

EFFECTS OF SUPPLEMENTING DRIED DISTILLERS GRAINS WITH SOLUBLES TO
YEARLING STOCKER CATTLE DURING THE LAST 90 DAYS OF GRAZING ON
ANIMAL PERFORMANCE, CARCASS CHARACTERISTICS AND MEAT QUALITY
WHEN UTILIZING A SHORT FEEDING PROTOCOL

by

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Abstract

Crossbred yearling steers ($n = 144$ initial BW 367 ± 18.46 kg) were randomly allotted by BW to a randomized complete block design with a 2x3 factorial treatment arrangement to 1) assess the impact of supplementing dried distiller grain with solubles (DDGS) while grazing late season forage for 90 d and 2) the impact of a short feeding period on animal performance, carcass characteristics and meat quality traits. Treatments consisted of DDGS supplementation during grazing (0 or 1% of BW as DDGS; DM basis) and finishing days on feed (DOF; 75, 100, 125). During grazing supplemented cattle had greater ($P < 0.01$) ADG than un-supplemented cattle but un-supplemented cattle had greater ADG than supplemented cattle during the finishing period. There were no differences between grazing treatments for DMI ($P = 0.91$) during the finishing period. Supplemented cattle had decreased ($P = 0.02$) G:F during the finishing period compared to un-supplemented cattle. Supplemented cattle had heavier ($P < 0.01$) HCW and larger ($P = 0.02$) LM area than un-supplemented cattle. Increasing DOF linearly increased ($P \leq 0.03$) HCW, 12th rib fat thickness, LM area and USDA marbling score. No differences were observed for USDA yield grade. Increasing DOF decreased (Linear; $P < 0.01$) carcass protein %, moisture %, and increased (Linear; $P < 0.05$) carcass fat %. Increasing DOF increased (Quadratic; $P = 0.01$) L* values, while decreasing (Quadratic; $P < 0.01$) a* and b* values for external fat color. No differences were observed with respect to the percentages of any fatty acids for any treatment. Increased ($P = 0.01$) sensory off-flavors were present at 100 DOF when compared to 125 DOF. No other differences among treatments were observed for any sensory traits, instrumental tenderness, lean color or fatty acid profile for any treatment. In conclusion, supplementing cattle with 1 % DDGS during grazing altered grazing and feedlot performance as well as impacted carcass characteristics. In addition, utilizing a shortened feeding period had minimal effects on meat quality traits, but increasing DOF resulted in a greater amount of whiter external fat.

Key Words: beef, days on feed, dried distiller's grains with solubles, fat color, grazing

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Dedication

I dedicate this thesis to my parents Dale and Mary Elyse Stickel and to my Grandma Stickel. Without your love and support I never would have made it.

Chapter 1 - Review of Literature

Different management strategies are employed by beef producers throughout the United States. While no one management strategy is ideal for every producer, the efficient production of a safe, wholesome, consistent product for human consumption is held as a common goal. Different from other industries such as pork and poultry, the beef industry has a minimal amount of vertical integration. A highly segmented beef industry allows for producers to manage different biological types of cattle, use available feedstuffs as well as have the opportunity to add value to the cattle they raise. This literature review will focus on how managing rate of growth (grazing vs. concentrate feeding) prior to entering the feedlot phase of beef production affects performance and carcass characteristics. Cattle in the United States are typically brought to market weight by being fed a high-concentrate diet, targeting a fast growth rate for a period of time before they are harvested (Coleman et al. 1993). The length of time cattle are finished is dependent on the biological type of cattle (Block et al., 2001), frame size (Dolezal et al., 1993), rate of growth (Griffin et al., 2007), and the type of marketing program the producer is targeting (Block et al., 2001). Lewis et al. (1990) stated that the most efficient cost of gain occurs while cattle are grazing forage. The use of available forage for grazing throughout states such as Kansas and Oklahoma allows producers to grow cattle on grass at a moderate rate of gain. This practice is known as backgrounding. Backgrounding is described as the period between weaning and finishing. This time period can be useful in preparing cattle for finishing by increasing BW and improving uniformity. A backgrounding program usually targets a modest rate of growth and allows cattle to mature without depositing fat (Block et al. (2001).

In a study done by Vaage et al. (1998) 120 crossbred steers were used to evaluate the effects of a high-concentrate diet for the entire finishing period versus the effects of a prolonged backgrounding period followed by a high-concentrate finishing period on performance and carcass characteristics. Cattle were slaughtered at 8 mm of backfat. High concentrate cattle reached 8 mm faster but had lighter hot carcass weights. No differences were recorded for finishing performance.

Griffin et al. (2007) used a meta-analysis to compare a calf-fed production system vs. a long-yearling finishing system. These studies occurred from 1996 to 2004. The meta-analysis

included 80 pens of calf-fed cattle and 18 pens of long yearlings totaling over 1,100 head. Long-yearling steers had heavier hot carcass weights and leaner carcasses but no differences occurred in marbling score. Long yearling cattle used in the analyzed studies tended to have greater ADG during the finishing period in addition to consuming less feed over the entire finishing period. Long yearlings were finished for an average of 90 d while calf-fed cattle were finished for 168 d. Yearling cattle in this analysis consumed less high-concentrate feed during the finishing period. An economic assessment was included in this meta-analysis. Yearling steers were found to be more profitable due to the increased weight gain during the entire production system.

Compensatory growth is the period of accelerated gain that occurs after an animal experiences a nutritional deficiency (Bohman, 1955). Compensatory gain occurs frequently during backgrounding as compared to calf-fed production systems. Following a period of nutrient restriction, cattle experience an unusually strong increase in intake and ADG. Cattle buyers may target cattle that have been fed for a moderate rate of growth, knowing that they will outperform cattle that were previously on a higher plain of nutrition. Compensatory gain can allow previously restricted cattle to rapidly equalize BW compared with cattle without a history of restriction (Sainz et al. 2007). Compensatory gain allows for the backgrounding industry to grow cattle cost-effectively without sacrificing performance during the finishing period. In summary, the backgrounding industry plays a key role in beef production in the United States.

Dried Distillers Grains

The commitment of the United States to the ethanol and renewable fuels movement has substantially increased the amount of ethanol produced annually. The Renewable Fuels Association (RFA) industry statistics indicate significant increases in year-on-year ethanol production (Figure 1.1). The numbers of ethanol producers have increased recently as well. Increased ethanol production has allowed the beef industry to have greater access to a feedstuff known as distiller's grains. Distiller's grains are a by-product of the dry corn milling process. Dry milling has the objective of removing the starch portion of the corn kernel for fermentation to ethanol. The fibrous portion of the corn kernel, through further processing, can be marketed as wet distiller's grain (WGS) or dried distiller's grain (DDG). In addition, another by-product of the dry corn milling process called thin stillage is captured and condensed to a product called condensed distiller's solubles (CDS). It can be combined with WDG and dried to form a product

called dried distiller's grains with solubles (DDGS). The products known as WDG, DDG, and DDGS retain much of the nutritional value of corn (Stock et al., 2000); WGS and DDGS are around 29% protein, 9% fat and 4% fiber on a DM basis with moisture contents of 60-75% and 10 to 13%, respectively (Distillers Grains Technology Council, 2007).

Distiller's grains (WDG and DDGS) are a valuable, readily-available feed ingredient for the United States beef industry. A meta-analysis done by Klopfenstein et al. (2008) indicated that WDG and DDGS could be included in finishing diets to improve efficiency and ADG. Using the predicted meta-analysis values, DDGS fed at different levels had no lower than 100% of the feeding value of corn.

With DDGS having 3 times the protein content of corn, it could be useful as a supplemental protein source for forage-fed cattle. The drying process associated with DDGS production is known to reduce ruminal protein availability. According to the Dried Distillers Technology Council, roughly 55% of the CP in DDGS is resistant to ruminal protein degradation. Similarly, MacDonald et al. (2007) indicated that 50% of CP available in DDGS was ruminally unavailable. Spiels et al. (2002) sampled DDGS from South Dakota and Minnesota plants that were less than 5 y old over a 3-y period (1997 to 1998). They compared the proximate analysis of the samples obtained from plants less than 5 y old to values published by NRC (1996). Dry matter tended to be slightly lower (88.9 vs. 92.0), while CP (30.2 vs. 29.1), crude fat percent (10.9 vs. 8.8), NDF (42.1 vs. 37.2), and calculated energy values were slightly higher for DDGS produced by new ethanol plants compared to ethanol plants greater than 5 y of age. Improvements in the dry milling process may have allowed for increased protein and energy nutrient values of DDGS.

DDGS Supplementation

Roughly 40% of distiller's grains (WDG and DDGS) produced annually in the United States are used in beef production (Wisner, 2012). One avenue in which beef producers use DDGS is as a supplement for grazing cattle.

Morris et al. (2005) evaluated the use of DDGS on ninety heifers. Heifers were stratified by weight and assigned to 1 of 10 treatments. Cattle were assigned to consume brome hay or alfalfa hay and sorghum silage. The brome hay was used to simulate low-quality forage and the alfalfa hay to simulate high-quality forage. Heifers were fed for 84 d with 5 levels of DDGS: 0,

0.45, 0.68, 1.3, 2.0, 2.3 or 2.7 kg/heifer on a dry matter basis. Heifers consuming the high-quality forage had greater ($P < 0.001$) ADG than those consuming the low-quality diet regardless of DDGS supplementation level; however, the response to supplementation favored those cattle consuming the low-quality diet. A substitution effect was observed as DDGS level increased. Supplemented cattle consumed less forage than control cattle. A linear decrease in total dry matter consumed was observed as feeding level of DDGS increased.

Morris et al. (2006) reported results from supplementing DDGS at various levels (0, 0.26, 0.51, 0.77, and 1.03 % BW) to 56 yearling steers grazing summer pasture for 88 d. Supplemented cattle had greater ADG compared with cattle receiving no supplementation. In addition, a linear increase in ADG was reported with increasing amounts of DDGS. In contrast, the growth response to supplementation diminished as amount of DDGS increased. Morris et al. (2005) predicted forage dry matter intake would decrease linearly as amount of DDGS increased. In addition to summer grazing performance, feedlot performance was also measured. Control cattle were 18.14 kg lighter than the closest supplemented group. The additional gain from supplementing cattle on grass was maintained throughout the finishing period. Supplemented cattle did not manifest decreased feed efficiency or performance.

Gustad et al. (2006) conducted a study grazing study involving steers on corn-stalk residue. Feeding levels of DDGS were: 0.29, 0.49, 0.69, 0.88, 1.08 and 1.27 %BW. A quadratic response in ADG was noted as DDGS supplementation increased. This research suggested that targeting a specific ADG may be warranted when feeding DDGS to grazing cattle. In agreement with the two previous studies (Morris et al. 2005 and 2006), forage intake decreased as supplementation level increased.

Substitution effects attributed to DDGS supplementation may allow for increased stocking rate while grazing. Gustad et al. (2008) evaluated the effects of DDGS when stocking density was above recommended rates. The treatment structure included an un-supplemented control at 1 times the recommended stocking rate, 2 times the recommended stocking rate with no supplementation, and a DDGS-supplemented group stocked at 2 times the recommended stocking rate. Control cattle had the least forage utilization throughout the grazing period (June to August). Among treatments stocked at 2 times the recommended rates un-supplemented and supplemented cattle did not differ in average forage utilization. Supplementing with DDGS did

not allow a doubling of stocking rate; however, DDGS supplementation promoted increased ADG compared to both non-supplemented treatments.

Lomas and Moyer (2011) conducted a study to evaluate the effect of supplementing DDGS on grazing performance, subsequent feedlot performance, and carcass characteristics. Steers were assigned to 3 treatments: control (no supplementation), supplementation with 0.5% BW DDGS, and supplementation with 1.0% BW DDGS. Cattle were supplemented daily for 196 d; feeding levels were adjusted every 28 d. Cattle were shipped to a finishing yard and fed for 126 d. Cattle supplemented while grazing had increased ADG during grazing; moreover, cattle supplemented at 1% BW had greater ADG than cattle at 0.5% BW. The increased ADG resulted in heavier cattle sent to the feed yard. This additional weight gain achieved on pasture resulted in greater BW pre-harvest and greater carcass weight. No differences in carcass merit were observed between treatments. Un-supplemented cattle were more efficient during the finishing period compared with cattle supplemented at 1% BW. Average daily gains were similar between treatments.

Epp et al. (2007) supplemented stocker cattle grazing native range with 4 different levels of DDGS (0, 0.25, 0.5%, and 0.75% BW). Performance on grass, performance in the feedlot, and carcass merit were similar to research discussed previously.

Griffin et al. (2010) documented the effects of supplementation of DDGS on grazing performance, feedlot performance, and carcass characteristics. In experiment 1, steers were assigned to 1 of 2 treatments: no DDGS supplement or DDGS supplement at 0.6% BW. Supplemented cattle had slightly greater gain over 92 d. Feedlot performance indicated no differences between control or supplemented cattle. In experiment 2, steers were assigned to 1 of 3 treatments (0 DDGS, 0.6% BW DDGS, 1.2% BW DDGS) while grazing. Supplemented treatments exhibited greater ADG than un-supplemented treatment. A linear increase in ADG occurred as supplemented DDGS levels increased. Cattle supplemented during grazing entered the feedlot at higher BW and had greater finishing ADG than un-supplemented cattle. Increased performance resulted in heavier carcasses at harvest. These results do not agree with others (Lomas and Moyer, 2011; Epp et al., 2007). Lomas and Moyer, (2011) and Epp et al. (2007) found that cattle supplemented with DDGS while grazing had decreased performance in the feedlot. In addition, Buttrey et al. (2012) found that in a 2-y experiment where Hereford steers grazed wheat pasture, no significant performance differences occurred between DDGS-

supplemented cattle and non-supplemented cattle during the grazing or finishing periods. Furthermore, no treatment differences were detected in any carcass characteristics, in fatty acid content of meat, or in total carcass weight.

On balance, supplemental DDGS for cattle grazing summer pasture seems to improve ADG. While only one of the previously reviewed studies (Gustad et al, 2006) evaluated supplementing DDGS while grazing low-quality forage (corn stalk residue), increased performance was also noted. Protein and energy requirements are different between cattle grazing medium- to high-quality forages and those consuming mature, low-quality forages. Little research has specifically targeted the use of DDGS with growing cattle consuming low-quality forage.

Grazing and Forage Quality

Kansas has an abundant supply of native forage that is an integral part of the beef industry of the state. While producers may graze year round, the greatest nutritional values of native forage occurs while plants are in the vegetative stage of growth. Rao et al. (1973) documented the effects of seasonal changes in nutritive value of pasture forage in the Kansas Flint Hills. This study used both esophageally-fistulated steers and intact steers to measure nutritional value of forage and animal performance from May 1 to October 1. Forage samples were collected using both fistulated steers and via hand clipping. Cattle performance decreased from May to October. Both fistulated and intact steers had the least BW gains during the month of September, while the greatest BW gains were seen during the month of June. This decrease in performance was related to the decrease in nutritional value over the grazing period. Both forage-collection methods documented decreased OM and DM digestibility. In addition, there was a significant reduction in forage CP from May to October. As these forages matured, lignin content, NDF and ADF all increased, thus reducing forage digestibility. Decreased digestibility has a direct effect on energy availability (Buxton and Redfearn, 1997). A reduction in energy availability and a reduction in microbial protein synthesis render low-quality forage less useful to ruminants, especially those with significant protein requirements (i.e., those in the growing phase). One way in which to offset decreased digestibility and lower protein values in low-quality forages is to provide animals with supplemental protein. Supplementing protein increases

forage intake and digestion and may also extend the grazing season for producers who want to target certain marketing opportunities.

Supplemental Protein

Many studies have documented the importance of protein in cattle diets. Protein requirements vary with age, growth stage, and production system. There are two main components of CP in ruminant diets: ruminally-degradable protein (RDP) or ruminally-undegradable protein (RUP). Ruminally-degradable protein is considered to be the percentage of dietary CP that is susceptible to microbial degradation, whereas RUP is resistant to microbial degradation and is instead digested in the abomasum and duodenum. Koster et al. (1996) and Olson et al. (1999) reported that RDP was the first-limiting nutrient in low-quality forage diets (< 7% CP) fed to beef cattle. With decreased digestibility and the reduction of RDP in low quality forages, supplementing with an RDP source improves the utilization of low-quality forages. Olson et al. (1999) evaluated the effects of 4 levels of supplemental RDP and 2 levels of starch on DM intake and total-tract diet digestion by beef cattle consuming a low-quality forage (4.9% CP, 44% ADF). They observed a linear increase in DM intake and total-tract DM digestion as supplemental RDP increased.

Mathis et al. (2000) evaluated the use of supplemental RDP on intake and digestibility of 3 different forages: bermudagrass (8.2% CP), bromegrass (5.9% CP), and forage sorghum (4.3% CP). Three independent studies evaluating each of the aforementioned forages were completed using 16 ruminally-fistulated steers. Steers were randomly assigned to 1 of 4 treatments including no supplemental protein or RDP fed at 0.041%, 0.082%, and 0.124% of BW. Sodium caseinate, a protein source that is completely ruminally-degradable was used as the RDP supplement. Mathis et al. (2000) reported that RDP had no effect on intake and total digestion of bermudagrass. This research confirmed the general assumption that forages above 7% CP do not respond favorably to supplemental protein (Paterson et al., 1994). When evaluating 2 forage sources, (bromegrass and sorghum forage) under that threshold, supplemental RDP increased both intake and digestion. Total-tract OM digestion of the bromegrass diet increased linearly as supplemental RDP increased; moreover, cattle consuming forage sorghum forage showed a linear improvement in both intake and OM digestion in response to RDP supplementation.

Bandyk et al. (2001) researched the effects of supplemental sodium caseinate infused ruminally or post-ruminally in steers consuming low-quality forage. This study used 12 fistulated steers with 3 treatments (Control, ruminally-infused sodium caseinate or post-ruminally infused sodium caseinate). Tallgrass prairie hay (3.4% crude protein, 49.5% ADF) was used as the forage source. Control steers showed no improvement in intake or digestion. Ruminally-infused sodium caseinate stimulated an immediate increase in forage intake and total-tract OM digestion. Conversely, post-ruminally infused sodium caseinate caused a much slower response in intake and digestion. No difference in intake was noted between non-infused and post-ruminally infused steers for the first 4 d of the trial; however, by d 14 the post-ruminally infused steers had reached a level of DM intake that was intermediate between ruminally-infused steers and control steers. Post-ruminally infused protein (i.e., 100% RUP) may contribute to ruminally-available nitrogen through urea recycling.

Research supplementing DDGS to cattle fed high-quality forage is relatively common, whereas little work has been done when DDGS is supplemented to growing cattle consuming low-quality forage. The usefulness of DDGS as an RDP source is unclear at this point and needs to be investigated further. In summary, supplemental RDP is usually the first-limiting nutrient while ruminants are grazing low-quality forages. The improvement in intake and digestibility of low-quality forages that can be stimulated with supplemental RDP allows ruminants to efficiently use them. Utilization of low-quality pasture forages not harvested during summer months in conjunction with protein supplementation is a viable way for beef producers to capture value

Effects of Time on Feed

Performance and Carcass Characteristics

Much research has been done to target the optimum number of days cattle should be finished in the feedyard. The concept of feeding all types of cattle to one specific fatness, weight or total number of days on feed has proved difficult to define. With many different biological types, production systems, available feedstuffs and marketing programs the cattle feeding industry may utilize a combination of different production practices and marketing indicators. The following studies will discuss data looking at how the number of day's cattle are finished affects cattle performance, carcass characteristics, and meat quality. With increased focus on

consumer demands and tight cattle feeding margins, feeding cattle to the appropriate fat thickness, quality grade and final BW could reduce the number of undesirable carcasses and improve cattle feeding margins. To complicate this issue, the primary grain used by consulting nutritionists in diet formulation was corn (Vasconcelos and Gaylean. 2007), making the number of days cattle are fed even more relevant. Corn prices have increased (Figure 1.2) substantially over the last 10 years.

When reviewing the data, May et al. (1992) used 48 crossbred steers to evaluate the relationship between days fed, carcass weight, subcutaneous fat, marbling score and beef palatability. These 48 steers were selected based on weight, age and frame size. Steers were assigned to one of eight treatments based on live bodyweight. Treatments included serial slaughter day intervals of 28 d. Cattle were slaughtered beginning at 28 d on feed until the final slaughter day of 196 d. As the number of days on feed increased shrunk slaughter weight increased linearly with the initial and final slaughter day groups having the lowest and highest slaughter weights respectively. In addition, dressing percentage increased linearly from 28 to 196 d on feed. A quadratic effect was seen as day on feed increased. Cattle that were slaughtered at 28 d on feed had significantly ($P < 0.05$) higher shrunk average daily gain than all other slaughter day treatments. It is important to note that cattle slaughtered at d 28 could have exhibited some compensatory gain from just being adapted to a high concentrate diet. No other differences were detected between any other slaughter day treatments. This data indicated a significant ($P < 0.01$) quadratic relationship, suggesting that increasing days on feed may decrease performance.

In addition to performance, May et al., (1992) found that as days on feed increased, fat thickness, *longissimus* muscle area and kidney pelvic and heart fat percentage (KPH%) increased linearly ($P < 0.01$). As a result, carcass weight also increased linearly from d 0 to 196. Marbling score increased, but displayed a quadratic effect ($P < 0.01$). This research showed that Cattle fed to 112 d on feed had the highest marbling score and subsequent treatments showed no significant differences. This data indicates that once cattle reach a certain point on feed, marbling score may vary but does not increase significantly. This plateau effect may be due to other factors such as genetics and breed type. Data (Utera and Vleck, 2004) has shown that marbling is a highly heritable trait.

Van Koevering et al. (1995) conducted a study that documented the effect of days on feed on animal performance, carcass quality and tenderness. This particular study used two hundred fifty-six crossbred steers weighing an average of 329 kg. Steers were blocked by weight into four weight groups. Cattle were randomly assigned within weight groups to 8 pens with 8 head per pen. 2 pens from each of 4 weight groups were slaughtered after 105, 119, 133 and 147 d on feed. Cattle were fed an ad libitum, high concentrate diet for the entire finishing period. While May et al., (1992) did not focus on the performance data, Van Koevering et al. (1995) found a linear ($P < 0.01$) trend in final live weight over days fed. In addition to a linear trend, a quadratic trend was also seen, implying that live weight was increasing at a decreasing rate between treatment groups. Additionally, a quadratic ($P < 0.05$) effect was noted for average daily gain as days on feed increased. Cattle slaughtered at 119 and 133 d on feed exhibited the highest average daily gain with the cattle being slaughtered at 147 d on feed having lower (1.37 vs 1.44 kg/d) gains per day. While all slaughter endpoints showed similar average daily dry matter intake (ADMI) there tended to be a linear ($P < 0.08$) increase in ADMI which would be expected as BW increases. Cattle fed to 119 d were significantly ($P < 0.05$) more efficient on a live and carcass basis when compared to cattle fed for 147 d.

Furthermore, Van Koevering et al. (1995) found that as days on feed increased; hot carcass weight, subcutaneous fat thickness, KPH% and USDA calculated yield grade increased linearly ($P < 0.01$). In addition, at 147 d on feed a significantly higher percent (9.38 vs. 1.56) of USDA yield grade 4 carcasses were seen. Furthermore, marbling score displayed a significant linear ($P = 0.01$) and a quadratic ($P = 0.02$) effect. Cattle slaughtered at 105 d had the highest percentage of Standard and Select carcasses for all treatments. As days on feed increased percent Choice increased while Selects and Standards both decreased. Cattle at 199 and 133 d on feed had 0% Standard carcasses while cattle harvested at 147 d had 1.56%. This reaffirms the idea that some cattle will not increase marbling deposition with increased days on feed.

Hicks et al., (1987) conducted a study showing results similar to what May et al., (1992) and Van Koevering., (1995) found. Using 4 different slaughter endpoint treatments (100, 114, 128 and 142 d) they evaluated performance and cutability of 480 steers. This study reported that cattle on feed longer, 100 vs 148 d on feed were less efficient as time on feed increased. Cattle showed a significant linear ($P < 0.01$) increase in live weight, but at a decreasing rate suggesting that cattle were gaining less than earlier in the finishing period. Cattle consumed the same

amount of feed on a dry matter basis making them less efficient. Cattle harvested at 128 d had greater gains than cattle slaughtered at 114 or 142 d (4.57 vs. 2.86 vs. 1.57 lb/d), respectively. A linear ($P < 0.01$) increase was seen in carcass weight, dressing percent, KPH%, fat thickness and marbling score as days on feed increased. Percent Choice and percent yield grade 4 carcasses also increased with days on feed.

Previous studies documenting the effects of time on feed on carcass characteristics and palatability could be misleading if they do not account for the age of the animal as stated by Miller et al. (1987). Therefore, a study was done utilizing a backgrounding program that targeted two different rates of growth. Seventy two, 8-month old Simmental steers were randomly assigned to a low or high energy backgrounding diet. Cattle were backgrounded from 8 to 14 months and then were randomly assigned a finishing d treatment within the backgrounding treatments. All cattle were slaughtered at 20 months of age. Finishing treatments included 0 d on a high concentrate diet. Finishing day treatments included 56, 112 and 168 d on feed until they reached 20 months. In addition to carcass data, sensory characteristics and shear force values were reported (Meat Quality Section). Increasing the number of days on a high concentrate diet increased hot carcass weight, fat thickness, and USDA quality grade. Increasing days on feed significantly improved marbling score from d 0 to d 56. While not significant, marbling score did improve from d 56 to treatment d 112, but did not increase from d 112 to 168. Moreover, the high energy backgrounding diet produced significantly heavier carcasses, increased fat thickness, and increased marbling score.

In summary, this data clearly indicates there are an optimum number of days at which cattle should be fed in order to maximize performance and efficiency. However, as stated earlier that point is highly variable. The point at which cattle are the most efficient on feed may not be the point at which they reach a desirable quality grade, carcass weight or meet specific marketing criteria. These studies also indicate that from a meat quality and tenderness standpoint there is an optimum point. With tenderness said to be the threshold trait, it is important to note that feeding cattle past an optimum point could increase shear force values. None of these studies provided data about heavy or lightweight carcasses, so it is difficult to speculate how much revenue is lost because of over or underfeeding cattle. This data demonstrates that there are optimum points to reach maximum performance or carcass characteristics, however those must be established based on the producers own criteria and cattle.

Meat Quality

Factors influencing meat quality can include genotype, environmental conditions, backgrounding, diet constituents and the time beef cattle are on a high concentrate diet. These factors have been shown to influence lean color, sensory and flavor attributes, fat color, tenderness, and fatty acid profile. In beef production systems other than the United States, cattle are typically brought to market weight on a pasture or forage based system as compared to the high concentrate finishing system used in the U.S. Performance and efficient gains benefit the use of a pasture based backgrounding system when bringing beef cattle up to weight. Consumer purchasing decisions drive changes in the beef industry so therefore the effects of different production systems need to be evaluated on how they affect meat quality.

Lean Color

Fresh meat lean color is the number one purchasing criteria for consumers. Consumers equate color to freshness (Mancini and Hunt, 2000). Many different factors affect fresh meat lean color; they may include but are not limited to pH, age of animal and diet. A study done by Vestergaard et al. (2000) found that cattle fed forage for the entire production system had darker *longissimus dorsi* and *semitendinosus* when compared to cattle consuming a high concentrate diet. Whereas French et al. (2000) evaluated the use of different levels of concentrate feeding and found no effect on L*, a* or b* values. The use of high concentrate feeding to improve lean color has shown much variability.

Muir et al. (1998) documented the effects of animals finished on a forage and high concentrate diet for various amounts of time on instrumental lean color. In two experiments using 3-year old Angus steers a combination of cattle fed a high concentrate diet and cattle on a pasture finishing diet were slaughtered at 0, 6, 10 and 14 weeks on feed. Experiment 2 utilized the same structure but cattle were harvested at 0, 10 and 16 weeks. Each experiment was analyzed separately. *Longissimus* L*, a* and b* values were recorded at the 12th and 13th rib interface following a 30 minute bloom time for both experiments. They found that in experiment 1 time on feed had no significant effect on lean color. However, in experiment 2 using the same type of cattle, diet and treatment structure; a time effect was seen as L* values increased as days on feed increased. No differences were seen for a* values in experiment 2. In both experiment 1 and 2 in this study a diet effect for both L* and a* values were seen. At only the 16 week

slaughter period, high concentrate fed cattle had significantly ($P < 0.01$) higher a^* values in both experiments. In experiment 2, L^* values were shown to increase over 16 weeks on a high concentrate diet whereas no differences were seen in experiment 1. This data would indicate that the *longissimus dorsi* in cattle fed a grain diet should be redder in color. Conflicting results from this study for L^* values make it tough to determine the actual effect of diet on lightness. In addition to instrumental color measurements, a trained color panel assessed the color differences between treatment and diet using a scale where 1 was “unacceptable” and 5 was “excellent bright red.” Panelists found pasture fed cattle were more unacceptable than high concentrate for each of the harvest treatments. No difference was noted as days on a high concentrate diet increased. This work supports that of Mandell et al. (1997) who found that no subjective color differences were seen as the number of days cattle were on feed increased.

Little effect is seen when younger cattle are finished for various amounts of time. It has been suggested that cattle in a forage-based pasture finishing exhibit a darker lean from lower glycolytic stores and increased exercise thus affecting pH (Mancini and Hunt, 2005).

Fat Color

Yellow fat occurs from cattle being raised on predominantly forage based diets. Cattle consuming a high forage diet ingest a yellow carotenoid pigment known as beta-carotene which is responsible for the yellow fat color. Yang et al. (2002) measured the beta-carotene levels in cattle consuming an all forage diet vs. cattle consuming a high concentrate diet for 132 d prior to slaughter. They found that the longer cattle consume a forage diet, the higher the beta-carotene levels were in body tissue. Whereas cattle consuming a high concentrate diet showed a decrease in beta-carotene levels over day fed. Beta-carotene is essential to the body as it is metabolized into a supply of vitamin A. With increasing amounts of beta-carotene prevalent in body tissues, cattle consuming high forage diets cannot metabolize all ingested beta-carotene to vitamin A, thus creating a surplus in the body. The excess beta-carotene is stored in fat, resulting in a yellow fat color. To reduce the prevalence of yellow fat, research (Forrest, 1998; Muir et al., 1998; Kerth et al., 2007) has shown that transitioning cattle to a high concentrate diet for a period of time following a high forage diet will turn that fat white in color.

Kerth et al. (2007) used 30 steers to document the effects of cattle consuming a forage diet, cattle consuming a forage diet and then moved to a high concentrate diet or a high concentrate diet for the finishing period. Cattle consuming the all forage diet had significantly

higher ($P < 0.05$) subcutaneous fat b* values when compared with either of the high concentrate finishing treatments. Moreover, Forrest et al. (1981) evaluated the effects of high concentrate feeding after a period of grazing on fat color. Fifty crossbred steers grazed pasture from May to November and then were adapted to a high concentrate diet. Cattle were slaughtered at d 0 and every 28 d thereafter until 112 d on feed. Carcasses were evaluated on a scale of 1 to 9, with 1 being white and 9 equaling intense amber. In addition, a fat sample was taken to evaluate the amount of carotene present in the fat. Cattle harvested at d 0 had significantly higher fat color values than cattle harvested at any point thereafter. This research indicates that it only took 56 d on a high concentrate diet to reach a rating of 4 or less, which in this study was deemed “acceptable”. This research showed that after the first 28 d on feed, the fat carotene levels decreased significantly.

Muir et al. (1998) found that cattle elicited the same response to high concentrate feeding as Kerth et al. (2007) reported. Muir et al. (1998) used two separate experiments to document the effects of short term grain feeding following grazing. This study concluded that increasing the number of days on a high concentrate diet would result in whiter fat.

Cattle producers utilizing a forage backgrounding system need to be aware of potential issues such as fat color. This research shows that cattle who consume a high concentrate diet should be fed at least 56 d in order to turn yellow fat white.

Sensory Analysis

Camfield et al. (1997) evaluated the sensory characteristics of cattle that were backgrounded prior to the finishing period. One hundred eight steers representing two different frame sizes were backgrounded for 150 d prior to finishing. Cattle were assigned a slaughter day treatment of 0, 30, 60 or 90 d after backgrounding. Sensory analysis was conducted using a trained sensory panel. Panelists recorded aromatics, taste descriptors, myofibrillar tenderness, connective tissue amount, overall tenderness, and flavor intensity. Panelists recorded a significant increase in cooked/beef broth aromatics as finishing day on feed increased. Camfield et al. (1997) reported that cattle harvested at d 0 displayed the lowest amount of subcutaneous fat and the lowest marbling score. Both subcutaneous fat and marbling score increased significantly over the finishing period. Cattle slaughtered at d 90 had significantly higher flavor intensity than those slaughtered at d 0. While May et al. (1992) did not report significant differences, there was an increase in flavor intensity as days on a finishing diet increased. Moreover, May et al. (1992)

found that panelists recorded higher flavor scores when marbling score was also increased. In addition, Camfield et al. (1997) found that as days on feed increased detectable connective tissue amount increased. No other differences were seen between any of the other variables tested.

Melton et al. (1982) conducted a similar study as Camfield et al. (1997). Cattle were backgrounded for a constant period and were then slaughtered at specific number of days on feed. At the end of the backgrounding period, one group was harvested. The remaining cattle were then slaughtered at 28, 56, 84, 112, and 140 d on a high concentrate finishing diet. Quantitative descriptive analysis was conducted on ground beef samples formulated from beef brisket fat and *semimembranosus* muscle to a 20% fat level. It is important to note that cattle the 84 d group had significantly lower fat content than other treatments. No differences were recorded between any other slaughter day treatment ground beef samples. Intensity of flavors and aroma were recorded on an mm line scale with 10 being slight and 140 being intense. A significant decrease in milky-oily aroma was noted by panelists as days on feed increased, while an increase in beef fat aroma was recorded. The milky oily aroma and flavor is associated with pasture finished cattle whereas the beef fat aroma and flavor was associated with corn finished beef (Melton et al, (1982).

Larick et al. (1987) investigated the effects forage and grain feeding on flavor profiles. One hundred forty four steers were used in a two year study. Cattle were grazed from April to October for each year and subsequently placed on a high concentrate diet for a specified number of days. Serial slaughter treatments included 0, 56, 84 and 112 d on a finishing diet. Sensory analysis was conducted by a trained sensory panel to evaluate the abundance of grass flavor. A 10 cm line scale was used with “no grassy flavor” and “strong grassy flavor” as anchors. Panelists sampled a section of the longissimus dorsi and a ground beef sample formulated to 25% fat. Steers harvested immediately after grazing had the highest “grassy flavor.” The prevalence of “grassy flavor” decreased as the number of d on high concentrate feeding increased. No other sensory characteristics were evaluated during this study.

These previous studies documented the effects of a finishing period following a grazing period on sensory analysis, however they do not give insight as to what would be an optimum time on feed to maximize eating satisfaction.

To complement the carcass data discussed earlier, May et al. (1992) serially slaughtered cattle from 0 to 196 d on a high concentrate diet. 2.54 cm steaks were obtained from the 8th and

9th rib section of each slaughter day, vacuum packaged and aged for 7 d. Using a trained sensory panel this study evaluated juiciness, ease of fragmentation, connective tissue amount, flavor intensity and tenderness. In addition, shear force values were also recorded. No differences were seen between any treatment for juiciness or flavor intensity. Panelists noted an increase in beef flavor for slaughter treatment of 112, 140 and 168 d. These treatment periods had some of the highest marbling scores, suggesting that marbling score may have an impact on panelist flavor score. Furthermore, panelists found samples from the 84 and 112 d treatments to have the highest, most desirable ease of fragmentation score and the least amount of connective tissue. A significant difference was seen between the samples from the 112, 140 and 160 d treatments and the remaining treatment days for tenderness. A quadratic effect ($P < 0.01$) was seen for ease of fragmentation, connective tissue amount and tenderness. This research concluded that cattle fed for 112 d would be optimum in maximizing beef flavor and ease of fragmentation. This research would be supported by that of Tatum et al. (1980), while Dolezal et al. (1982) found mixed results in the number of d to reach optimum flavor and tenderness value. These mixed results could be due to the amount of cattle variation used within the study (Dolezal et al., 1982).

Miller et al. (1987) conducted a sensory panel on the effects of days on feed on *longissimus dorsi* (LD) and the *semitendinosus* (SM). Cattle were harvested from 0 to 168 d on feed. Panelists found that LD samples from the high energy backgrounding diet had a significantly lower amount of connective tissue and were more tender than low energy LD samples. No differences were found by panelists for any of the sensory traits tested. Increasing days on feed decreased the amount of connective tissue found by sensory panelists. No differences were recorded for any other sensory panel trait. This contradicts the research of May et al. (1992) who found that detectable connective tissue amount increased as days on feed increased. Tatum et al. (1980) found that no advantage was given to samples fed over 100 d for any palatability trait.

Tenderness (WBSF)

Miller, 2001 stated that consumers are willing to pay for products that are tender, creating a need for the industry to focus on tenderness as an issue.

May et al. (1992) found the lowest shear force values were obtained when cattle were fed to 112 d. As days on feed increased, shear force values displayed a quadratic effect ($P < 0.01$) with the lowest shear force values occurring at 112 d. This data agrees with Zinn et al., (1970b)

who evaluated shear force values on the *triceps brachii*, *longissimus* and *semimembranosus* of both heifers and steers. Zinn et al. (1970a) did not test for a quadratic effect but the lowest average shear force values for both sexes and all three muscles occurred on either d 150 or 180 of the feeding period. However, it is important to note that shear force values for the remaining treatments tended to increase for both sexes and all 3 muscles. This variation could be due to the increased number of days on feed and maturity of the animal.

Camfield et al. (1997) found that as days on feed after the backgrounding period increased, shear force tended to decrease. Cattle slaughtered at d 0 had the highest shear force values. Dolezal et al. (1982) found that for steers, tenderness decreased as days on feed increased. Cattle that were harvested at d 0 had the highest shear force value and cattle slaughtered at 230 d on feed had the lowest shear force values. Mandell et al. (1997) found a significant difference between slaughter treatments of 7 and 10 mm of backfat. Cattle fed to a higher backfat had lower shear force values which can be attributed to increased days on feed.

Miller et al. (1987) found that backgrounding energy diet had no effect on shear values. This research concluded that cattle not fed a high concentrate diet had higher *longissimus dorsi* shear force values than cattle that were fed a high concentrate diet. Shear force values improved from d 56 to 112, but no improvement was seen between 112 and 168 d. No significant difference was found among 56, 112 or 168 d on feed. Shear force values for the *semimembranosus* and *semitendinosus* were not affected by increasing the number of d on feed.

With the importance of tenderness to the consumer, variable results among studies have shown that the optimum number of days to feed cattle on a high concentrate in order to maximize tenderness is difficult to specify. McKeith et al. (1985) found that variability exists between muscles, time on feed, and breed. The variability within the studies reviewed could be attributed to those factors. These studies indicate a plateau affect occurs when grain finishing cattle and that cattle fed grain for a short amount of time will have lower shear force values than those cattle slaughtered immediately after backgrounding.

Carcass Composition

Much time and research has been spent trying to predict carcass composition and cutability. As evidenced by this literature review and the many production practices referenced, predicting carcass yield and composition based only on a few factors would effectively calculate body composition. Differences in breeds, environment and technology make it very difficult to

conclude with certainty which factors are best. Currently the USDA (1997) has a yield grade equation that uses 4 variables, hot carcass weight, longissimus muscle area, 12th rib back fat and KPH% to predict cutability. Adjustments are made based on these factors to estimate yield grade or the amount of boneless closely trimmed retail cuts on a carcass. Moreover, many harvest facilities do not record or place any premium or discount on yield grade.

In order to predict moisture, fat, protein, bone and ash content of a carcass, researchers have developed regression equations and methods to estimate beef carcass composition without dissecting the whole carcass. In a very good review of composition determining techniques, Shackelford et al. (1995) used data from 1,602 calf-fed steer carcasses to determine which traits such as, but not limited to; hot carcass weight, wholesale rib weight or 9-10-11 rib section muscle weight would be most useful in predicting retail product yield, prediction of fat trim yield, and prediction of bone yield. They found that a wholesale rib dissection was best for predicting retail product, fat trim and bone yield. However, rib sections are very costly to destroy for dissection and the increase in prediction power from using the whole rib section is due to the fact the wholesale rib represents a larger portion of the carcass. It was also shown that any trait measured from the rib section would be beneficial to predict composition. In addition, Miller et al. (1988) found that dissecting the 9-10-11 rib section explained 85% of carcass variability. When using single carcass characteristics to measure retail fat yield, fat trim and bone yield, hot carcass weight and longissimus muscle area displayed the highest correlations for determining retail product yield. In addition, 12th rib adjusted fat thickness displayed the highest correlation for fat trim, while longissimus muscle area showed the highest correlation for bone yield. Additionally, Hankins and Howe (1946) found that dissecting the 9-10-11 rib section and using proximate analysis of the edible portion of the rib section would account for over 85% of carcass variability when predicting the moisture, protein and fat content of a dressed beef carcass.

Fatty Acid Profile

Rising health concerns in recent years have consumers wanting products that are low in saturated fatty acids (SFA). SFA's have been associated with negative health effects such as high cholesterol. Whereas polyunsaturated (PUFA), monounsaturated (MUFA) and conjugated linoleic acid (CLA) have been associated with increased health benefits. Of the major animal protein sources beef is highest in SFA and lowest in PUFA's. Increased amounts of SFA are due to the hydrogenation of fat in the rumen; whereas monogastrics deposit fat in the same form as

what they have consumed. Ruminant animals consume fat as an energy source; especially cattle fed high concentrate diets. MUFA and PUFA's ingested can be hydrolyzed completely leaving very little MUFA or PUFA available for absorption in the small intestine (Doreau and Ferlay, 1994).

Camfield et al. (1997) found that increasing days on a high concentrate changed the fatty acid profile. They saw an increase in palmitic and oleic acid, two very common fatty acids in beef. Not all fatty acid concentrations increased as evidenced by a decrease in stearic and linoleic acid. Duckett et al. (1993) used serial slaughter of cattle from d 0 to 196 to document the effects of increasing time on a high concentrate diet as it related to fatty acid profile. Results showed increasing time on feed, linearly decreased SFA's. MUFA's increased linearly while PUFA'S remained about the same as days on feed increased. Individual fatty acids which increased as days on feed increased were palmitic, and oleic acid. However, palmitoleic, and alpha linoleic decreased as d on feed increased. Moreover, Mandell et al. (1997) found that these same fatty acids responded in the same manner as d on feed increased.

A recent study done by Buttrey et al. (2012), looked at the effect of supplementing DDGS to steers grazing growing wheat pastures and how DDGS supplementation affected fatty acid profile. They reported DDGS supplementation had no effect on any fatty acid tested. No increases were seen in SFA, MUFA or PUFA's.

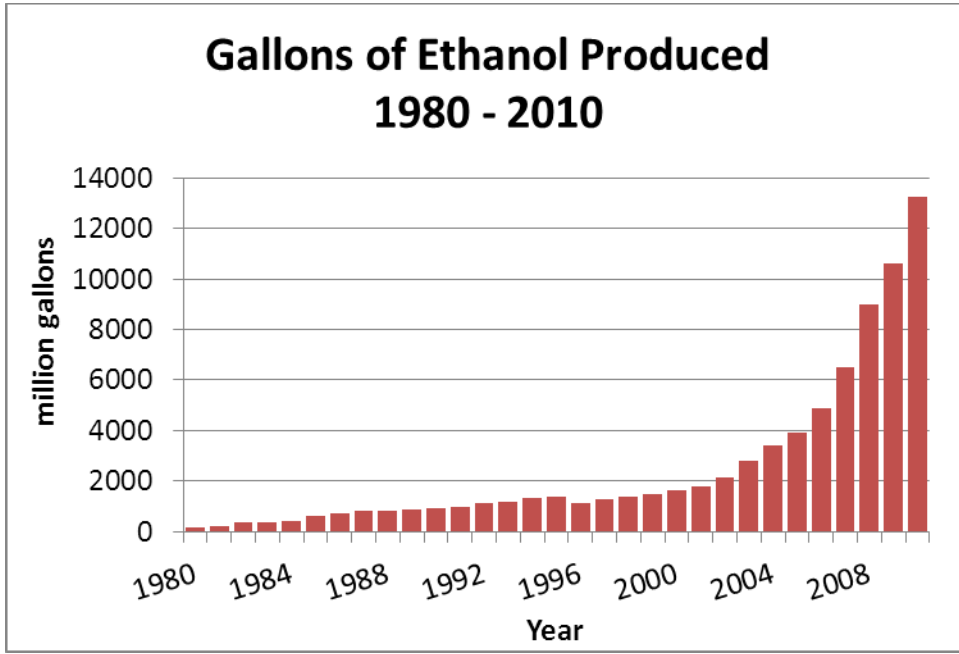
Duckett et al. (1993) reported total SFA% increased as time on a high concentrate diet increased. Total MUFA% percentages showed a quadratic increase ($P < 0.01$) as days on feed increased. The percentage of PUFA decreased linearly ($P < 0.01$) with the lowest percentage of PUFA's being found at 196 d on feed. Individual fatty acids concentrations are variable between studies, making it difficult to conclude as to which increase or decrease significantly. Duckett et al. (1993) suggested a rumen pH drop from grain feeding may inhibit hydrolysis and allow for more monounsaturated fatty acids to be absorbed which could be the case as MUFA's showed a quadratic response to days on feed; increasing at an increasing rate. Research (May et al., 1992) presented earlier showed that increasing days on feed increases both subcutaneous fat and intramuscular fat. Increasing the amount of fat deposited by the animal could lead to higher SFA levels as days on feed increase. Fatty acids are hydrolyzed in the rumen; the extent to which they are hydrolyzed plays a key role in the availability to be absorbed. Fatty acids such as linoleic may be hydrolyzed to a greater extent, leaving less for absorption into the body.

Summary

This literature reviews a broad spectrum of topics within the beef industry. The optimum time to feed cattle to maximize meat quality attributes is difficult to define and is dependent on the biological type and target market. The time cattle spend on a high concentrate finishing diet to optimize carcass cutability and meat quality can be affected by factors such as management strategy, backgrounding, and DDG's supplementation. However, utilizing late season, low quality forages with a supplement such as DDGS may prove beneficial to the industry and present producers with some unique opportunities to add value to the backgrounding production system.

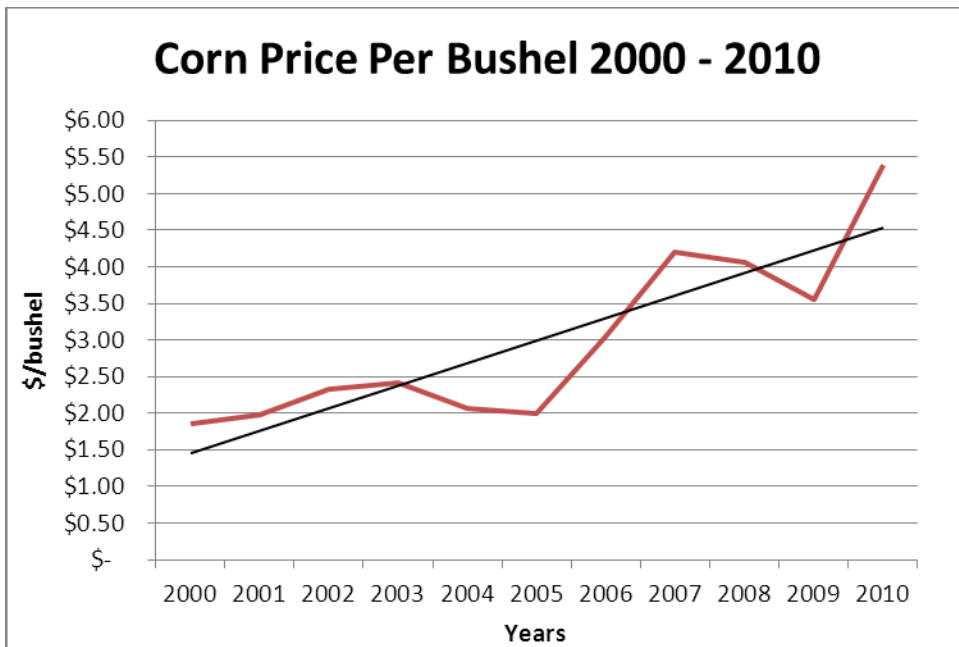
Figures and Tables

Figure 1.1 Gallons of Ethanol Produced in the United States



¹Renewable Fuels Association, 2012

Figure 1.2 United States Corn Price Per Bushel



¹National Agriculture Statistic Service, 2012

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Chapter 2 - Effects of supplementing dried distiller's grains with solubles to yearling stocker cattle during the last 90 days of grazing on animal performance, carcass characteristics, and meat quality when utilizing a short feeding protocol.

Abstract

Crossbred yearling steers ($n = 144$; initial BW 367 ± 18.46 kg) were randomly allotted by BW to a randomized complete block design with a 2x3 factorial treatment arrangement to 1) assess the impact of supplementing dried distiller grain with solubles (DDGS) while grazing late-season native forage for 90 d and to 2) assess the impact of a short feeding period on animal performance, carcass characteristics and meat quality traits. Treatments consisted of DDGS supplementation during grazing (0 or 1% of BW as DDGS; DM basis) and finishing d on feed (DOF; 75, 100, or 125). During grazing and finishing, steers were fed once daily. During the finishing period, steers received a high concentrate. Cattle were harvested on the assigned day, carcass data and 12th rib and plate sections were collected 24 to 48-h postmortem. Steaks were aged for 14 d and used to evaluate sensory characteristics, lean color and fatty acid content. During grazing supplemented steers had greater ($P < 0.01$) ADG than un-supplemented steers (1.11 vs 0.345 kg/d); however, un-supplemented steers had greater ($P < 0.01$) ADG than supplemented steers during the finishing period (1.67 vs 1.45 kg/d). There were no treatment differences in finishing DMI ($P = 0.91$). Feeding DDGS during grazing decreased ($P = 0.02$) finishing G:F compared to un-supplemented cattle. Supplemented cattle had heavier HCW ($P < 0.01$; 362.5 vs 330.4 kg) and larger LM area ($P = 0.02$; LMA 90.4 vs 85.4 cm²) than un-supplemented cattle. Increasing DOF linearly increased HCW ($P < 0.01$), 12th rib fat thickness ($P = 0.03$), LM area ($P = 0.01$) and USDA marbling score ($P = 0.02$). No differences ($P = 0.28$) were observed for USDA yield grade. Increasing DOF decreased (Linear; $P < 0.01$) carcass protein %, moisture %, and carcass fat %. Increasing DOF increased (Quadratic; $P = 0.01$) L* values also, while decreasing (Quadratic; $P < 0.01$) a* and b* values for external fat color. No treatment differences ($P > 0.05$) were observed in %SFA, MUFA, or in steaks. Increased ($P = 0.01$) sensory off-flavors were present in steaks from cattle fed 100 and 125 DOF relative to steaks from cattle fed for shorter time periods. No other treatment differences ($P > 0.05$) in any sensory traits, instrumental tenderness, lean color, or fatty acid profile were detected. In conclusion, supplementing cattle with DDGS at 1% of BW during a late-season grazing period altered grazing performance, feedlot performance, and carcass characteristics. In addition, utilizing a shortened feeding period had minimal effects on meat-quality traits but increasing DOF resulted in whiter external fat.

Key Words: beef, days on feed, dried distiller's grains with solubles, fat color, grazing

Introduction

Recent increases in corn prices (NASS 2012) have forced beef producers to evaluate by-product feeds and new management techniques to reduce the cost of gain throughout the entire beef production system. Many beef producers throughout the central and high plains utilize native forage throughout the summer and late fall months as a cost-effective way to increase weight gain. Ruminally-degradable protein (RDP) is known to limit performance of cattle grazing low-quality mature forages. Dried distillers grain with solubles (DDGS) is a by-product of the ethanol industry. It is readily available to beef producers and may be effective as a source of supplemental protein, although it tends to have a poor RDP content. Supplementing cattle during fall and winter grazing may allow beef producers to better utilize forages and reduce costs of gain without losing performance during such times. Additionally, bringing cattle to the feedyard at heavier weights could ultimately reduce days to finish. Reducing days on feed is related to decreased tenderness, carcass weight, and ribeye size as compared with longer, more traditional finishing periods. Therefore, the objectives of this study were to 1) assess the impact of supplementing DDGS while grazing late-season forage for 90 d and to 2) assess the impact of a short, high-concentrate feeding period on animal performance, carcass characteristics, and meat quality traits.

Materials and Methods

Procedures followed in this study were approved by the Kansas State University Institutional Animal Care and Use Committee protocol No. 2714 and the Kansas State University Institutional Review Board protocol No. 4412. The live animal portion of this experiment was conducted at Kansas State University from August 2009 to March 2010.

Live Animal

Grazing

In August 2009, 144 yearling crossbred steers (initial BW = 367 ± 18.46 kg) were received at the Kansas State University Beef Research Unit. Upon arrival, steers were fed grass hay to equalize gut fill for 7 d and were then weighed, tagged, vaccinated against clostridial diseases (Ultrabac 7, Pfizer, Exton, PA), and respiratory diseases (Bovi-Shield GOLD[®] 4, Pfizer,

Exton, PA), and treated for internal parasites (Safe-Guard, Intervet Inc. Milsboro, DE). Steers were also given an implant containing 40 mg trenbolone acetate and 8 mg estradiol (Revalor G, Intervet Inc. Milsboro, DE) at that time.

Steers were blocked by BW and randomly assigned to 1 of 12 pastures (12 steers/pasture) managed by the Kansas State University Cow Calf Unit. Pastures were blocked by location ($n = 2$) and randomly assigned one of the following treatments: no supplementation (Control) or supplementation with dried distiller's grains + solubles (DDGS) at a rate of 1% of steer BW/d (DM basis; Table 2.1). Eight adjacent pastures were located in Riley County, Kansas (average size = 97 ± 40 ha; 39.2310°N , 96.6698°W) and 4 adjacent pastures in Pottawatomie County, Kansas (average size = 75 ± 22 ha; 39.2343°N , 96.5293°W). All pastures contained a single centrally-located water source; supplemental salt and trace-mineral were available continually. Major graminoid species in pasture, in order of abundance, were big bluestem, (*Andropogon gerardii* Vitman), indiangrass [*Sorghastrum nutans* (L.) Nash], little bluestem [*Schizachyium scoparium* (Michx.) Nash], sideoats grama [*Bouteloua curtipendula* (Michx.) Torr], and switchgrass (*Panicum virgatum* L.; Towne and Owensby, 1984).

Forage samples were collected each month (August to November) by clipping forage 1 cm above the ground from within a randomly-placed sampling frame (0.25 m^2 ; Table 2.2). Forage samples were dried in a forced air oven (50°C , 96 h; Model VWR 1650; VWR Scientific; Randor, PA), ground to pass a 1-mm screen (No. 4; Wiley mill, Thomas Scientific, Swedesboro, NJ), and analyzed for N (FP-528, LECO, St. Josephs, MI). Forage NDF (without amylase and without ash correction) and non-sequential ADF were determined using an Ankom 200 Fiber Analyzer (Ankom Technologies, Macedon, NY). Supplemented steers were brought to bunks each d at 0600 h and supplement intake was recorded. All steers were weighed 45 d into the study in order to adjust supplement feeding rates. After 90 d of grazing native pastures, steers were returned to the Beef Research Unit at Kansas State University and were placed in separate pens according to pasture grouping and fed ground hay for 7 d to equalize gut fill.

Feedlot

Steers were weighed and given an implant containing 120 mg trenbolone acetate and 24 mg estradiol 7 d after the grazing period ended (Revalor S; Merck Animal Health; Whitehouse Station, NJ). Steers remained with grazing cohorts during the finishing period. Steers were adapted to a high-concentrate finishing diet over 21 d; the final finishing diet is presented in

Table 2.3. Steers were fed for *ad libitum* intake once daily at 0800 h. Steers were housed in uncovered, concrete pens for the duration of the finishing period. Steers were randomly assigned a slaughter d treatment based on final grazing ADG. Steers were weighed every 25 d during the finishing periods. Orts were collected also at those times. At 75, 100, and 125 d of high-concentrate feeding, 2 pens of control steers and DDGS-fed steers were weighed and then transported to Tyson Foods (Holcomb, KS) for slaughter. Final BW were calculated assuming a 4% shrink.

Carcass Data

Following slaughter, carcasses were chilled for 24 to 48 h at 0 to 2°C before grading and carcass measurements were collected. After chilling HCW, LM area, 12th rib fat thickness, and KPH% were gathered and recorded by trained university personnel and used to calculate USDA (1997) yield grade. In addition, USDA marbling score was evaluated by a USDA grader and recorded.

Carcass composition, Warner-Bratzler Shear Force

After carcass measurements were collected, 6 carcasses were randomly selected from each pen. Rib and plate sections from those 6 carcasses were gathered for use in evaluating sensory characteristics, Warner-Bratzler Shear Force (WBSF), instrumental lean and exterior fat color and chemical and fatty acid composition. Rib sections were fabricated from the 6th through 12th ribs with the plate section remaining on the wholesale rib. After fabrication, the rib and plate sections were collected and transported to the Kansas State University Meat Laboratory for analysis. Rib and plate sections were then fabricated into 9-10-11 rib sections by the procedure outlined by Hankins and Howe (1946) in order to predict carcass composition. As described by the procedure outlined by Hankins and Howe the 9-10-11th rib section was fabricated and all bones were removed. Samples were ground (Model 6732; Hobart Manufacturing; Troy, OH) while partially frozen through a 0.63 cm plate and mixed, then ground through a 0.32 cm plate, mixed again and sampled in triplicate for ether extract, moisture, protein and ash content (AOAC PVM 1:2003; AOAC 990.03). Two, 2.54 cm thick steaks were cut from the caudal end of the rib section. The most caudal steak was used for WBSF analysis and the second most caudal steak was used for both instrumental color analysis and trained sensory panel evaluation. All WBSF and sensory analysis samples were vacuum packaged immediately after sample fabrication and

allowed to age until 14 d postmortem. After aging, samples were frozen and stored at -20°C until sensory analysis and WBSF analysis were initiated. Steaks frozen for WBSF evaluation were thawed for approximately 12 hours at 0-2°C and cooked to 40°C, turned, and cooked to a final internal temperature of 70°C in a dual flow, forced-air convection gas oven (Blodgett, model DFC-102 CH3; G.S. Blodgett Co.; Burlington, VT) preheated to 163°C. Steak temperatures were monitored with copper-constantan thermocouples (Omega[®] Engineering; Stamford, CT) inserted into the approximate geometric center of each steak and attached to a Doric temperature recorder (Model 205; Vas Engineering; San Francisco, CA). Steaks were chilled overnight at 0-2°C before 8 round cores (1.27 cm diameter) were obtained from each steak parallel to the long axis of the muscle fibers using a 1.27 cm corer (G-R Manufacturing Co., Manhattan, KS). Each core was sheared once perpendicular to the direction of the muscle fibers using a Warner-Bratzler V-shaped blunt blade (G-R Manufacturing Co., Manhattan, KS) attached to an Instron Universal Testing Machine (Model 4201, Instron Corp., Canton, MA) with a 50 kg compression load cell and a crosshead speed of 250 mm/min. Peak shear force values were recorded in kg and the values from the cores were averaged for statistical analysis.

Instrumental Color

Before fabrication instrumental color measurements were taken of the exterior fat covering the wholesale rib section. Additionally, instrumental color of the *longissimus* was evaluated using the second most caudal steak fabricated from the wholesale rib section. The steak was cut and allowed to bloom for 30 min prior to instrumental measurement. Instrumental color was measured using a HunterLab Miniscan[™] XE Plus Spectrophotometer (Model 45/0 LAV, 2.54 cm diameter aperture, 10° standard observer, Illuminant A; Hunter Associated Laboratories Inc.; Reston, VA) and L* (lightness), a* (redness), b* (yellowness) values were recorded.

Sensory Analysis

Frozen steaks for sensory analysis were thawed at 2-4°C for approximately 12 h and cooked using the same procedures used for WBSF measurement. Cooked steaks were cut into 2.54 cm x 1.27 cm x 1.27 cm samples and placed in enamel double-boiler pans with warm water in the bottom portion. Each panelist received two cubes from each sample in random order. Each session included a warm-up sample and samples from all treatments ($n = 6$ LM steaks per

session). Distilled water and crackers were used to cleanse the palate of each panelist between samples. There were no more than 2 sessions per day. A trained (AMSA, 1995) sensory panel ($n > 6$) evaluated steaks on an 8-point scale for myofibrillar tenderness, connective tissue amount, overall tenderness, juiciness, beef flavor intensity, and off-flavor intensity. The scale used for myofibrillar and overall tenderness was 1 = extremely tough, 2 = very tough, 3 = moderately tough, 4 = slightly tough, 5 = slightly tender, 6 = moderately tender, 7 = very tender, and 8 = extremely tender. For juiciness, the scale used was 1 = extremely dry, 2 = very dry, 3 = moderately dry, 4 = slightly dry, 5 = slightly juicy, 6 = moderately juicy, 7 = very juicy, and 8 = extremely juicy. The scale used for beef flavor was 1 = extremely bland, 2 = very bland, 3 = moderately bland, 4 = slightly bland, 5 = slightly intense, 6 = moderately intense, 7 = very intense, and 8 = extremely intense. For connective tissue and off flavor intensity, the scale used was 1 = abundant, 2 = moderately abundant, 3 = slightly abundant, 4 = moderate, 5 = slight, 6 = traces, 7 = practically none, and 8 = none. Panelists described off-flavors, if present, using a provided list of potential descriptors and their own descriptors not present on the list. Panel was blocked by panelists with each grazing and harvest day treatment represented on each panel. Panelists' scores were averaged for statistical analysis.

Fatty Acid Composition

A *longissimus* muscle sample was taken immediately cranial from the 8th rib for fatty acid analysis and proximate analysis. A modified gas chromatography procedure was used for fatty acid analysis of LM samples (Sukhija and Palmquist, 1988). A single 2.54-cm LM steak from each rib was frozen in liquid nitrogen, pulverized using a blender (Model 33BL79; Waring Products, New Hartford, CT), and analyzed for fatty acids. Loin (50 μ g) samples were combined with 2 mL of methanolic-HCl and 3 mL of internal standard (2 mg/mL of methyl Heptadecanoic acid, C17:0, in benzene) and heated in a water bath for 120 min at 70°C for transmethylation. After cooling, the addition of 2 mL of benzene and 3 mL of K₂CO₃ allowed the methyl esters to be extracted and transferred to a vial for subsequent quantification of the methylated fatty acids by gas chromatography for fatty acid analysis. Fatty acids reported for each of the LM samples were expressed as a percentage of the entire sample.

Statistical Analysis

A randomized complete block design with a 2 x 3 factorial treatment arrangement was analyzed using the GLM procedure (SAS Inst. Inc.; Cary, NC). The main effects consisted of DDGS supplementation during grazing (0 or 1% of BW as DDGS; DM basis) and finishing days on feed (DOF; 75, 100, or 125). Main effects for grazing treatments were analyzed using pairwise t-test whereas all other variables were included as fixed effects in the model as well as the interaction of supplementation and day on feed. Sensory panel was blocked with all treatments represented during each sensory panel. Pen was used as the experimental unit and least-squares means were computed for all fixed effects; means were separated using the Students *t*-test when the F- Test (α -level ≤ 0.05) was protected. Linear and quadratic effects of days on feed were evaluated using planned contrasts

Table 2.1 Nutritional analysis of supplemental dried distiller’s grains

Item	Percentage
DM,	92.0
CP, %DM	31.4
Calcium, %DM	0.1
Phosphorus, % DM	0.93
Sulfur, %DM	0.46
Crude Fiber, %DM	9.3
NDF,%DM	30.5

Table 2.2 Average standing biomass in native tallgrass prairie pastures (\pm SD) and chemical composition of native tallgrass-prairie forage grazed by yearling steers¹

Item	August	September	October	November
Forage Availability, kg of DM/ha	3786 \pm 824	2990 \pm 738	2830 \pm 694	2756 \pm 602
DM%	94.6	94.8	90.3	91.5
CP, %DM	6.3	6.8	2.6	2.5
NDF, %DM	63.9	64.6	67.0	75.3
ADF, %DM	41.5	43.4	46.2	51.9

¹ Estimates were derived from hand clipped samples.

Table 2.3 Final feedlot finishing diet

Ingredient	Finishing Diet
	DM Basis
Dry rolled corn	62.18%
Sorghum dried distillers grains	24.37%
Corn silage	8.62%
Feedlot additive premix ¹	2.37%
Supplement ²	2.47%
Nutrient Composition, DM basis	
CP	14.4%
ADF	8.5
Calcium	0.75
Salt	0.3

¹Formulated to provide 300 mg monensin and 90 mg tylosin per animal daily in a ground corn carrier.

²Formulated to provide 0.1 mg/kg Cobalt; 10 mg/kg Copper; 0.5 mg/kg Iodine; 50 mg/kg Manganese; 0.25 mg/kg Selenium; 50 mg/kg Zinc; 2,200 IU/kg Vitamin A; and 22 IU/kg Vitamin E.

Results and Discussion

Grazing

Standing forage biomass in this study ranged from 3786 ± 824 kg/ha during August to 2576 ± 602 kg/ha during November (Table 2.2). Based on these figures we concluded that forage availability did not limit DM intake of steers at the stocking rates in this study. Steers assigned to DDGS consumed an average of 3.77 kg/d of DDGS (DM basis) over the entire grazing period. Forage nutrient values from August to November are depicted in Table 2.2. As the grazing period progressed, CP values decreased while NDF and ADF values increased, indicative of changes anticipated with advancing forage maturity (Rao et al, (1973).

Only main effect means are presented as there were no interactions present. Cattle responded favorably to DDGS supplementation in our study (Table 2.4). During the grazing period, DDGS-supplemented cattle had greater ($P < 0.001$) ADG than control steers. The increase in gain over the entire period could be attributed to the available RDP in DDGS, increased availability of recycled N, increased energy intake or a combination of all 3 possibilities. Forage below 7% CP responded favorably to supplemental RDP (Paterson, 1994; Olson et al., 1999; Mathis et al, 2000). Olson et al. (1999) observed a linear response in intake and total tract digestibility as RDP levels increased. The calculated RDP of the forage and DDGS consumed daily was 1.03 lbs. Assuming a 62.9% total tract OMD from Olson et al., (1999), and a calculated intake of 24.7 lbs of DMI, 6.65% of DOM is RDP. Dried distiller's grains with solubles are not typically used as a source of RDP; exposure to heat during the manufacturing process renders a large portion of DDGS protein undegradable in the rumen. Our study agrees with that of Lomas and Moyer (2011) and Morris et al. (2005) who found that supplementation with DDGS while grazing improved ADG. Cattle not supplemented DDGS in our study lost weight during the final 45 d of grazing. These results were interpreted to suggest that animals grazing without supplement were in a negative energy balance during the last 45 d of grazing. Forage intake or digestibility were not measured in our study, it could be assumed that cattle grazing without supplementation were not able to effectively utilize forage due to a deficiency in RDP. Dried distiller's grains with solubles proved an effective supplement for cattle grazing low-quality forage; whether or not its value is due to the availability of RDP or energy is beyond the scope of this study. This study utilized cattle that were heavier than what would be typical of a

backgrounding program. Cattle at this weight have historically been placed on a high-energy diet in a feedlot due to the perception that economically-acceptable gains are not possible for heavy cattle grazing low-quality forages. Conversely, supplementing DDGS to relatively heavy cattle during fall grazing provided substantial improvements in gain relative to similar cattle that were un-supplemented.

Finishing Performance

Only main effects of grazing treatment and slaughter day treatment can be seen in Table 2.5, as no interactions were present. Cattle supplemented with DDGS on grass had lower ($P = 0.002$) ADG than control cattle during the finishing period. No difference in DMI ($P = 0.71$) was seen between DDGS and control cattle for the finishing period. Control cattle had improved ($P < 0.05$) G:F during the finishing period. DDGS had heavier ($P < 0.05$) initial and final body weights. The weight advantage of DDGS was sustained throughout the finishing period. No differences ($P > 0.05$) were seen for ADG, DMI or G:F for cattle slaughtered at 75, 100 or 125 d on feed. Increasing days on feed increased body weight linearly ($P < 0.001$). These results agree with that of Lomas and Moyer (2011) and Epp et al. (2007) who found that DDGS supplemented cattle while grazing had decreased performance during the finishing phase. May et al. (1992) found that as days on feed increased, cattle performance decreased. It is important to note that while cattle in other studies have shown decreased performance, the cattle used in our study may not have been fed for enough days to demonstrate decreased performance and that the point of diminishing performance may not have been reached. Supplemental performance for each 25 d period can be seen in Appendix A Table A.1. Cattle did exhibit compensatory gain during the finishing period, but it appears that supplementing DDGS while grazing did not reduce the amount of compensatory gain.

Carcass Characteristics

Mean values for the effects of DDGS supplementation and time on feed on carcass characteristics are reported in Table 2.6. Only main effect means are presented as there were no interactions present. DDGS cattle had heavier ($P < 0.05$) HCW and larger LM area. No differences were observed for USDA yield grade or dressing percent. We attributed the increased HCW, and LM area to the increased gains while grazing and the use of a high concentrate diet. DDGS cattle held a live weight advantage throughout the finishing period, resulting in heavier

HCW. Supplementation of DDGS while grazing had no effect on marbling score. No differences were observed for KPH% between treatments. Effects of supplementation showed that DDGS had no effect on quality grade or distribution of quality grades. Lomas and Moyer, (2011) found that supplementing dried distillers grains while grazing resulted in heavier carcass weights, but no other differences were seen for any other carcass trait measured. In addition, Griffin et al. (2010) found no carcass differences between cattle supplemented with DDGS vs. those who received no DDGS supplementation while grazing.

Increasing days on feed showed a linear ($P < 0.05$) increase in HCW, dressing percentage, fat thickness, LM area, KPH% and marbling score, and. In addition, increasing days on feed linearly decreased the percentage of carcasses grading Select. These results agree with May et al. (1992) who found that increasing days on feed linearly increased HCW, LM area, fat thickness and marbling score. May et al. (1992) fed cattle from 0 to 196 d, serially slaughtering every 28 d. These researchers found that HCW, LM area and fat thickness increased linearly from d 0 to 196 d. They also observed a linear increase in marbling score. They found marbling score was the highest at 112 d on feed. No significant increase in marbling score was observed after d 112. Our results would agree as marbling score increased significantly from d 75 to 100 d, but did not increase from d 100 to 125. This effect has been noted in other research (Hicks et al, 1987; Van Koevering et al, 1995) and suggests marbling is optimized around 110 to 120 d on feed. Increasing the number of days on feed past 120 has shown no significant increase in marbling score. With the beef industry targeting high quality cattle, it is important to note that nutritional regimen may only increase marbling until a certain point.

Meat Quality

Carcass Composition

No difference ($P > 0.05$) in carcass cutability as measured by USDA yield grade (Table 2.6) or 9-10-11 rib dissection (Table 2.7) was observed between grazing treatments. Shackelford et al. (1995) found a 9-10-11 rib dissection to be a very useful in predicting carcass composition. USDA yield grade data as seen in Table 2.6 showed no difference ($P > 0.05$) between 75, 100 or 125 days on feed. Cattle fed to 75 d on feed had a significantly higher carcass protein percentage than cattle fed to 100 and 125 days on feed. Carcass fat percentage showed an increasing quadratic trend ($P = 0.06$) and a linear increase ($P < 0.01$) as days on feed increased. Cattle fed

to 125 d had significantly ($P < 0.05$) higher carcass fat percentage than cattle harvested at 75 and 100 d. Cattle harvested at 125 d had significantly ($P < 0.05$) less carcass moisture percentage than cattle harvested at 75 or 100 d. This increase in carcass fat percentage agrees with our increase in 12th rib backfat as seen in Table 2.6. This dissection and carcass composition prediction enables us to better quantify the changes in carcass protein, fat and moisture. No differences ($P > 0.05$) in fat, moisture, protein or ash content of the *longissimus* dorsi for either of the grazing treatments was observed. Cattle fed for 75 d had ($P < 0.05$) a higher percentage of longissimus protein than cattle fed for 100 and 125 d resulting in a and quadratic relationship ($P < 0.05$). No significant ($P > 0.05$) difference was seen in *longissimus* dorsi fat percentage between any harvest day treatments. *Longissimus* dorsi moisture showed a quadratic relationship ($P = 0.02$). Cattle fed to 125 d had significantly less *longissimus* dorsi moisture than cattle fed to 100 d. *Longissimus* ash content displayed a decreasing linear trend ($P < 0.01$) as days on feed increased. Cattle fed to 75 d had higher ($P < 0.05$) *longissimus* dorsi ash percentage than those fed to 100 and 125 d. This data would agree with Duckett et al. (1993) who found that protein and ash content decreased as days on feed increased. However, they reported that *longissimus* fat content increased as intramuscular fat increased, until d 112, and remained relatively unchanged for the remaining slaughter day treatments whereas this data showed no significant differences in *longissimus* dorsi fat percentage for any harvest day treatments

Instrumental Lean and Fat Color

Only main effect means are presented as there were no interactions present. Lean color is one of the most important traits to consumers when they purchase meat (Mancini and Hunt, 2005). Our results (Table 2.8) show that DDGS supplementation had no effect ($P > 0.05$) on *longissimus* muscle instrumental L*, a* or b* values. Additionally, no differences ($P > 0.05$) were recorded for any *longissimus* instrumental color value as days on feed increased. Mandell et al., (1997) found that increasing the number of days on a high concentrate diet did not affect instrumental longissimus L*, a* or b* values.

DDGS supplementation had no effect on external fat color as seen in Table 2.8. External fat L*, a* and b* instrumental color values all exhibited a significant ($P < 0.01$) quadratic relationship to days fed. Cattle fed to 75 d had lower external fat color L* values than cattle fed to 100 and 125 d indicating that external fat was getting whiter as days on feed increased. In addition, external fat a* values for cattle fed to 75 d were significantly ($P < 0.05$) higher than

cattle fed to 100 and 125 d. Cattle fed to 75 d revealed significantly ($P < 0.05$) higher external fat b* values than cattle harvested at 100 or 125 d. This data indicates that cattle fed to 75 d had darker, redder and more yellow fat than cattle fed to 100 or 125 d. Kerth et al.(2007) and Muir et al. (1998) have documented the same response in turning fat white While these studies suggested that 56 d on a high concentrate diet is adequate time to turn fat white our study found that at 75 d on feed yellow fat is still prevalent.

Warner Bratzler Shear Force

Only main effect means are presented as there were no ($P > 0.05$) interactions present. No differences ($P > 0.05$) in WBSF values were seen (Table 2.9) between grazing treatments or between harvest day treatments. An increasing linear trend ($P = 0.06$) was noted as days on feed increased. This is contradictory to May et al. (1992) found that shear force values were minimized at 112 d on feed. In addition, Zinn et al. (1970a) found that shear force values decreased until 150 d. Additionally, Miller et al (1987) found that as the age of animals was kept constant, shear force values decreased until d 112 and no significant improvement was seen thereafter. Mandell et al. (1997) found that cattle slaughtered at a greater backfat had lower shear force values. This may be partially attributed to the reduction in cold shortening that animals with higher backfat may experience. May et al. (1992) found that cattle fed a high concentrate diet exhibited a slower rate of temperature decline which could reduce the amount of cold shortening exhibited by animals with less backfat. Our study showed a linear increase in backfat as days on feed increased, thus minimizing the effect of cold shortening and failing to explain why our values increased.

Sensory Analysis

Only main effect means are presented as there were no interactions ($P > 0.05$) present for sensory traits. Supplementing DDGS had no effect ($P > 0.05$) on any palatability trait evaluated (Table 2.9). Off flavor intensity showed a quadratic relationship ($P = 0.02$) for days on feed. Cattle fed to 125 d had higher off-flavor intensities than cattle fed to 100 d. No differences were observed for any other palatability trait measured. May et al. (1992) found that as days on feed increased, beef flavor tended to increase, and cattle fed to 112 d would maximize palatability traits. Our study results agree with those of Miller et al. (1987) who found no difference in any palatability trait tested as d on feed increased. In addition, Tatum, (1980) found that palatability

traits did not improve for cattle fed over 100 d. Our increase in off-flavor from 100 to 125 d on feed is difficult to explain. Mandell et al. (1997) tested for off flavors and found no difference as days on feed increased. Poly-unsaturated fatty acids have been known to increase off-flavor, in testing for polyunsaturated fatty acids, no differences were found in percentage of total fatty acids. The off-flavor descriptors most common for those steaks harvested at 125 d were “bitter,” “livery” and “sour.” Camfield et al. (1997) found that vaccenic acid was negatively correlated ($P < 0.05$) with all of the off-flavor descriptors found in our study. Our fatty acid analysis showed that vaccenic acid was the lowest for slaughter d 125.

Fatty Acid Profile

Results from our study showed that supplementing cattle DDGS while grazing and increasing days on a high concentrate diet did not affect ($P > 0.05$) any of the fatty acids tested (Table 2.10). Other studies (Camfield et al., 1997; Duckett et al., 1993) have shown that increasing days on a high concentrate diet changes fatty acid profile. They saw an increase in palmitic and oleic acid, two common fatty acids in beef. Their results showed increasing time on feed, linearly decreased SFA's. MUFA's increased linearly while PUFA's remained about the same as d on feed increased. Our study showed no significant difference ($P > 0.05$), in SFA, MUFA, or PUFA as days on feed increased. In conclusion, supplementing cattle DDGS while grazing or increasing the number of days on feed did not affect fatty acid profile.

Summary

In summary, this research found that supplementing DDGS to cattle grazing late season low quality forage increased average daily gain while grazing. However, control cattle showed improved performance during the finishing period as evidenced by having higher ADG, and better efficiency's. DDGS cattle showed heavier final weights at each slaughter day, thus resulting in DDGS cattle having heavier carcass weights and larger LM area. Supplementing DDGS had no effect on meat quality traits. Cattle placed on feed for a shorter periods of time should be feed to 100 d as this research showed that cattle showed improved fat color to 100 d. Increasing days on feed increased marbling score and carcass weight. In addition, carcass fat percentage also increased as days on feed increased. No differences were seen in any palatability trait, fatty acid or WBSF value for any slaughter day treatment. DDGS supplementation can be utilized to improve gain on low quality forage. Supplementing DDGS while grazing can

effectively decrease the number of days cattle are on a high concentrate diet. This research showed that to optimize performance, carcass characteristics and meat quality, cattle should be fed to at least 100 d.

Table 2.4 Least squares mean values for performance data for the main effects of grazing supplementation.

Trait	Grazing supplementation		
	Control	DDGS	SEM ¹
Pens	6	6	
Initial BW, kg	366.9 ^a	367.1 ^a	0.224
ADG, 0-45 d ² , kg	0.918 ^b	1.54 ^a	0.070
ADG, 45-90 d ³ , kg	-0.263 ^b	0.655 ^a	0.062
ADG, 0-90 d ⁴ , kg	0.345 ^b	1.11 ^a	0.053
Total gain ⁵ , kg	31.11 ^b	100.2 ^a	4.756
Final BW, kg	398.3b ^a	467.2 ^a	5.19
Average DDGS DM Intake, 0 to 45 d, kg	-----	3.4	-----
Average DDGS DM Intake, 45 to 90 d, kg	-----	4.1	-----
Average DDGS DM Intake 0 to 90 d, kg	-----	3.8	-----

^{a-b}Means within a row with different superscripts differ ($P < 0.05$).

¹Standard error of the mean.

²Average daily gain for first 45 d while grazing native pasture.

³Average daily gain for last 45 d while grazing native pasture.

⁴Average daily gain for entire 90 d while grazing native pasture.

⁵Total weight gained while grazing native pasture

1 **Table 2.5 Least squares mean values of feedlot performance for the main effects of grazing supplementation and days on feed.**

Trait	Grazing Treatment			<i>P</i> -Value	Days on Feed				<i>P</i> -Value	
	Control	DDGS	SEM ¹		75	100	125	SEM	Linear	Quadratic
Pens	6	6			4	4	4			
Final BW, kg	542.1	588.1	5.16	<0.001	528.5 ^c	566.2 ^b	600.6 ^a	6.32	<0.001	0.83
ADG ² , kg	1.67	1.45	0.031	<0.01	1.55	1.63	1.50	0.03	0.390	0.076
Avg. DMI ³ , kg	12.5	12.5	0.174	0.91	12.5	12.4	12.6	0.21	0.751	0.473
Gain:feed ⁴	0.132	0.117	0.005	0.02	0.125	0.128	0.120	0.00	0.550	0.493

2 ^{a-c}Means within a row under a common main effect with different superscripts differ (*P*<0.05).

3 ¹Standard error of the mean

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7 **Table 2.6 Least squares mean values for carcass characteristics for main effects of grazing supplementation and days on feed.**

Trait	Main Effects									
	Grazing supplementation			<i>P</i> -Value	Days on Feed				<i>P</i> -Value	
	Control	DDGS	SEM ¹		75	100	125	SEM ¹	Linear	Quadratic
Pens	6	6		4	4	4				
HCW, kg	330.4	362.5	3.27	<0.001	319.3 ^c	348.2 ^b	371.9 ^a	8.85	<0.001	0.61
Dressing percentage, %	61.1	61.7	0.003	0.25	60.5 ^b	61.7 ^a	62.0 ^a	0.004	0.05	0.47
Yield grade	2.1	2.2	0.08	0.28	2.1	2.1	2.4	0.10	0.10	0.28
Fat thickness, mm	7.0	8.1	0.46	0.16	6.8 ^b	7.0 ^{ab}	8.9 ^a	0.56	0.04	0.28
LM, cm ²	85.4	90.4	1.15	0.02	84.2 ^b	88.5 ^{ab}	91.1 ^a	1.40	0.01	0.65
Kidney pelvic heart fat, %	1.86	1.96	0.03	0.06	2.08 ^b	2.07 ^b	2.36 ^a	0.10	0.02	<0.01
Marbling Score ²	387.6	399.6	9.08	0.37	363.6 ^b	407.1 ^a	409.5 ^a	11.12	0.02	0.18
% Moderate	3.05	2.77	1.40	0.89	0	2.03	6.66	1.71	0.03	0.57
% Modest	8.72	15.27	3.34	0.21	6.28	14.77	14.58	4.09	0.21	0.43
% Small	28.05	25.00	4.80	0.66	21.21	36.74	21.66	5.87	0.95	0.07
% Slight	55.42	52.77	1.55	0.69	70.07	44.31	47.91	5.57	0.03	0.07
% Traces	4.72	4.16	2.18	0.86	2.08	2.08	9.16	2.67	0.11	0.32

8 ^{a-c}Means within a row under a common main effect with different superscripts differ ($P < 0.05$).9 ¹Standard error of the mean.10 ²Marbling score: small = 400 to 499; slight = 300 to 399

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14 **Table 2.7 Least squares mean values for carcass composition¹ equations and *longissimus* composition for the main effects of**
 15 **grazing and days on feed**

Trait	Main Effects									
	Grazing supplementation			<i>P</i> -Value	Days on feed				<i>P</i> -Value	
	Control	DDGS	SEM ²		75	100	125	SEM ²	Linear	Quadratic
Pens	6	6		4	4	4				
Carcass composition										
Protein,%	16.7	16.4	0.168	0.30	17.0 ^a	16.5 ^{ab}	16.0 ^b	0.261	0.011	0.920
Fat, %	25.5	26.6	0.452	0.16	24.2 ^b	25.0 ^b	28.9 ^a	0.554	0.009	0.060
Moisture, %	56.7	55.7	0.321	0.07	57.8 ^a	56.9 ^a	54.0 ^b	0.393	<0.001	0.087
<i>Longissimus</i> muscle composition										
Protein, %	22.8	23.0	0.118	0.38	23.7 ^a	22.5 ^b	22.6 ^b	0.145	0.002	0.010
Fat, %	5.38	5.41	0.359	0.94	5.11	4.81	6.28	0.440	0.110	0.150
Moisture, %	70.4	70.3	0.289	0.70	70.1 ^{ab}	71.3 ^a	69.7 ^b	0.353	0.420	0.020
Ash, %	1.35	1.36	0.023	0.84	1.45 ^a	1.34 ^b	1.29 ^b	0.028	0.006	0.395

16 ^{a-b}Means within a row under a common main effect with different superscripts differ ($P < 0.05$).

17 ¹Carcass composition percentages derived from Hankins and Howe (1946) prediction equations.

18 ²Standard error of the mean.

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20 **Table 2.8 Least squares mean values for instrumental¹ color of ribeye steaks and exterior fat covering for main effects of**
 21 **grazing supplementation and days on feed.**

Main Effects										
Trait	Grazing supplementation			P-Value	Days On Feed				P-value	
	Control	DDGS	SEM ²		75	100	125	SEM ²	Linear	Quadratic
Pens	6	6			4	4	4			
<i>Longissimus</i> lean L*	42.4	42.8	0.244	0.69	42.9	42.2	42.8	0.298	0.90	0.11
<i>Longissimus</i> lean a*	28.4	28.3	0.218	0.31	28.0	28.6	28.3	0.267	0.48	0.18
<i>Longissimus</i> lean b*	20.0	19.8	0.278	0.06	19.6	20.1	20.0	0.341	0.46	0.43
Exterior fat L*	79.0	79.9	0.281	0.07	78.0 ^b	80.8 ^a	79.7 ^a	0.344	0.01	0.004
Exterior fat a*	8.60	8.27	0.344	0.52	10.4 ^a	6.43 ^c	8.53 ^b	0.421	0.02	0.001
Exterior fat b*	15.4	15.3	0.290	0.77	17.1 ^a	14.3 ^b	14.6 ^b	0.356	0.002	0.01

22 ^{a-c}Means within a row under a common main effect with different superscripts differ ($P < 0.05$).

23 ¹L* lightness (0=black, 100=white); a* redness/greenness (positive values = red, negative values = green); b* yellowness/blueness
 24 (positive values= yellow, negative values=blue)

25 ²Standard error of the mean.

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33 **Table 2.9 Least squares mean values for palatability and Warner-Bratzler Shear Force for the main effects of grazing**
 34 **supplementation and days on feed.**

Trait	Main Effects									
	Grazing supplementation			<i>P</i> -value	Days on feed				<i>P</i> -Values	
	Control	DDGS	SEM ¹		75	100	125	SEM ¹	Linear	Quadratic
Pens	6	6			4	4	4			
Myofibrillar tenderness ²	6.2	6.2	0.07	0.18	6.3	6.2	6.0	0.09	0.08	0.77
Juiciness ³	5.6	5.6	0.04	0.54	5.6	5.6	5.6	0.05	0.94	0.28
Beef flavor intensity ⁴	5.6	5.6	0.03	0.25	5.6	5.6	5.6	0.03	0.35	0.79
Connective tissue amount ⁵	6.8	6.7	0.06	0.37	6.8	6.8	6.7	0.07	0.30	0.86
Overall tenderness ⁶	6.2	6.2	0.07	0.469	6.3	6.3	6.1	0.09	0.21	0.66
Off flavor intensity ⁷	7.5	7.6	0.04	0.18	7.5 ^{ab}	7.7 ^a	7.4 ^b	0.05	0.31	0.02
Warner-Bratzler shear force, kg	3.47	3.46	0.090	0.14	3.27	3.52	3.62	0.110	0.06	0.59

35 ^{a-b}Means within a row under a common main effect with different superscripts differ ($P < 0.05$).

36 ¹Standard error of the mean.

37 ²8=Extremely tender, very tender, moderately tender, slightly tender, slightly tough, moderately tough, very tough, 1=extremely
 38 tough.

39 ³8=Extremely juicy, very juicy, moderately juicy, slightly juicy, slightly dry, moderately dry, very dry, 1=extremely dry.

40 ⁴8=Extremely intense, very intense, moderately intense, slightly intense, slightly bland, moderately bland, very bland, 1=extremely
 41 bland.

42 ⁵8=None, practically none, traces, slight, moderate, slightly abundant, moderately abundant, 1=abundant .

43 ⁶8=Extremely tender, very tender, moderately tender, slightly tender, slightly tough, moderately tough, very tough, 1=extremely
 44 tough.

45 ⁷8=None, practically none, traces, slight, moderate, slightly abundant, moderately abundant, 1=abundant.

46

47 **Table 2.10 Least squares mean values for fatty acids for the main effects of grazing supplementation and days on feed.**

Fatty Acid ¹	Main Effects									
	Grazing supplementation			P-Value	Days on feed				P-value	
	Control	DDGS	SEM ²		75	100	125	SEM ²	Linear	Quadratic
Pens	6	6		4	4	4				
14:0, myristic, %	2.73	2.68	0.095	0.68	2.57	2.79	2.81	0.117	0.18	0.76
16:0, palmitic, %	24.19	24.21	0.271	0.94	23.84	24.27	24.49	0.333	0.21	0.81
17:0, margaric, %	1.48	1.22	0.052	0.06	1.25	1.29	1.52	0.061	0.14	0.02
18:0, stearic, %	16.48	16.44	0.369	0.20	17.17	16.08	16.14	0.45	0.15	0.34
14:1, myristoleic, %	0.425	0.431	0.021	0.89	0.36	0.47	0.45	0.03	0.11	0.17
16:1, palmitoleic, %	3.16	3.06	0.051	0.94	3.04	3.22	3.06	0.062	0.79	0.06
18:1n-9t, elaidic, %	4.38	5.06	0.234	0.23	4.98	4.52	4.67	0.287	0.47	0.24
18:1n-9c, oleic, %	34.00	33.77	0.904	0.86	33.29	33.51	34.85	1.10	0.35	0.69
18:1n-7c, vaccenic, %	1.55	1.38	0.060	0.09	1.41	1.58	1.40	0.073	0.89	0.09
18:2n-6c, linoleic, %	7.16	7.34	0.346	0.42	7.74	7.57	6.43	0.424	0.74	0.15
18:3n-3 α -linolenic %	0.32	0.32	0.018	0.89	0.35	0.33	0.29	0.022	0.12	0.76
Total saturated, %	45.83	45.65	0.701	0.83	45.79	45.47	46.01	0.859	0.86	0.69
Total monounsaturated, %	44.83	44.87	0.906	0.64	44.26	44.58	45.70	1.11	0.39	0.77
Total polyunsaturated, %	9.2	9.47	0.481	0.14	9.93	9.94	8.27	0.589	0.09	0.28
Total fatty acid	4.65	4.79	0.332	0.77	4.43	4.13	5.60	0.406	0.08	0.12

48 ¹Calculated percent of total fatty acid.49 ²Standard error of the mean.

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Appendix A - Supplemental Data

175 **Table A.1 Effects of DDGS supplementation and days on feed on finishing performance.**

Item	Grazing Treatment ²	
	Control	DDGS
Pens	6	6
Initial BW, kg	382.3	448.5
Day 25	442.4	510.0
Day 50	468.4	521.3
Day 75	506.1	554.6
Day 100	542.4	591.2
Day 125	586.7	614.4
Finishing Day 0 to 25		
ADG, kg	2.48	2.46
Avg. DMI, kg	12.1	11.2
Gain:feed	0.22	0.21
Total gain, kg	62.0	61.5
Finishing Day 25 to 50		
ADG, kg	0.95	0.45
Avg. DMI, kg	13.1	12.3
Gain:feed	0.07	0.03
Total gain, kg	24.0	11.2
Finishing Day 50 to 75		
ADG, kg	1.56	1.33
Avg. DMI, kg	13.3	13.3
Gain:feed	0.11	0.10
Total gain, kg	37.6	33.3
Finishing Day 75 to 100		
ADG, kg	1.39	1.36

Avg. DMI, kg	12.4	12.8
Gain:feed	0.12	0.11
Total gain, kg	34.85	34.04
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Finishing Day 100 to 125		
ADG, kg	1.43	1.23
Avg. DMI, kg	12.2	11.3
Gain:feed	0.12	.011
Total gain, kg	35.8	30.9
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