, final BW for all calves was calculated by adjusting HCW to a common dressing percentage (63%).

Statistical Analysis.

Data were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC) with animal as the experimental unit for both the summer grazing period and finishing performance. For Exp. 1, a protected F-test was included in the model statement and significance was determined when $P \leq 0.05$. Data from Exp. 2 were analyzed using linear and quadratic contrasts to determine linear and quadratic effects of supplementation level.

RESULTS AND DISCUSSION

Experiment 1.

Daily gain was not different when comparing nonsupplemented steers to supplemented steers ($P = 0.16$; Table 3). In addition, BW at the end of the grazing period was not significantly different across treatments ($P = 0.52$). When comparing feedlot performance for supplemented and nonsupplemented steers there were no differences in HCW ($P = 0.94$), QG ($P = 0.47$), YG ($P = 0.69$), or FT ($P = 0.61$). However, LM area tended ($P = 0.06$) to be greater for nonsupplemented steers during summer grazing.

When evaluating MP balance, dietary intake of forage was not actually measured therefore the 1996 NRC model was used to evaluate the amount of forage steers would have needed to consume to achieve observed ADG in the current study. Results from the 1996 NRC model predicted nonsupplemented steers consumed 7.8 kg (DM-basis) of forage daily and were 49 g/d (6.9% of the total requirement) deficient in MP. Steers supplemented DDGS consumed excess MP (281 g/d) due to supplementation and forage intake.

Experiment 2.

Steer ADG and BW at the end of the grazing period increased linearly ($P < 0.01$; Table 4) with increasing level of supplementation. Final feedlot BW was increased linearly ($P = 0.02$) with increasing level of supplementation. Interestingly, the increase in final BW observed after finishing was greater than the increase in BW observed at the end of the summer grazing period. After the grazing period, supplemented steers were 15 and 26 kg heavier for DDGS supplementation at 0.6 and 1.2% BW, respectively, compared to nonsupplemented. At the end of the finishing period, DDGS supplemented steers had final live BW that were 18 and 45 kg heavier for 0.6 and 1.2% BW, respectively, compared to nonsupplemented. These results suggest that nonsupplemented steers did not exhibit any compensatory gain during the finishing period. When comparing carcass characteristics among treatments, there were no differences in QG (P = 0.54), YG (P = 0.46), FT (P = 0.18), or LM area (P = 0.75).

Results from the 1996 NRC model predicted nonsupplemented steers consumed 9.0 kg (DM-basis) of forage daily and were 89 g/d (12.7% of the total requirement) deficient in MP when not supplemented. However, steers supplemented DDGS consumed excess MP (0.6% = 241 g/d and 1.2% = 571 g/d) due to supplementation and forage intake.

There was no response to DDGS supplementation in Exp. 1 suggesting that cattle consuming cool season meadow did not exhibit a protein deficiency while summer grazing. A greater response to DDGS supplementation was observed in Exp 2, with a linear increase in gain with increased DDGS supplementation. Comparing the two current experiments suggests that steers in Exp. 1 did not exhibit a protein response to DDGS supplementation; however, steers from Exp. 2, exhibited a combination of a protein and energy response to supplementation based on the linear response observed with increasing level of DDGS supplementation. When comparing Exp. 1 and 2, nonsupplemented cattle had similar summer ADG suggesting that steers were on a similar plane of energy and protein nutrition across years.

Forage quality from the two experiments may offer some explanation for differences observed in the current studies. When comparing nonsupplemented steers from both studies, ADG was the same in both years. However, in Exp. 1, steers consumed a diet that was 63.1% TDN and 13.0% CP compared to Exp. 2, where steers consumed a diet that was 58.7% TDN and 11.6% CP. Based on the differences in diets across studies, one would expect that steers from Exp. 2 would have had a greater response to DDGS supplementation, which was observed, but gains were similar in the control steers across experiment suggesting that steers in Exp. 2 had greater forage intake. Results from the 1996 NRC further support this because the calculated MP deficiency was minimal in nonsupplemented steers from Exp. 1 (43 g/d) however, in Exp. 2 when a greater response to DDGS supplementation was observed the MP deficiency was calculated to be 89 g/d. In addition, calculated forage intake for Exp. 2, was greater than calculated forage intake for Exp. 1. In Exp. 1 and 2, supplementation level that protein requirement is met is not obvious from data in the current studies because only one or two levels of DDGS were used, but when calculating MP balance using the 1996 NRC model, MP availability from forage, and steer protein requirements, 0.19 and 0.35 kg/d of DDGS would have met MP requirements in Exp 1, and 2, respectively.

Klopfenstein (1996) reviewed supplementation studies for growing cattle and found that UIP supplementation increased gain by meeting a MP deficiency and that increased energy from supplemental feeds increased ADG as well. The dynamics between energy and protein supplementation and the observed responses can be very difficult to differentiate as an energy or UIP response in the ruminant animal because the addition of energy can increase microbial protein synthesis. In addition, other considerations must be made when considering protein degradation within the rumen. Protein degradation rates determined from in situ degradation could be less than what is actually occurring in the animal (Broderick, 1994). This is related to the soluble fractions of feedstuffs that enter the liquid portion of rumen contents and pass from the rumen at a faster rate than particulate matter allowing for less ruminal degradation and a potential underestimation of UIP content of feedstuffs given current in situ techniques (Huhtanen et al, 2007). Given the forage quality in the current studies it is possible that MP from the forage available to the animal is underestimated because of passage of soluble protein prior to degradation.

When evaluating UIP from DDGS supplementation, MacDonald et al. (2007) reported UIP content of DDGS to meet a MP deficiency to be a major contributing factor to increased ADG. Correcting a MP deficiency accounted for up to one-third of the increase in ADG in their study. In addition, MacDonald et al. (2007) reported a 0.06 kg increase in ADG for each 0.1% of BW increase in DDGS supplementation. In Exp. 1, it was calculated that steers exhibited a considerably lower response to DDGS supplementation with 0.01 kg increase in ADG for every 0.1% of BW increase in DDGS supplementation. In Exp. 2, steers exhibited a 0.02 kg increase in ADG with each 0.1% of BW increase in DDGS supplementation. In contrast, Lomas and Moyer (2008) reported a quadratic gain response to DDGS supplementation when steers grazed cool season grasses. In their study, steers supplemented 0.5% BW of DDGS exhibited a 53% increase in ADG; however, when supplementation increased to 1.0% of BW, gain was only improved by 50% compared to nonsupplemented steers. Results from Lomas and Moyer (2008) do not show a linear response when supplementing DDGS. The response reported in Lomas and Moyer (2008) is greater than the response to DDGS supplementation in the current study and suggest an MP response to DDGS supplementation based on the quadratic response to ADG observed with increased level of supplementation. Similar to Lomas and Moyer (2008), Corrigan et al. (2007) reported a quadratic ADG response when level of DDGS supplementation was increased up to 1.0% of BW in a high forage diet. Another possible explanation for quadratic responses observed in Lomas and Moyer (2008) and Corrigan et al. (2007) is that at higher levels of DDGS supplementation, fat intake is enough inhibit fiber digestion (Hess et al., 2008). However, dietary fat may not be of concern until fat is $\geq$ 6% of the total diet DM (Doreau and Chilliard, 1997). In the current studies, fat intake from supplementation was estimated to be 2.7 to 3.7% of diet DM. In addition, fat intake from the current study is similar to fat intake for cattle used in Lomas et al. (2008) and Corrigan et al. (2007).

When comparing the current studies, steers in Exp. 1 exhibited no difference in BW after summer grazing and no difference in BW after finishing. However, when supplemented a similar level in Exp. 2 (0.6 % of BW) steers gained 15 kg more during summer grazing and were 18 kg heavier at slaughter compared to cattle that were not supplemented. Rolfe et al. (2011) reported that steers supplemented while grazing native Sandhills range had a 49% improvement in gain when supplemented modified distillers grains at a rate of 0.6% of BW daily. The increase in ADG during summer grazing resulted in a 47 kg increase in BW at feedlot entry. Rolfe et al. (2011) utilized steers that grazed 44 d longer compared to steers in the current study. When adjusted to a similar number of days grazing, steers from Rolfe et al. (2011) would have gained an additional 33 kg during the summer grazing period which is greater than Exp. 1 and 2 in which steers supplemented DDGS at a rate of 0.6% of BW were 6 and 15 kg heavier than nonsupplemented steers, respectively. Perhaps the differences observed between Rolfe et al. (2011) and the current studies can be explained in the type of forage cattle were consuming. Steers from Rolfe et al. (2011) were consuming warm season native range during the summer and steers from the current study were consuming cool season dominated meadows in which CP would be greater (Benton et al; 2006). In addition Rolfe et al. (2011) used modified distillers grains plus solubles which would be between 40 and 45 % DM compared to DDGS which is 90 % DM. However, this may not matter in growing diets and grazing programs as moisture has not been shown to have an impact on distillers grains energy values when compared to corn in forage based diets (Ahern et al., 2011; Nuttelman et al., 2008).

Morris et al. (2006) reported an increase in ADG of 16 and 33 % when steers were supplemented DDGS at a rate of 0.6 and 1.2% of BW while grazing native range. Even though forage resources were similar in Morris et al. (2006) compared to the current studies, results are consistent with the results seen in Exp. 2, in which steers exhibited a 16 and 34 % improvement in ADG with DDGS supplementation at 0.6 and 1.2 % of BW daily. However, in Exp. 1 steers did not exhibit an improvement in ADG when supplemented DDGS at a rate of 0.6 % of BW. In addition, Morris et al. (2006) reported a linear increase in ADG with increased level of supplementation, which is in agreement with results observed from Exp. 2. Morris et al. (2005) also evaluated DDGS supplementation to heifers consuming low and high quality forage and reported that heifers supplemented 0.6 and 1.2% BW and fed smooth bromegrass hay (i.e., low quality) gained 40 and 76 kg more during the 84 d feeding period respectively, compared to heifers not supplemented DDGS. In that study, when heifers consuming alfalfa hay (i.e. high quality) were supplemented DDGS at a rate of 0.6 and 1.2% BW they gained 31 and 58 kg more during the 84 d feeding period, respectively, compared to heifers not supplemented DDGS. The difference in DDGS supplementation responses observed between Morris et al. (2005) and the current studies is not explained by differences in TDN of the diets as cattle from Morris et al. (2005) consumed diets that were 55 and 65% TDN compared to Exp. 1 and 2 where TDN of the meadow averaged 63 and 59%, respectively. Watson et al. (2011) concluded that steers supplemented DDGS at a rate 0.6% of BW daily gained an additional 40 kg over a 156 d grazing period which is consistent with Greenquist et al. (2009) in which cattle gained 37 kg (35% improvement in ADG) more BW over a 160 d grazing period when supplemented DDGS at a rate of 0.6% BW. When adjusting grazing days for Watson et al. (2011) and Greenquist et al. (2009) to a 92 d grazing period which would be similar to the grazing length in the current studies, steers would have gained an additional 22 and 21 kg over the grazing period, respectively, which is similar to the DDGS supplementation response exhibited by steers in Exp. 2 supplemented at a rate of 0.6% of BW.

Funston et al. (2007) reported a 44% improvement in ADG when DDGS was fed to calves free choice, which calculated to be supplementing at 1.5% BW DDGS daily. In addition, Gustad et al. (2008) reported a 0.68 kg/d increase, a 150% improvement in ADG when growing cattle were supplemented at 1.0% BW DDGS daily. Compared to the current studies and previous work (Watson et al., 2011; Rolfe et al., 2011; Lomas and Moyer, 2008; MacDonald et al., 2007; Funston et al.; 2007; Morris et al., 2006; Morris et al., 2005) the response to DDGS supplementation observed by Gustad et al. (2008) was the greatest. The large response to DDGS supplementation observed in Gustad et al. (2008) is perhaps explained by the cattle used, which weighed 40 kg less than steers used in the current studies and suggest that cattle in Gustad et al. (2008) would have responded to increased MP and energy from DDGS supplementation.

It is important to consider the length of the grazing season and time of year that grazing is occurring. Changes in forage quality can have a large impact on ADG response to DDGS supplementation. This perhaps explains some of the greater gains from previous work with DDGS supplementation compared to the current studies. In Watson et al. (2011) TDN was 68% at the beginning of the grazing season and 53% at the conclusion of the grazing season. The change in forage quality caused the gain response from DDGS supplementation to increase from 0.2 kg/d to 0.4 kg/d as the grazing season progressed. The increase in ADG throughout the grazing season occurs due to increased protein and energy from DDGS supplementation while forage protein and energy content are declining. Most grazing studies occur during the forage growing season. During the growing season, forage quality would be the greatest (Geisert et al., 2008; Benton et al., 2006). However, some grazing studies are conducted through the forage growing season and continue well past the growing season (Rolfe et al., 2011; Watson et al.; 2011, Gustad et al., 2008; Lomas and Moyer, 2008).

Another consideration that should be made is the amount of forage that DDGS supplementation replaces. Watson et al. (2011) reported that with 2.3 kg/d of DDGS intake, supplemented steers consumed 5.8 kg/d forage compared to nonsupplemented cattle that consumed 8.6 kg/d forage. Forage intake was not measured in the current studies but perhaps offers some explanation for performance differences observed in Exp.

1 and 2. In Exp. 1, steers may have replaced forage intake with DDGS at a 1:1 ratio or greater, whereas Exp. 2, DDGS was consumed to complement forage intake. If this did occur, it would explain why the performance response to DDGS supplementation was greater in Exp. 2 compared to Exp. 1.

When evaluating subsequent feedlot performance and carcass characteristics after summer grazing there were no differences in Exp. 1. However, in Exp. 2, differences in final BW after finishing were greater than the differences observed in BW at the end of summer grazing. However, ADG, YG, and carcass quality were not affected by DDGS supplementation level during summer grazing. Watson et al. (2010), Greenquist et al. (2009), and Funston et al. (2007) concluded no difference in feedlot performance and marbling scores between calves supplemented DDGS and nonsupplemented calves. However, Greenquist et al. (2009) reported increased BW after finishing for supplemented steers; however, the difference in BW after finishing and at the end of summer grazing were similar suggesting that supplementation of DDGS during summer grazing did not affect subsequent feedlot gain. Data from the current studies, Watson et al. (2010), Greenquist et al. (2009), and Funston et al. (2007) suggest that there is no compensatory gain for nonsupplemented cattle during the finishing period. However, Lomas and Moyer (2008) reported a 0.12 kg/d increase in feedlot ADG for nonsupplemented calves compared to calves supplemented DDGS during summer grazing, suggesting that nonsupplemented calves do exhibit compensatory gain. In the largest supplementation study, Rolfe et al. (2011) used 240 steers/yr (120 steers/treatment) and followed treatments through harvest for 2 yr. From this study, Rolfe et al. (2011) reported no difference in feedlot ADG for steers that were supplemented 0.6% BW DDGS or nonsupplemented during summer grazing. Unlike the current studies, Watson et al. (2010), Greenquist et al. (2009), and Funston et al. (2007), Rolfe et al. (2011) fed supplemented steers fewer days than nonsupplemented steers and reported lower marbling scores compared to nonsupplemented steers.

IMPLICATIONS

Supplementing DDGS to steers grazing cool season forage dominated meadows increases ADG during summer grazing. In addition, the increase in BW gain with increased level of supplementation is due to increased energy in the diet since MP requirements are met at less than 0.5 kg of DDGS supplementation daily. Based on summer grazing performance, MP deficiency for nonsupplemented steers grazing cool season dominated meadows during the summer is minimal. Increased BW from summer grazing and DDGS supplementation does not appear to affect subsequent feedlot performance. Supplementing DDGS during summer grazing does not affect carcass quality; however, increased BW from DDGS supplementation during summer grazing does appear to be maintained through the finishing.

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Table 1. Nutrient analysis for cool season dominated meadow[1]

Item	Exp. 1[2]	Exp. 2[3]
TDN, %	63.1	58.7
CP, %	13.0	11.6
Undegradable protein, % of CP	11.1	10.3
NDF, %	64.6	65.8

[1]Nutrient profile for both experiments is the average of each variable for the entire grazing season.
[2]Reported nutrient value is the average of 62 samples taken over 14 weeks.
[3]Reported nutrient value is the average of 50 samples taken over 13 weeks.

Table 2. NRC inputs and MP Balance for Control Steers[1]

Item	Exp. 1	Exp. 2
1996 NRC Inputs		
Average BW[1], kg	331	320
ADG, kg/d	0.88	0.89
NE Adjusters	100	100
Results		
Forage Intake[2], kg/d	7.8	9.0
MP balance[3], g/d	-49	-89

[1]Average BW is the average of the intitial BW prior to summer grazing and the BW at the end of summer grazing.
[2]forage intake calculated using the 1996 NRC Model and animal performance from each experiment.
[3]MP balance is the metabolizable protein balance for the control steers in each experiment.

Table 3. Results from Exp.1 when steers were supplemented 0.0 or 0.6%BW DDGS during summer grazing[1].

Item	Control	Supplemented[1]	SEM	P-value
Grazing Performance				
Initial BW, kg	290	291	6	0.94
Final grazing BW, kg	372	378	6	0.52
Grazing ADG, kg/d	0.88	0.94	0.03	0.16
Feedlot Performance				
Final BW, kg	647	645	12	0.94
Feedlot ADG, kg/d	1.80	1.75	0.05	0.53
Carcass Characteristics				
Carcass weight, kg	408	407	8	0.94
Marbling score[2]	596	576	20	0.47
Calculated YG[3]	3.1	3.2	0.1	0.69
Fat thickness, cm	1.37	1.30	0.10	0.61
LM area, cm^2	91.7	88.0	1.4	0.06

[1]Calves supplemented dried distillers grains at 0.6% of initial BW.
[2]Marbling score = 500 = small^{00}, 600 = Modest^{00}, etc…
[3]Calculated YG = 2.5 + 6.35 × fat thickness (cm) + 0.0017 × carcass weight (kg) + 0.2 × KPH (%) − 2.06 × LM area (cm^2; Boggs and Merkel, 1993).

Table 4. Results from Exp.2 when steers were supplemented 0.0, 0.6, or 1.2%BW DDGS during summer grazing[1].

		Supplemented[1]			P-value	
Item	Control	0.6%	1.2%	SEM	Linear	Quadratic
Grazing Performance						
Initial BW, kg	280	283	280	9	0.93	0.67
Final grazing BW, kg	361	376	387	6	< 0.01	0.79
Grazing ADG, kg/d	0.89	1.03	1.19	0.04	< 0.01	0.85
Feedlot Performance						
Final BW, kg	646	664	691	15	0.02	0.79
Feedlot ADG, kg/d	1.85	1.87	1.97	0.07	0.19	0.60
Carcass Characteristics						
Carcass weight, kg	407	418	435	10	0.02	0.79
Marbling score[2]	655	685	667	22	0.66	0.35
Calculated YG[3]	2.7	2.9	2.9	0.2	0.32	0.58
Fat thickness, cm	1.09	1.30	1.17	0.18	0.48	0.12
LM area, cm^2	94.7	96.6	96.8	2.6	0.51	0.80

[1]Calves supplemented dried distillers grains as a % of initial BW.
[2]Marbling score = 500 = small^{00}, 600 = Modest^{00}, etc…
[3]Calculated YG = 2.5 + 6.35 × fat thickness (cm) + 0.0017 × carcass weight (kg) + 0.2 × KPH (%) − 2.06 × LM area (cm^2; Boggs and Merkel, 1993).

A Meta-Analysis Evaluation of Supplementing Dried Distillers Grains plus Solubles to Cattle Consuming Forage Based Diets[1]

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ABSTRACT

Data from twenty (13 grazing and 7 confinement) studies utilizing 790 growing steers and heifers supplemented dried distillers grains (**DDGS**) were analyzed using mixed models to determine the response to supplementing different levels of DDGS on gain and forage intake. Thirty-eight treatment means (442 cattle) were from grazing cattle managed on pasture and supplemented DDGS (range: 0.00 to 1.03% BW/d). Twenty-eight treatment means (348 cattle) were from confinement fed cattle consuming forage based diets and supplemented DDGS (range: 0.00 to 1.27% BW/d). Outcomes of interest were the effect of DDGS intake on forage intake (confinement studies), final BW, and ADG. In pasture grazing studies, final BW increased linearly ($P < 0.01$) and tended to increase quadratically ($P = 0.07$) with increasing DDGS supplementation. Daily gain increased linearly ($P < 0.01$) with increased DDGS supplementation. Results from confinement fed studies indicate that final BW ($P < 0.01$) and ADG ($P < 0.01$) increased quadratically with increasing DDGS supplementation. Intakes measured in the confinement studies suggest that increasing DDGS supplementation increases total DMI ($P < 0.01$) quadratically, even though forage intake decreases ($P < 0.01$) quadratically with increased DDGS supplementation. Results from all studies indicate that increasing DDGS supplementation increases ADG and final BW, and supplementation of DDGS replaces some forage in growing cattle consuming forage based diets.

Keywords: dried distillers grains plus solubles, forage intake, grazing, supplementation

INTRODUCTION

Increasing ethanol production has led to increased feed prices and increased finishing cost of cattle. This increase in finishing cost has caused producers to evaluate opportunities to increase cattle BW prior to feedlot entry using lower priced feed resources. Dried distillers grains plus soluble (**DDGS**) is typically priced lower than corn grain (approximately 70 to 90% the price of corn on a DM basis; USDA/AMS, 2010) and because of increased supply and competitive price of DDGS relative to corn, DDGS have become a viable resource for supplementing growing cattle consuming forage based diets. In addition forage prices have been on the rise and continue to increase (Johnson, B. and A. Raymond, 2007-2010), creating increased cost for production systems.

Dried distillers grains are a byproduct from the dry milling industry. In the dry milling process starch is removed from the grain, primarily corn, to produce ethanol, the remaining nutrients are recovered, dried and marketed as DDGS (Stock et al., 2000). Approximately two thirds of corn grain is starch, therefore, concentrations of protein, fat, fiber, and P in DDGS are increased approximately three fold when compared to corn (Klopfenstein et al., 2008). Because of increased NDF content and little to no starch, DDGS likely reduce the negative associative effects of supplementing traditional energy sources that contain starch to forage-fed cattle (Fieser and VanZant, 2004).

When DDGS was supplemented to cattle consuming low and high quality forages ADG increased (Loy et al., 2008; Morris et al., 2005). The increase in ADG is due to both metabolizable protein and energy (MacDonald et al., 2007). Growing studies comparing growing rations containing corn or DDGS showed that DDGS contains 118 to 130% the energy value of corn (Loy et al., 2008). In addition, supplementing DDGS to cattle consuming forage based diets has been shown to linearly decrease forage intake with increasing DDGS supplementation (Gustad et al., 2006; Corrigan et al., 2007; Nuttleman et al.; 2008).

Therefore, the objective of this meta-analysis was to evaluate multiple research trials to determine the effect of increasing DDGS supplementation in forage based production systems on cattle performance and forage replacement.

MATERIALS AND METHODS

Pasture studies.

Treatment means (n = 38) were compiled from 13 different studies (Table 1) in which 442 crossbred steers and heifers (279 ± 51 kg) were allowed to graze pasture and supplemented varying levels of DDGS daily (range = 0.00 to 1.03% BW/d; average = 0.39% BW/d). Amount of supplementation represented as percent of BW is the amount of DDGS supplementation (kg/d) divided by the average BW for the grazing period. In these studies, cattle were allowed to graze from late spring until early fall for an average of 117 d (range = 60 to 196 d) grazing.

These experiments consist of 2 experiments (9 treatment means) in which cattle were allowed to graze warm season species dominated pastures and 10 experiments (29 treatment means) in which cattle were allowed to graze cool season species dominated pasture. Pastures included smooth bromegrass (*Bromus inermis*) and bermudagrass (*Cynodon dactylon*) in Kansas, and smooth bromegrass, sub-irrigated meadow (species composition is slender wheatgrass [*Elymus trachycaulus* (Link) Matte], redtop bent (*Agrostis stolenifera* L.), Timothy (*Phelum pretense* L.), Kentucky bluegrass (*Poa pratensis* L.), smooth bromegrass (*Bromus inermus* Leyss.), Woolly sedge (*Carex* *lanuginose* Michx.), spike rush (*Eleocharis* spp.), white clover (*Trifolium repens* L.), alsike clover (*Trifolium hybridium* L.), red clover (*Trifolium pretense* L.), prairie cordgrass (*Spartina pectinata* L.), and big bluestem (*Andropogon gerardii* Vitman; Volesky et al., 2004), and native Sandhills range in Nebraska that would be characterized as dominated by little bluestem [*Andropogon scoparius* (Michx.) Nash], prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.], sand bluestem (*Andropogon hallii* Hack.), sand lovegrass [*Eragrostis trichoides* (Nutt.) Wood], and blue grama [*Bouteloua gracillis* (H.K.B.) Lag. Ex Griffiths] (Adams et al., 1998).

Within each pasture grazing experiment, cattle were stratified by initial BW and assigned randomly to supplementation treatment. Additionally, within experiment, cattle in each treatment were allowed to graze the same number of days. Three hundred fifty-six of the 442 cattle used in this study were finished in the feedlot to determine carry-over effects of supplemental DDGS on final BW of the cattle at harvest.

Confinement studies.

Treatment means (n = 28) were compiled from 7 different studies (Table 2) in which 348 crossbred steers and heifers (265 ± 20 kg) were fed high forage diets and supplemented DDGS in a confined feeding environment. In the confinement studies, the forage diet was either hay or a mixture of hay with either sorghum silage or haylage to simulate nutrient composition of lush pasture. In this data set, 220 cattle (26 treatment means) were individually fed a high forage diet and supplemented DDGS using a Calan gate system and 128 cattle (2 treatment means) were fed a high forage growing diet and housed in open feedlot pens. Level of supplementation ranged from 0.00 to 1.27% BW (average = 0.56% BW).

Cattle were on experiment for an average of 86 d (range = 82 to 95 d). Within each experiment, cattle were stratified by initial BW and assigned randomly to supplementation treatment. Additionally, within experiment, cattle in each treatment were fed the same number of days. Amount of supplementation represented as percent of BW is the amount of DDGS supplementation (kg/d) divided by the average BW for the trial duration. Because cattle were confinement fed, intake could be accurately measured allowing for determination of forage replacement within each DDGS supplementation level. Additionally, the amount of forage replaced per additional increment of DDGS supplementation was calculated by subtracting the amount of forage intake from supplemented cattle from forage intake of the control cattle and dividing the difference by DDGS supplementation amount.

Statistical Analysis.

Treatment means from confinement and pasture studies were analyzed separately using an iterative meta-analysis methodology that integrated quantitative findings from multiple studies using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). This type of analysis is designed to account for the fixed and random effects of each individual study (St-Pierre, 2001). Treatment means were the experimental unit. Studies were weighted by number of DDGS levels to prevent artificial linear responses from studies with 0 and one other level of supplementation. Biological performance equations were developed based on significant model variables. Variables tested include ADG and ending BW for pasture studies and ADG, ending BW, total intake, and forage intake for confinement studies. In the studies analyzed, warm season and cool season grasses were used for grazing resources in pasture studies and different forage mixes were used to simulate grazed forage in the confinement studies. Means for different forage types were not separated and analyzed separately because of changes in forage quality over time of the different forage resources utilized in pasture studies resulting with similar TDN and CP over the entire grazing season for warm season and cool season forages (Benton et al., 2006). In the confinement studies, forage quality was similar relative to TDN and CP since we were trying to simulate lush grazed forage. Equations developed allowed for evaluation of individual animal performance if fed certain levels of DDGS in grazing systems.

RESULTS AND DISCUSSION

Pasture Studies.

Effect of DDGS supplementation on ending BW and ADG are presented in Table 3. For gain and ending BW performance, supplemented DDGS is represented as % of BW because of differences in BW across pasture and confinement fed studies. Supplementing DDGS to cattle grazing pasture linearly increased ending BW ($P < 0.01$) and ADG ($P < 0.01$) with increased supplementation. Ending BW after the grazing period tended to be quadratic ($P = 0.07$). However, ADG response was not statistically quadratic ($P = 0.21$; Figure 1).

Confinement Studies.

Supplementing DDGS in growing rations and hay fed situations quadratically (P < 0.01) increased ending BW and ADG (Table 3; Figure 1) as DDGS supplementation increased. Total intake response to increasing levels of DDGS supplementation was quadratic ($P < 0.01$; Table 4). However, as DDGS supplementation increased, forage intake decreased quadratically (*P* < 0.01; Figure 2). Additionally, forage replacement per kg of DDGS supplementation increased as DDGS supplementation increased.

Ending BW and ADG exhibited a significant linear response in the pasture studies; however, in the confinement fed studies, ending BW and ADG were quadratically impacted by DDGS level. This difference in pasture and confinement fed studies is likely due to higher variation in the pasture studies when compared to the confinement fed studies. In the confinement fed studies, feeding conditions are more tightly controlled. We conclude performance response in the pasture studies are in fact quadratic; however, due to the increased variation we were only able to detect a linear response in the pasture studies.

There were large differences in the response to DDGS supplementation when comparing the studies used in this analysis. Although performance from each individual study is not the topic of this analysis, it is important to understand the range of responses from the experiments used for this analysis. In Griffin et al. (2011.), cattle supplemented DDGS at 0.6% BW did not exhibit a statistical improvement in ADG, but ADG was 7% numerically greater with DDGS supplementation; however, Gustad et al. (2008) reported ADG that were 150% greater than controls when cattle were supplemented DDGS at 1.0% BW. The response to DDGS supplementation in Gustad et al. (2008) was the greatest response to DDGS across the studies used in this analysis. Lomas and Moyer (2008) used the lightest cattle (215 kg) and MacDonald et al. (2006) used the heaviest cattle (366 kg). However, this analysis does not account for differences in performance based on animal BW.

Dried distillers grains plus solubles offer an ideal combination of energy (fat) and protein. When studies have evaluated nutrient profile for distillers grains across plants and days within plant, CP ranged from 28.1 to 34.0%, and fat ranged from 8.2 to 13.3% (DM basis; Spiehs et al., 2002; Buckner et al., 2011). In addition, the undegradable intake protein (UIP) content of DDGS is between 15 to 20% on a DM-basis (MacDonald et al., 2007), making it an excellent source of protein for growing calves. Klopfenstein (1996) reviewed supplementation studies for growing cattle and found that UIP supplementation increased gain by meeting a metabolizable protein deficiency and that increased energy from supplemental feeds increased ADG as well. The dynamics between energy and protein supplementation and the observed responses can be very difficult to differentiate as an energy or protein response in the ruminant animal because the addition of energy can increase microbial protein synthesis.

When considering the level of DDGS supplementation in forage based systems, fat intake must be considered. At higher levels of fat intake, fiber digestion can be inhibited (Hess et al., 2008). Doreau and Chilliard (1997) determined that $\geq$ 6% dietary fat to be the threshold at which performance declined in forage based diets. Using the intakes reported from the confinement studies and assuming forage to contain 1.25% fat on a DM-basis (MacDonald et al., 2007) and DDGS to contain 12.5% fat on a DM-basis (Spiehs et al., 2002; Buckner et al., 2011), 6% dietary fat would be achieved when intake of DDGS reached 3.4 kg/d (1.2% BW) and forage intake was 4.1 kg/d. Overfeeding protein should not have a negative effect on forage digestion in the ruminant, but could have a positive impact on grazing lands. In grazing systems, overfeeding CP and subsequent urinary excretion of nitrogen by cattle can improve soil nitrogen levels and forage production within forage growing systems (Greenquist et al., 2009; Watson et al., 2011).

When comparing ADG across pasture and confinement studies, confinement studies had a greater response to DDGS supplementation than pasture studies. The greater response may be due to differences in metabolizable protein requirements for the cattle (1996 NRC). MacDonald et al. (2007) reported that increased protein and energy were the reasons for increased ADG and that up to one-third of the gain response to DDGS supplementation is due to meeting a protein deficiency. In the confinement studies, cattle were lighter and younger at trial initiation leading to greater requirement for MP in terms of grams of MP required per kg of BW. Another consideration is that energy response for lighter animals is greater per kg of BW when compared to heavier cattle. Therefore, BW of cattle is a major consideration when trying to determine how DDGS supplementation will affect cattle performance.

Because the ADG response was greater for confinement fed than grazing cattle, forage replacement could have been greater in pasture fed animals than confinement fed calves. Since DDGS supplementation was the same amount, this leaves the forage intake as the variable input. Forage quality was similar in the pasture and confinement studies summarized here; therefore, the amount of forage replaced would be a logical explanation for the increased ADG response in the confinement studies compared to the pasture studies. Watson et al. (2011) reported that steers grazing smooth brome grass pastures replaced 0.79 kg of forage for every kg of DDGS intake. MacDonald et al. (2007) measured forage intake using chromic oxide as a marker and reported that 0.50 kg of forage were replaced with each kg of DDGS supplementation. In the confinement studies used in this analysis, replacement (kg/kg basis) increased with increasing level of DDGS supplementation. However, in the confinement studies when calves were supplemented 3.4 kg daily, only 0.48 kg of forage was replaced per kg of DDGS supplementation. In pasture studies reported by Watson et al. (2011) and MacDonald et al. (2007), cattle were supplemented 2.3 kg/d and replaced 0.73 and 1.03 kg of forage per kg of DDGS supplementation, respectively, compared to confinement studies reported in the current study.

In the studies used for this analysis, subsequent finishing performance was collected on cattle from 10 of the grazing trials. On average, the supplemented cattle gained 37 kg more weight on grass than non-supplemented controls. The supplemented cattle were 31 kg heavier than control cattle at slaughter indicating greater than 84% of the weight was maintained. In 6 of the 10 studies, DMI was measured in the feedlot. In general, DMI was not increased for cattle that had been fed DDGS on grass. In addition, carcass characteristics other than HCW were not consistently affected by supplementation of DDGS during the growing period.

IMPLICATIONS

Supplementing DDGS in forage based production systems increased final BW and ADG quadratically for cattle in forage based production systems. Additionally, feeding DDGS decreased forage intake quadratically with increasing level of DDGS supplementation. However; total intake for cattle supplemented DDGS increased quadratically with increased level of supplementation. Finished weight of cattle was increased by supplementing DDGS during the growing phases whether on pasture or in confinement without affecting carcass quality.

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Table 1. Pasture studies used for analysis.

Reference	State	Yrs	Grass[1]	DDGS[2]
MacDonald et al., 2004	NE	1	CS	0.58
Morris et al., 2006	NE	1	WS	1.03
MacDonald et al., 2007	NE	1	CS	0.57
Gustad et al., 2008	NE	2	WS	0.83
Lomas and Moyer et al., 2008	KS	3	CS-WS	1.00
Greenquist et al., 2009	NE	3	CS	0.62
Griffin et al., 2011	NE	2	CSM	1.20

[1]Grass is the type of grass that cattle were allowed to graze in each study. CS = cool season monoculture, WS = warm season, CSM = cool season mix.
[2]DDGS = upper level of dried distillers grains used in each study represented as % BW.

Table 2. Confinement studies used in analysis.

Reference	Forage[1]	DDGS[2]
Morris et al., 2005	Brome	0.84
Gustad et al., 2006	Mix	1.27
Buckner et al., 2007	Mix	0.76
Corrigan et al., 2007	Mix	1.00
Loy et al., 2008	Mix	0.81
Nuttelman et al., 2008	Mix	1.00

[1]Forage = Brome = bromegrass hay; Mix = combination of sorghum silage and alfalfa to simulate grass cattle consume while grazing.
[2]DDGS = upper level of dried distillers grains used in each study represented as % BW

Table 3. The effect of supplementation level on final BW and ADG.

DDGS supplementation[1]:	0.0	0.2	0.4	0.6	0.8	1.0	1.2	L[2]	Q[2]
Pasture Studies (35 means)									
Final BW, kg	376	390	402	409	413	413	409	< 0.01	0.07
ADG, kg	0.67	0.78	0.86	0.93	0.89	1.01	1.03	< 0.01	0.21
Confinement Studies (28 means)									
Final BW, kg	311	327	340	351	359	365	369	< 0.01	< 0.01
ADG, kg	0.54	0.73	0.88	1.00	1.08	1.13	1.14	< 0.01	< 0.01

[1]DDGS supplementation = supplementation as % BW.
[2]Estimation equation linear and quadratic term t-statistic for variable of interest.

Table 4. Effect of supplemental level of dried distillers grains plus solubles (DDGS) on intake of growing cattle in confinement studies.

DDGS supplementaion[1]:	0.0	0.7	1.4	2.0	2.7	3.4	L[2]	Q[2]
Total Intake, kg/d	5.8	6.3	6.8	7.1	7.4	7.5	< 0.01	< 0.01
Forage Intake, kg/d	5.8	5.6	5.4	5.1	4.7	4.1	0.31	< 0.01
Forage replacement[3], kg/d	0.0	0.2	0.4	0.7	1.1	1.7	---	---
Forage replaced/DDGS[4], kg/kg	0.00	0.20	0.27	0.33	0.40	0.48	---	---

[1]Supplemented level of DDGS (DM-basis) in kg/hd daily.
[2]Estimation equation linear and quadratic term t-statistic for variable of interest.
[3]Forage replacement calculated using forage intake at 0.0 kg/d supplementation and subtracting forage intake value for respective level of supplementation.
[4]The amount of forage replaced per kg of DDGS supplemented.

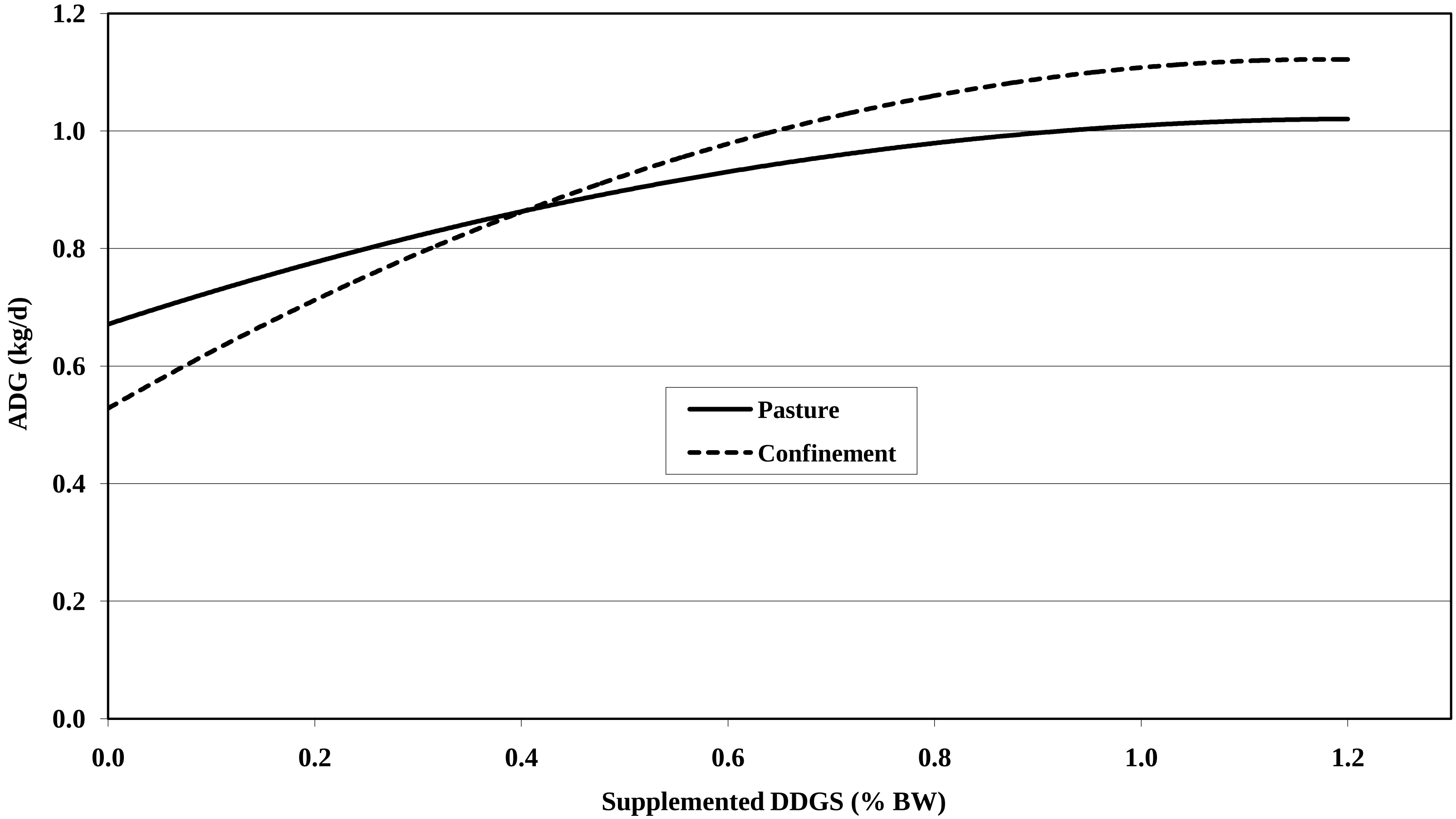

Figure 1. Effect of dried distillers grains plus solubles (**DDGS**) supplementation on ADG for growing cattle supplemented DDGS. Pasture ADG = $0.6712 + 0.5732x - 0.2351x^2$ (Linear < 0.01; Quadratic = 0.21). Confinement ADG = $0.5289 + 0.9966x - 0.4152x^2$ (Linear < 0.01; Quadratic < 0.01).

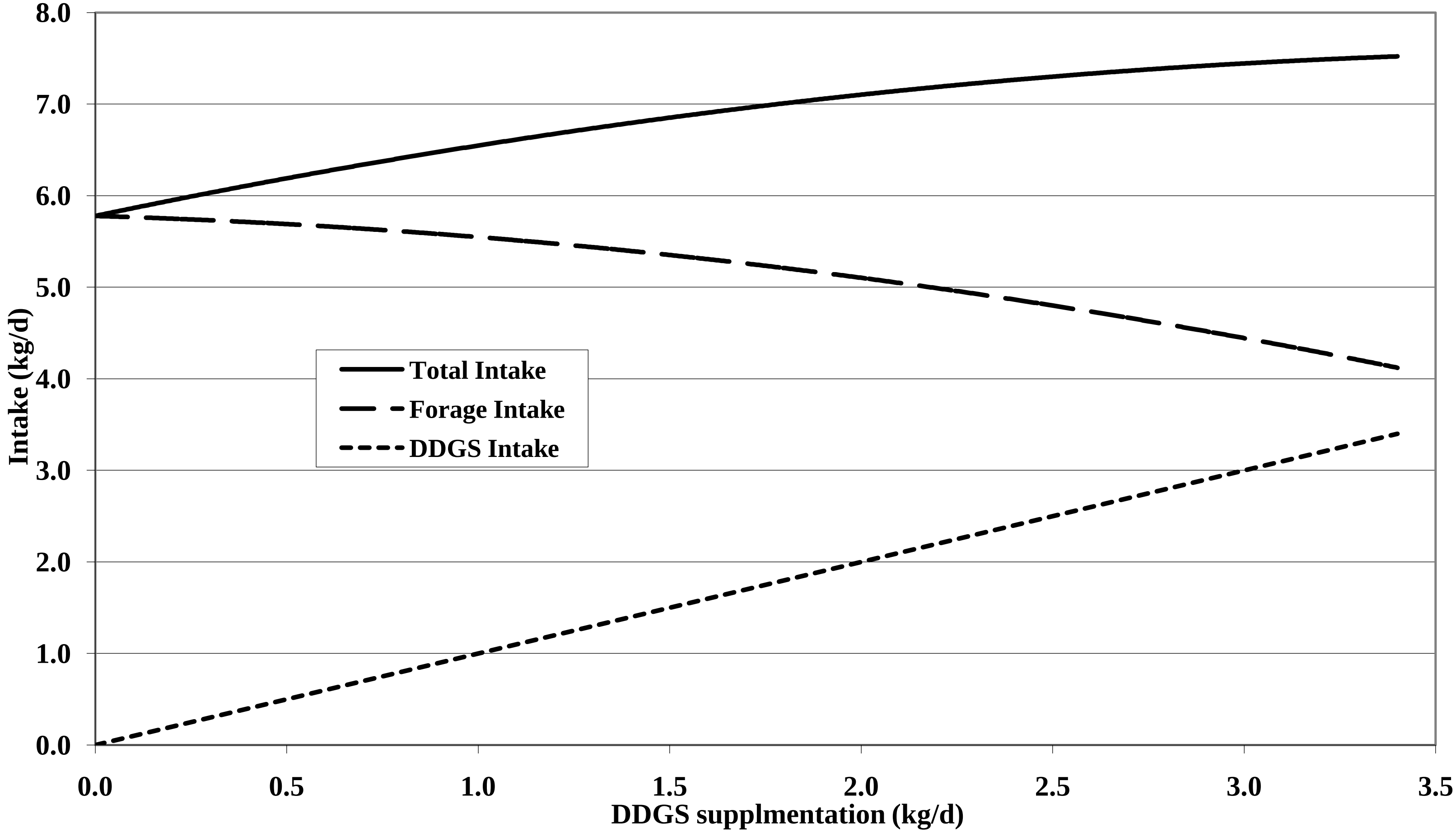

Figure 2. Effect of dried distillers grains plus solubles (**DDGS**) supplementation on intake for cattle fed in confinement studies. DDG Supplementation = x. Forage intake = 5.7781 -0.1238x – 0.1069x^2 (Linear = 0.31; Quadratic < 0.01). Total Intake = 5.7781 + 0.8762x – 0.1069x^2 (Linear < 0.01; Quadratic < 0.01).