EFFECTS OF DISTILLERS DRIED GRAINS WITH SOLUBLES SUPPLEMENTATION TO YEARLING HEIFERS GRAZING NORTHERN GREAT PLAINS RANGELAND; IMPACTS ON SUBSEQUENT FEEDLOT PERFORMANCE AND MEAT QUALITY

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ABSTRACT

Eighty two yearling heifers (319.5 ± 1.03 kg) were utilized in a completely randomized design to evaluate the effects of distillers dried grains with solubles (**DDGS**) supplementation on animal performance while grazing on rangeland of the Northern Great Plains; and subsequent feedlot performance, carcass characteristics, and meat quality traits. Treatments were 1) 0% DDGS supplementation (**CONT**) or 2) 0.6% of BW DDGS supplementation (**SUP**). Heifers received treatments for 70 d while grazing then acclimated to and fed a common corn based finishing diet for 109 d. Carcass characteristics were assessed by trained personnel, and strip loins were transported back to North Dakota State University for retail display life, tenderness determination, and trained sensory panel. Supplementation of DDGS during grazing improved ADG of yearling heifers with no effect on feedlot performance or carcass characteristics, but did improve tenderness and steak sensory attributes.

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LIST OF ACRONYMS

ADF……..Acid detergent fiber

ADG……Average daily gain

AMSA…….....American Meat Science Association

AOAC……..…Association of Official Analytical Chemists

BW…….Body weight

°C……..….Celsius

CGF…….Corn gluten feed

CGM……...Corn gluten meal

CGREC…….Central Grasslands Research and Extension Center

cm…….Centimeter(s)

CP…….Crude protein

d……...Day

DDG……Distillers dried grains

DDGS……Distillers dried grains with solubles

DIP……Degradable intake protein

DM……Dry matter

DMI……Dry matter intake

DOF……..Days on feed

DRC……...Dry rolled corn

g……Gram(s)

G:F…….Gain-to-feed ratio

GLM…….General linear model

h……Hour(s)

ha……...Hectare(s)

HCW……....Hot carcass weight

IMPS……...Institutional Meat Purchase Specifications

IU……International unit

IVDMD……In vitro dry matter digestibility

IVOMD……..In vitro organic matter digestibility

kg……Kilogram(s)

KPH……..Kidney, pelvic, and heart fat

LM……Longissium muscle

m^2…….....Meter(s) squared

mm……Millimeter(s)

mm/min……..Millimeter per minute

MP……...Metabolizable protein

MUFA……Monounsaturated fatty acid

NDF…….....Neutral detergent fiber

NRC……National Research Council

PUFA……Polyunsaturated fatty acid

PUFA:SFA…….....Polyunsaturated fatty acid-to-saturated fatty acid ratio

RFA……Renewable Fuels Association

SAS……..Statistical Analysis Software

SBM…….Soybean meal

TBARS……....Thiobarbituric acid reactive substances

TDN……...Total digestible nutrients

UIP……Undegradable intake protein

USDA……United State Department of Agriculture

WBSF……Warner-Bratzler shear force

CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW

Introduction

Some yearling production systems allow smaller framed, light weight calves added time for growth and development through wintering and pasture grazing prior to finishing. Supplementation while grazing becomes an important management strategy when when forage quality and quantity is typically lowest during the summer period when cool-season grasses are maturing and prior to fall regrowth of lush plant material (Caton and Dhuyvetter, 1997). Supplementation may improve animal performance by offsetting nutritional deficiencies in forage quality or quantity or by stretching existing forage supplies (Horn and McCollum, 1987; Caton and Dhuyvetter, 1997).

With the expansion of the ethanol industry, 39 million metric tons of livestock feed was produced in 2011 with 90% of this feed being distillers grains (RFA, 2012). Distillers dried grains with solubles (**DDGS**) has been extensively researched as an energy and protein source for grazing cattle. Removal of starch during ethanol production increases protein, fat, fiber and phosphorus concentrations 3-fold when compared to corn (Klopfenstein et al., 2008). Supplementation of DDGS has been shown to increase ADG and final BW during grazing (Morris et al., 2006); but may also be used to replace forage at a rate of approximately 50% thus allowing for increased stocking rates (MacDonald et al., 2007).

Once grazing has been terminated, cattle may be transported for finishing; however the animal's previous plane of nutrition must be taken into consideration (Drouillard and Kuhl, 1999). Reuter and Beck (2012) found that several factors such as forage type and quality, type and amount of supplementation, rate of gain, or animal related factors may have influential effects on subsequent feedlot performance. Perry et al. (1971) found that for each additional kg

of supplement cattle received during grazing, they gained 0.2 kg less on the same daily concentrate intake during the finishing period; and steers fed the highest amount of concentrate during grazing required fewer days on feed (**DOF**) to reach market weight. Stickel (2009) supplemented DDGS at 1% of BW to steers grazing late season native forage and found that unsupplemented steers had increased ADG and G:F during finishing while supplemented steers had increased final body weights.

Inclusion of DDGS in beef finishing rations has shown to increase formation of PUFA in meat leading to a faster oxidation or reduced a* (muscle redness) during retail shelf life (Gill et al., 2008; Depenbush et al., 2009). Zerby et al. (1999) correlated a* values to consumer acceptance of the product, with increased a* values leading to increased consumer acceptance. A consumer is more likely to buy a meat product that is bright cherry red in color (increased a*) versus a meat product that is discolored and brown (decreased a*). The following literature review will evaluate supplementation practices during grazing on the comprehensive impacts throughout the entire management system.

Literature Review

Ethanol Production and Ethanol Co-products

Farmers in the United States had one of the fourth largest corn crops recorded in history in 2011 (RFA, 2012). Five billion gross bushels of corn produced 13.9 billion gallons of ethanol and 39 million metric tons of livestock feed which over 90% were distillers grains (RFA, 2012). Ethanol can be made from a range of available feedstock, but the highly fermentable starch content in corn makes this feedstock the primary grain of choice (Hoffman and Baker, 2010). The removal of starch concentrates remaining nutrients in co-products (Hoffman and Baker, 2010). Corn is converted into ethanol by wet milling, dry grinding, or dry milling (Rausch and

Belyea, 2006) with different co-products being produced through each production process (Hoffman and Baker, 2010).

Upon entering the wet milling process, the corn kernel is fractionated into several components resulting in several co-products: corn gluten meal (**CGM**), corn gluten feed (**CGF**), crude corn oil, and germ meal (Rausch and Belyea, 2006). Fractionation does not occur during the dry grinding process; therefore, distillers grains are the only primary co-product (Rausch and Belyea, 2006). For the purpose of this discussion we will focus mainly on the dry grinding production process, specifically DDGS.

One bushel of corn will produce 10.22 liters of ethanol, 8 kg of DDGS, and 8 kg of carbon dioxide (Lardy, 2003). Dry grinding process utilizes the entire corn kernel for fermentation (Leupp, 2008), with 70% of the kernel comprised of starch that is converted to glucose and fermented into ethanol (Bothast and Schlicher, 2005). Upon entering the dry grinding process, whole corn kernels are ground by either a hammer mill or roller mill (Figure 1.1), facilitating water penetration during the subsequent cooking process. The dry granular meal is mixed with water to form slurry. The pH is adjusted to 6.0 and followed by the addition of alpha amylase which initiates breakdown of starch polymers to form a mash. Mash is cooked (approximately 104°C) using pressurized steam to rupture starch molecules, especially those of high molecular weight (Bothast and Schlicher, 2005). The temperature falls to approximately 85°C for a short period of time to liquefy the mash to further reduce starch polymers. After cooling the mash, pH is adjusted to 4.5 and glucoamylase is added to convert the liquefied starch into glucose and maltose (Bothast and Schlicher, 2005). Mash is transferred to fermenters where yeast (*Saccharomyces cerevisiae*; Knauf and Kraus, 2006) is added to initiate fermentation, which requires 48 to 72 h (Bothast and Schlicher, 2005).

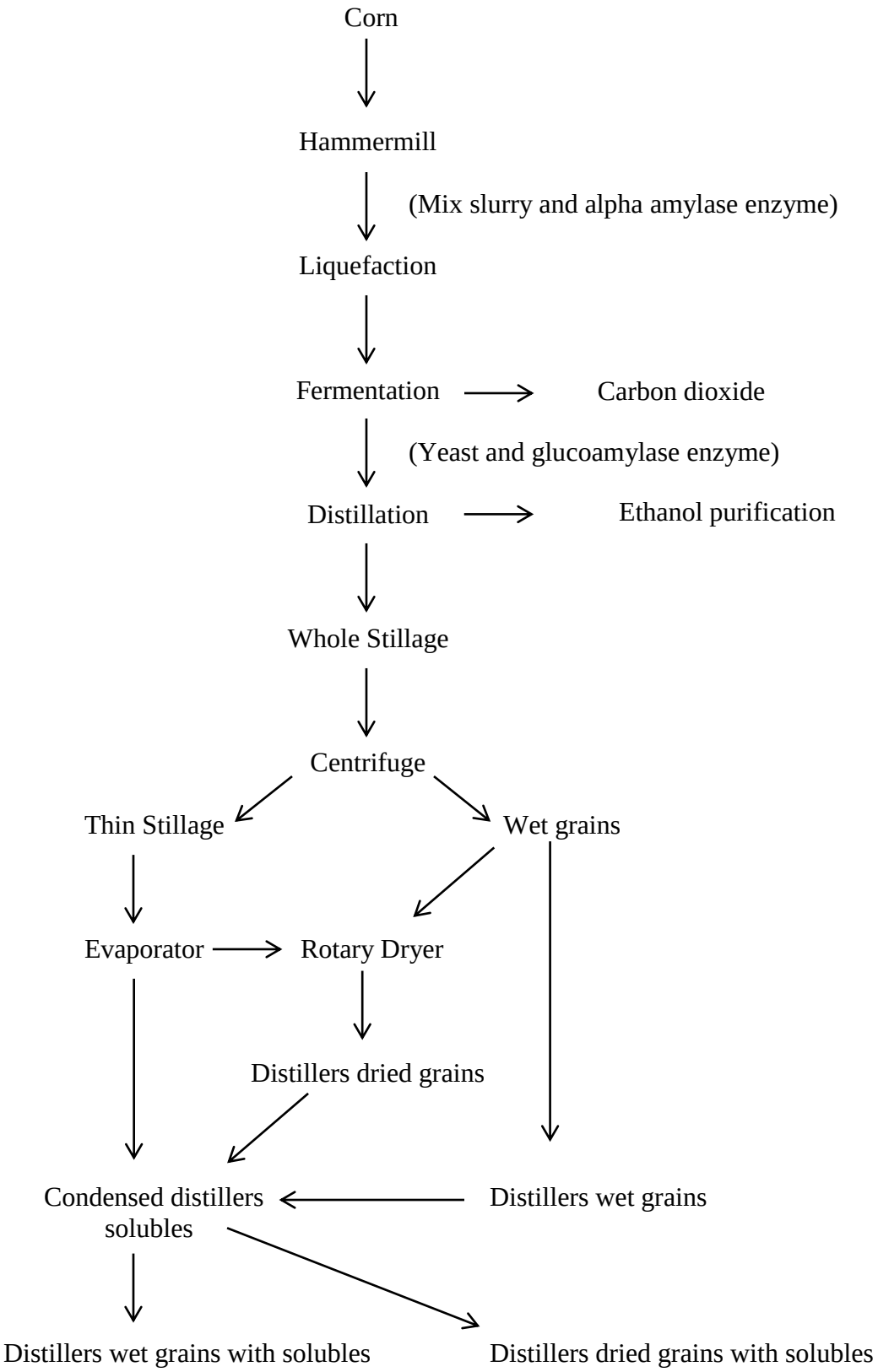

Figure 1.1. Flow diagram outlining the production of ethanol from corn.

During fermentation, carbon dioxide is formed lowering the pH to below 4, which is important for increasing the activity of glucoamylase and inhibiting the growth of contaminating bacteria (Bothast and Schlicher, 2005). At the completion of fermentation, the resulting material is referred to as 'beer'. Alcohol and water vaporize at different temperatures (78°C and 100°C, respectively) allowing for the separation of ethanol from solids, and water during distillation (Bothast and Schlicher, 2005). Solids and water portion, known as whole stillage mixture, consists of the non-fermentable components of corn, yeast and water. The whole stillage is centrifuged to separate the liquid (thin stillage) from solids (wet grains). Using an evaporator, thin stillage is concentrated into syrup and mixed with wet grains. Wet grains may be sold "as is" or go through a rotary dryer and be combined with condensed distillers solubles to be sold as DDGS (Raush and Belyea, 2006).

Distillers Grains

Nutrient Content

During the dry grinding process, starch content is removed to ferment ethanol while the remaining nutrients recovered in stillage. These recovered nutrients, protein, fat, and fiber are concentrated proportionally due to the fermentation of starch to ethanol (Neville, 2010); thus nutrient concentrations are increased 3-fold in DDGS compared to corn (Klopfenstein et al., 2008). Distillers dried grains with solubles contain, on a DM basis, approximately 30% CP, 11% ether extract, 52% rumen undegradable intake protein (**UIP**; % of CP), and 46% NDF (NRC, 2000). Table 1.1 contains the nutrient composition of corn and ethanol co-products.

Table 1.1. Nutrient composition of corn and ethanol co-products[1]

Item	DRC[2]	DDG[3]	WDG[4]	DDGS[5]	WDGS[6]	CDS[7]
DM, %	90.0	89.0	30.0	90.4	34.9	35.5
	----------DM basis----------					
CP, %	9.8	30.0	32.5	33.9	31.0	23.8
UIP[8], % of CP	60.0	55.0	52.0	52.0	52.0	20.0
Fat, %	4.5	9.0	10.0	9.0	10.0	12.0
TDN, %	90.0	82.5	126.0	101.0	112.0	112.0
Phosphorus, %	0.32	0.40	0.65	0.51	0.84	1.38
Sulfur, %	0.12	0.48	0.58	0.42	0.58	0.66

[1]Data are adapted from NRC (2000), Lardy (2003), Rausch and Belyea (2006), and Leupp (2008)
[2]Dry rolled corn
[3]Distillers dried grains
[4]Wet distillers grains
[5]Distillers dried grains with solubles
[6]Wet distillers grains with solubles
[7]Condensed distillers solubles
[8]Undegradable intake protein

Production Systems

Once calves are weaned, there are two major types of production systems. Yearling systems allow adequate time for growth and development through wintering and pasture grazing prior to finishing. Calf-fed systems place cattle directly on high concentrate diet until slaughter. Final market weight will determine which type of system producers will use. Smaller framed, light weight calves are placed into yearling production systems to allow extra time to finish within carcass specifications. If placed directly on feed light weight calves will finish at weights too low which may incur less profit or reductions (Lardy, 1998). Contrary, large framed exotic cattle do not need additional time for growth and development to meet market standards, and are best suited for calf-fed systems (Lardy, 1998). Any additional time given to this class of cattle may result in overweight discounts (Lardy, 1998; Griffin et al., 2007).

Griffin et al. (2007) analyzed an 8-year study at University of Nebraska comparing yearling and calf-fed systems for finishing performance and economics. During finishing, yearlings consumed more DM/d and had increased ADG leading to heavier final BW (Griffin et

al., 2007). However, calf-feds consumed more total DM during finishing due to being fed 78 d longer and were 16.7% more efficient than yearlings (Griffin et al., 2007). In a review of literature, Reuter and Beck (2012) summarized similar findings with yearling systems having increased daily feed intake and ADG, while calf-fed systems more feed efficient. Yearlings had lower input cost during winter, achieving compensatory gain during summer grazing resulting in cheap gains; therefore increasing total weight gain during production (Lardy, 1998). Economically, yearling systems led to a $60.04 added return for live weight and $41.91 for grid values, leading to a higher profitability than calf-feds (Griffin et al., 2007).

Grazing Systems

Grazing systems are designed to increase forage production through periodically resting pastures during growing season, managing uniform grazing distribution, and increasing stocking rate to reduce animal selectivity (Briske et al., 2008). All of these practices allow for adequate resources to reach vital forage species, and thus be utilized more efficiently by livestock (Briske et al., 2008). There has been a lot of debate on whether or not specialized grazing systems incur specific advantages when compared to continuous grazing systems. Specialized grazing systems are recurring periods of grazing, deferment, or rest of two or more pastures on a scheduled basis; while, continuous grazing allows grazing to any portion, unrestricted throughout the grazing season (Heady, 1970). This portion of the literature review will focus on comparing rotational grazing to continuous grazing.

Holechek et al. (1998) presented an excellent review on the potential impacts and pitfalls of implementing a grazing system with climate, topography, vegetation, kind of livestock grazed, and labor requirements being of specific importance to this decision. However, Briske et al. (2008) emphasized that when making comparisons between grazing systems, management is a

confounding variable that may affect the success of either system. Poor management will make any grazing system seem undesirable, while proper management may be able to meet production goals in either rotational or continuous grazing systems (Briske et al., 2008). In the Great Plains prairie, continuous grazing has been shown to be superior to rotational by reducing selectivity of forage species during critical growing season which lessens grazing pressure on grasses and minimizes livestock disturbance (Holechek et al., 1998). Briske et al. (2008) compiled data from several grazing studies for a comprehensive assessment of rotational grazing compared to continuous grazing at all stocking rates on plant production, livestock production per head, and livestock production per land area. All results from the variables that were assessed were characterized as either greater for continuous grazing compared to rotational (CG > RG), greater for rotational grazing compared to continuous (RG > CG), or equal if differences did not exist between continuous and rotational grazing (CG = RG) (Briske et al., 2008). The majority of the studies found that rotational and continuous grazing were similar for plant production, livestock production per head, and livestock production per land area (Figure 1.2), which leads back to the

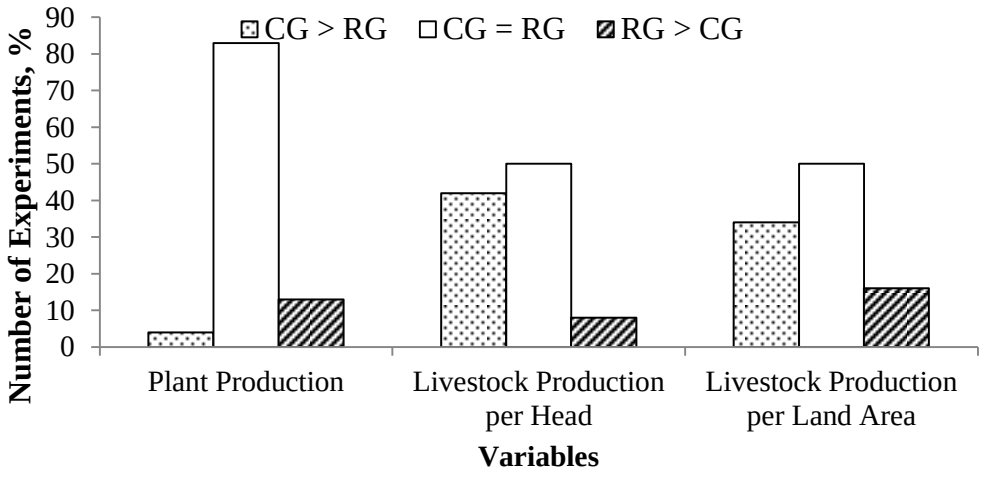

Figure 1.2. Percentage of published grazing experiments comparing continuous and rotational grazing on plant production, livestock production per head, and livestock production per land area (Briske et al., 2008).

concept of proper management skills when implementing either grazing system.

Stocking Rate

Stocking rate is the amount of land allocated to a given animal during the grazing season, and is one of the most critical management decisions that can influence vegetation, livestock, and economic return (Holechek et al., 1998). Stocking rate may be based on a prescribed or flexible system. Briske et al. (2008) suggested a flexible stocking rate so as to be adjusted throughout the grazing season in order for livestock to be maintained through periods of minimal forage growth. Lower stocking rates improve forage production since fewer animals are grazing; however more forage is wasted resulting in decreased grazing efficiencies (Smart et al., 2010). Higher stocking rates may decrease animal productivity due to declining forage production (Smart et al., 2010), leading to reduced forage intake (Holechek et al., 1998). However, higher stocked pastures may lead to improved grazing efficiencies since all forage is consumed (Smart et al., 2010).

Supplementation while Grazing

Energy, protein, phosphorus and vitamin A are nutrients often most limiting for grazing livestock (Holechek et al., 1998). Therefore, supplementation may be considered to improve animal performance by offsetting nutritional deficiencies in forage quality or quantity or stretching the existing forage supplies (Horn and McCollum 1987; Caton and Dhuyvetter, 1997).

Substitution

Supplementation may reduce forage intake by substituting the supplement into the animal's diet in exchange for forage (Caton and Dhuyvetter, 1997), therefore stretching the existing forage supply. This practice proves beneficial for cow-calf producers since increasing the number of grazing animals on a fixed land base is more vital than improving animal performance. Several factors affect the rate of substitution such as forage quality, supplement

type, and supplementation quantity (Stafford et al., 1996). With lower quality forage, protein supplementation generally increases forage intake and utilization; while energy supplementation has an opposite effect (Horn and McCollum, 1987). Reasons for this reduction on intake and utilization with energy supplementation have been attributed to declining ruminal pH associated with nonstructural carbohydrates shifting the proportion towards greater amylolytic and lower cellulolytic microbial population (Caton and Dhuyvetter, 1997; Kunkle et al., 2000). Distillers dried grains are high in digestible fiber, protein, and energy and low in nonstructural carbohydrates when supplemented at $< 1\%$ of BW daily resulted in reduced forage intake (Kunkle et al., 2000; Loy et al.; 2007; MacDonald et al., 2007; Leupp et al., 2009). Additionally, MacDonald et al. (2007) supplemented heifers (treatments: distillers dried grains [**DDG**], CGM, and corn oil) grazing actively growing forage and found that DDG replaces forage at a rate of approximately 50% of the amount supplemented for cattle receiving 7.5 g of DDG per kg of BW. Furthermore, MacDonald et al. (2007) suggested that this reduction in forage intake would allow for possibly 10 to 20% increased stocking rates by supplementing DDG from 0.50 to 0.75% of BW daily to cattle.

Supplemental Protein

Grazing cattle may be subjected to MP deficiency due to protein in actively growing forages being highly ruminal degradable (Klopfenstein et al., 2001). Metabolizable protein is the true protein that is either degraded in the rumen (degradable intake protein; **DIP**) or the portion of crude protein that is not degraded in the rumen and thus available for post-ruminal digestion (Klopfenstein et al., 2001). When either DIP or UIP is limiting, animal performance may suffer. Supplemental protein may be beneficial by improving animal performance by increasing forage

intake and utilization in either low quality forage (≤ 7%; Paterson et al., 1996) or when increasing forage maturity leads to declining forage quality (Greenquist et al., 2009).

Determination of when to supplement is difficult due to cattle selecting a higher quality diet than present in the average standing crop (Paterson et al., 1996); and the variability of forage's DIP and UIP throughout grazing months (Lardy et al., 1996). Degradable intake protein comprises the majority of the plant's total crude protein (Lardy et al., 1996); and often becomes limiting as forages mature (Figure 1.3). Ruminal microorganisms need DIP in order to

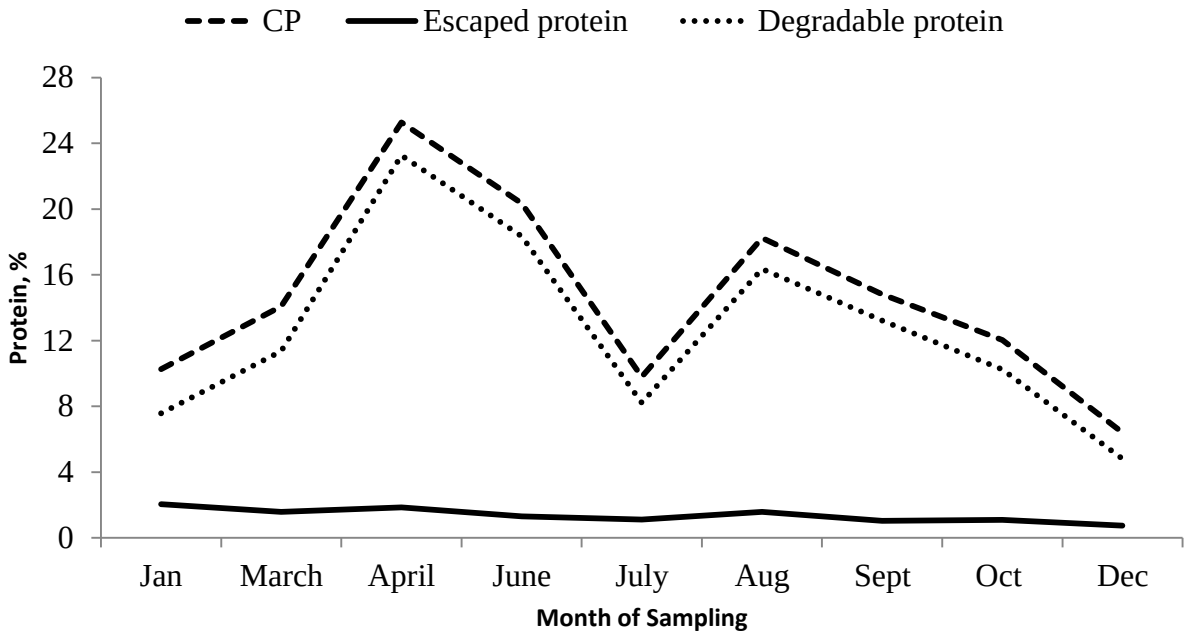

Figure 1.3. Changes in total crude protein, degradable protein, and escaped protein for subirrigated meadow forage samples throughout the year in western Nebraska (Lardy et al., 1996)

effectively grow and stimulate microbial digestion and forage utilization (Paterson et al., 1996; Drouillard and Kuhl, 1999). Amylolytic microorganisms out-compete cellolytic microorganisms for DIP which suggests the reason why forage digestion decreases when high amounts of starch are supplemented to lower quality forages (Paterson et al., 1996). However, over-supplying DIP has minimal effects on the MP status of the animal; and UIP supplementation must be

considered. Paterson et al. (1996) suggested that inconsistencies in protein supplementation research may be attributed to supplying additional DIP when UIP is actually limiting. Similarly to DIP, UIP is highest in actively growing forages (Lardy et al., 2004), but declines with the onset of maturity. MacDonald et al. (2007) supplemented UIP equal to the concentration in DDGS to heifers grazing smooth bromegrass pasture and found that the additional UIP found in DDGS resulted in one-third of the increased gains. This suggests that increased gains obtained when supplementing DDGS may be due to the heifer's response to UIP meeting a MP deficiency.

Supplemental Energy

Energy requirements for cattle are usually based upon confinement research studies which severely underestimate the amount of energy expended for increased maintenance and work associated with grazing cattle (Caton and Dhuyvetter, 1997). Cost of locomotion while grazing increases energy demands associated with muscular work (Caton and Dhuyvetter, 1997), and potentially increases maintenance requirements up to 50% when extensively grazing hilly pastures (Commonwealth Scientific and Industrial Research Organization, 1990). National research council (2000) states forage quality, forage availability, topography, weather distribution of water, and genotype as additional factors that need to be considered when evaluating energy requirements for grazing animals. For example, when forage availability starts to decline, grazing time and work associated with grazing increases (Caton and Dhuyvetter, 1997).

In order to meet increased energy demands of grazing animals, supplemental energy in the form of grains, readily digestible fiber sources and high-quality forages are provided during periods of summer forage quality declines or winter months (Caton and Dhuyvetter, 1997).

Energy supplementation may decrease forage intake and utilization allowing for increased stocking densities of grazing pastures which is important when stretching limited forage supplies or dealing with fixed land base (MacDonald et al., 2007). Montgomery et al. (2003) supplemented dry rolled corn (**DRC**) with a self-limiter (Accuration/Cattle Limiter; Purina Mills, LLC, St. Louis, MO) to steers grazing early-season, native range with supplemented pastures being over-stocked by 34%. Supplemented steers had increased ADG through the grazing season when compared to non-supplemented steers and supplemental energy increased forage quantity after being grazed for 30 d compared to moderately stocked, non-supplemented pastures (Montgomery et al., 2003). Similarly, Buttrey et al. (2012) concluded that providing supplemental energy (DRC or DDG at 0.5% of BW) decreased forage intake, allowed for a potential 10 to 12.5% increase in stocking rates over the course of grazing season compared to no supplement.

Protein: Energy Interactions

The classification of supplements as either protein or energy can be unclear, and often unimportant, since feeds may contain both protein and energy sources (Bowman and Sanson, 1996). For instance, protein supplements contain similar levels of energy when compared to common energy supplements; therefore importance should be placed not on the classification, but instead the interaction between protein and energy levels (Bowman and Sanson, 1996). If CP is deficient or ineffectively utilized in the diet than digestibility of carbohydrates may be decreased (Nocek and Russel, 1987) due to amylotyic microorganisms out-competing celloyltic microorganisms for DIP (Paterson et al., 1996).

DelCurto et al. (1990) conducted two studies investigating the interaction of differing levels of protein and energy supplements (treatments: low protein:low energy [LP-LE], low

protein:high energy [LP-HE], high protein:low energy [HP-LE], and high protein:high energy [HP-HE] to steers being fed dormant forage (2.9% CP). Results from these studies were contradictory, leading researchers to assume that previous plane of nutrition had an impact on protein:energy interactions. When steers were previously managed on low quality winter pastures, LP-HE treatment consumed 31% less forage than other treatments, and feeding high levels of supplemental protein or energy did not affect forage intake (DelCurto et al., 1990). Previous winter management may be a consideration for yearling systems when deciding to supplement during grazing; especially if the goal of the supplementation program is to stretch existing forage supply and manage cattle on a fixed land base. Contrary, steers previously managed on summer pastures with acceptable forage quality and availability had increased forage intake when fed high levels of protein supplementation, and decreased forage intake when increasing levels of energy were supplemented at low and high levels of protein (DelCurto et al., 1990). Therefore, previous plane of nutrition should be taken into consideration when deciding on supplementation practices.

Supplementation during Grazing on subsequent Feedlot and Carcass Characteristics

The beef industry is highly segregated and in order to maintain profitability the animal's previous plane of nutrition must be taken into consideration (Drouillard and Kuhl, 1999). This is especially vital when dealing with stocker cattle moving into finishing; since forage type and quality, type and amount of supplementation, rate of gain, or other animal related factors have enormous influences on subsequent feedlot performance (Reuter and Beck, 2012). For the purpose of this literature review, type and amount of supplementation affecting feedlot performance and carcass characteristics will be the main focus.

Felix et al. (2011) fed either corn or DDGS (65% DM in diet) to steers during the growing phase to achieve either 0.9 kg/d or 1.4 kg/d predicted BW gain and analyzed subsequent feedlot performance. Regardless of supplement, steers fed at a lower rate of gain (0.9 kg/d predicted BW gain) during the growing phase gained 14% faster during finishing; which could be explained by a compensatory response from restricted steers being more efficient during finishing (Felix et al., 2011). However, steers gaining 1.4 kg/d during the growing phase had reduced number of DOF and gained BW faster (Felix et al., 2011). In addition, Felix et al. (2011) noted that steers supplemented with DDGS had an increased number of DOF when compared to corn supplemented steers. This could be due to high inclusion (65% DM) of DDGS in the diet provided to steers during the growing phase, and such factors as excess nitrogen causing an adverse effect, or increased dietary sulfur could be responsible for this difference (Felix et al., 2011).

Buttrey et al. (2012) provided supplemental energy (DRC or DDGS at 0.5% of BW) to steers during winter wheat grazing and concluded that DMI, ADG, and total system gain were similar among all supplement treatments. Perry et al. (1971) noted that for each additional kg of supplement cattle received during grazing, they gained 0.2 kg less on the same daily concentrate intake during the finishing period. Owensby et al. (1995) supplemented sorghum (0, 0.91 kg, and 1.82 kg) to intensive stocked steers grazing northern Flint Hills and found that supplementation earlier in grazing (May to early-June) did not influence gain; however, ADG increased for supplementation treatments from early-June to Mid-July. In addition, no differences were seen for daily gain, feed intake, and G:F ratio during the finishing phase (Owensby et al., 1995).

Felix et al. (2011) supplemented to achieve differing rates of gain (0.9 and 1.4 kg/d predicted BW gain) to steers during grazing and found similar carcass characteristics. This implies when ADG is fed at a constant, energy source should not affect carcass characteristics, and more specifically marbling. Distillers dried grains with solubles supplementation increased marbling scores, and subsequent quality grade when compared to corn supplemented steers, even though corn supplemented steers had increased ADG during grazing when compared to DDGS supplemented steers (Felix et al., 2011). Stocker cattle that were under greater restriction during the growing phase had increased LM area, suggesting that greater energy restriction may cause a shift in relative tissue accretion rates resulting in less subcutaneous fat and more muscle accretion at a similar final BW (Felix et al., 2011).

Stickel (2009) assessed the impacts of supplementing DDGS at 1% of BW to steers grazing late season native forage and the impact of differing DOF on animal performance during finishing and carcass characteristics. Steers supplemented with DDGS during grazing had heavier HCW and increased LM area, although no differences were seen in USDA yield grades, marbling scores, KPH or quality grades (Stickel, 2009). Heavier HCW and increased LM area were attributed to increased gains while grazing since DDGS steers were heavier at the conclusion of grazing and maintained this live weight advantage throughout finishing (Stickel, 2009).

Meat Quality

Yield and Quality Grading

Beef yield and quality grading helps to assess the expected cutability and palatability attributes of carcasses (Aberle et al., 2001). Yield grades are objective measurements that are obtained from carcasses and measure the cutability or expected yield of trimmed retail cuts

(Aberle et al., 2001). Quality grades are subjective measurements that categorize meat on the basis of the flavor, juiciness, and tenderness; or known all together as palatability and the acceptability for consumer cuts (Aberle et al., 2001; Burson, 2005).

Beef yield grades take into account adjusted fat thickness, LM area, KPH, and HCW to identify differences in cutability among carcasses (Aberle et al., 2001). These measurements are placed into an equation to calculate numerical grades: 1, 2, 3, 4, and 5 (Aberle et al., 2001); with 1 having the highest and 5 the lowest percentage of boneless, closely trimmed retail cuts from the round, loin, rib and chuck (Burson, 2005). Fat thickness is one of the most influential factors when assessing percent retail cuts since excess fat must be removed for consumer acceptance which requires time and labor (Aberle et al., 2001). *Longissimus* muscle area must be taken into consideration in relation to carcass size; as carcass weight increases LM area must increase to maintain the same yield grade (Aberle et al., 2001). If LM area does not increase with carcass weight there is a lower ratio of muscle to bone, and estimated cutability will be decreased resulting in a higher yield grade (Aberle et al., 2001).

Quality grades indicate the expected palatability or eating satisfaction of the meat with marbling and maturity being two major considerations (Aberle et al., 2001; Burson, 2005). Marbling is visually assessed in the LM area between the 12^{th} and 13^{th} rib. The presence of marbling is assumed to have a positive influence on meat tenderness; however, research indicates a stronger effect of marbling on juiciness and flavor of meat than on tenderness (Aberle et al., 2001). Instead, maturity is one of the factors most closely related to meat tenderness (Aberle et al., 2001). Maturity is defined as the physiological age of the animal from which carcasses are produced with cartilage ossification, texture and lean color being key measurements (Aberle et al., 2001 and Burson, 2005). Increasing maturity leads to cartilage ossification in the hind

portion of the backbone beginning in the sacral and lumbar vertebrae, and progressing towards the forequarter (Burson, 2005). Texture of the lean can affect the shape of retail cuts with firmer textures being more attractive than softer cuts even though there is no direct contribution to palatability (Aberle et al., 2001). The total amount of fat surrounding the carcass contributes to overall firmness since chilling rate makes fat much firmer while muscles and carcasses with soft, oily fat lack firmness (Aberle et al., 2001). Color and structure of lean are evaluated because consumer acceptability reflects the appearance of retail cuts (Aberle et al., 2001). Myoglobin concentrations in the lean increase becoming a darker red as maturity of the animal increases; with younger animals having less myoglobin concentrations and very light red lean color (Aberle et al., 2001). More specifically, consumers object to dark meat or "dark cutters" because it often is associated with meat from old animals or with deteriorated meat (Aberle et al., 2001).

Dark cutters are produced from cattle that have been stressed for a relatively long period of time and produce dark red to almost black color lean with a sticky or gummy texture (Burson, 2005). Preharvest stress starts to deplete muscle glycogen stores and this glycogen depletion reduces lactic acid production resulting in an abnormally high pH (> 6.0) of postmortem muscle (Lister, 1988; Scanga et al., 1998). The high pH of postmortem muscle increases the water binding abilities which produce an undesirable dark, firm, and dry cut lean surface (Lister, 1988). This quality defect may reduce carcasses up to a full quality grade (Burson, 2005), but under proper management techniques may be reduced (Scanga et al., 1998). Intact heifers produce higher mean percentages of dark cutters across all pens and feedyards, which indicate a higher susceptibility for heifers to produce dark cutting carcasses than steers and spayed heifers (Scanga et al., 1998).

Tenderness

One of the most important factors affecting palatability or consumer's perception of palatability is tenderness (Morgan et al., 1991). Miller et al. (2001) conducted a consumer survey for establishing tenderness thresholds and suggested threshold classes of < 3.0, 3.0 to 4.3, and > 4.9 kg Warner-Bratzler shear force (**WBSF**), which results in customer satisfaction of 100, 93, and 25%; respectively. In addition, 78% of consumers said they would purchase steaks if the retailer guaranteed them tender; and were willing to pay a higher price for more tender steaks of the same USDA quality grade (Miller et al., 2001).

Leupp et al. (2009) included 30% DDGS during growing and finishing periods (treatments: 0:0, 30:0, 0:30, 30:30) to steers analyzing meat quality attributes and found no differences in WBSF or cooking loss across treatments. Segers et al. (2011) fed steers DDGS, soybean meal (**SBM**), or CGF (25% DM basis) from weaning until slaughter and found after 7 d of aging steers fed SBM were tougher than the other two treatments. However, after steaks were aged between 14 and 21 d there were no differences between treatments for WBSF (Segers et al., 2011). This implies that aging steaks may be able to overcome finishing nutritional regime. Contrary, no differences in WBSF values were seen when DDGS were supplemented at 1% of BW to steers during grazing (Stickel, 2009).

Sensory Analysis

Stickel (2009) found that supplementation of DDGS did not affect myofibrillar tenderness, connective tissue amount, overall tenderness, juiciness, beef flavor intensity, or off-flavor intensity. Similarly, Leupp et al. (2009) found no differences in tenderness from trained panelists when feeding 30% DDGS to steers during growing or finishing; however; steaks from

steers fed 30% DDGS during finishing tended to be juicier and more flavorful than steaks from control steers (no supplement).

Miller et al. (1987) analyzed palatability attributes of yearling steers supplemented energy for differing growth rates (low: 0.41 kg/d or high: 0.68 kg/d) as a pre-finishing diet. After 112 DOF, low and high energy steers had similar quality grades, but sensory panel ratings for tenderness still favored steaks from high energy steers. These findings suggest that differences in pre-finishing nutritional regimen may result in tenderness differences that are not counteracted by subsequent feeding of concentrates (Miller et al., 1987).

Depenbusch et al. (2009) fed differing levels of DGS (0, 15, 30, 45, 60, and 75%, DM basis) to heifers during finishing and found myofibrillar and overall tenderness increased linearly as dietary level of DGS increased from 0 to 75%. Steaks from heifers fed DGS at 45% and 60% were rated greatest by panelist in beef flavor intensity and least for heifers fed no DGS. However, juiciness, off-flavor intensity, and TBARS were not different between treatments (Depenbusch et al., 2009).

Retail Display Life

When making meat purchasing decisions, consumers associate discoloration as an indicator of freshness; which is why meat color is critical in retail display life (Mancini and Hunt, 2005). Myoglobin is the primary protein responsible for meat color and can be oxidized to undesirable brown color known as metmyoglobin (Zerby et al., 1999; Mancini and Hunt, 2005). Discoloration is referred to as the amount of surface area covered by metmyoglobin; oxygen partial pressure, temperature, pH, meat's reducing activity, and microbial growth are several factors that may influence metmyoglobin formation (Mancini and Hunt, 2005). In addition, diet affects muscle by altering glycogen storage, chilling rate, and antioxidant accumulation. All

together, these factors affect muscle pH, oxygen consumption, intrinsic color traits and metmyoglobin reducing activity (Marcini and Hunt, 2005).

Stickel (2009) supplemented DDGS to steers during grazing (1% of BW) and found no differences between L*, b*, or a* lean color values of the LM area. However, inclusion of 30% DDGS in growing diets for steers tended to reduce L* (muscle lightness) and b* (muscle yellowness) in steaks when compared to steaks from steers consuming 0% DDGS during growing (Leupp et al., 2009). Furthermore, Leupp et al. (2009) found a reduction in a* (muscle redness) values when DDGS were fed during the growing and finishing periods when compared with feeding DRC. Segers et al. (2011) noted that at d 9 in the retail display life steers supplemented with DDGS from weaning to finishing had a reduction in a* values when compared to SBM supplemented steers, and DDGS supplemented steaks were more discolored when compared to SBM and CGF steaks. This reduction may be due to the increase in oxidation of PUFA (Leupp et al., 2009).

Fatty Acid Profile

Cattle supplemented with DDGS have higher values of PUFA which are associated with increased oxidation resulting in a reduced shelf life (Segers et al., 2011). Buttrey et al. (2012) found no differences in total fat content of steaks supplemented with DDGS or DRC during winter wheat grazing. Stickel (2009) found that supplementing DDGS (1% of BW) to cattle while grazing did not affect any of the fatty acids tested.

Depenbusch et al. (2009) fed differing levels of DGS (0, 15, 30, 45, 60, and 75%, DM basis) to heifers during finishing and found concentrations of conjugated linoleic acid, linoleic acid, total n-6 fatty acids, and total PUFA increased linearly as dietary level of DGS increased. In addition, ratios of PUFA to saturated fatty acids (**PUFA:SFA**) and n-6:n-3 increased linearly

as levels of DGS increased (Depenbusch et al., 2009). Feeding DGS appears to alter fatty acid profiles of beef, favoring a greater ratio of PUFA:SFA which may be more detrimental on lipid oxidation and color stability than the actual amount of PUFA (Depenbusch et al., 2009). Total concentrations of MUFA were similar among increasing dietary levels of DGS; however, steaks from steers fed 20% DGS contained 4% more MUFA than steaks from steers fed 40% DGS (Depenbusch et al., 2009).

Steaks from steers fed DDGS had decreased concentrations of MUFA and increased PUFA compared with CGF and SBM steaks (Segers et al., 2011). As expected, steaks from DDGS fed steers had greater PUFA:SFA; which is likely due to the increased concentrations of corn oil in the DDGS diet (Segers et al., 2011).

Conclusions

This literature review describes a broad spectrum of topics within the beef industry related to supplementation during grazing, subsequent finishing, and meat quality attributes. During later summer grazing forage quality or quantity declines leaving nutritional deficiencies that may be offset by supplementation. Distillers dried grains with solubles have been found to improve grazing performance on moderate and low quality forage with no effects on finishing performance. Research has shown that inclusion of distillers dried grains with solubles may increase palatability attributes. However, consumers relate lean color as an indicator to freshness or wholesomeness of the meat product. A reduction in a* values (muscle redness) in retail display life has been seen with the inclusion of distillers dried grains with solubles due to the formation of polyunsaturated fatty acids, although more research is needed in this area. Distillers dried grains with solubles improve animal performance while grazing, but may affect meat quality and sensory attributes.

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CHAPTER 2. EFFECTS OF DISTILLERS DRIED GRAINS WITH SOLUBLES SUPPLEMENTATION TO YEARLING HEIFERS GRAZING NORTHERN GREAT PLAINS RANGELAND; IMPACTS ON SUBSEQUENT FEEDLOT PERFORMANCE AND MEAT QUALITY

Abstract

Eighty two yearling heifers (319.5 ± 1.03 kg) were utilized in a completely randomized design to evaluate the effects of distillers dried grains with solubles (**DDGS**) supplementation on animal performance while grazing on rangeland of the Northern Great Plains; and subsequent feedlot performance, carcass characteristics, and meat quality traits. Treatments were 1) 0% DDGS supplementation (**CONT**) or 2) 0.6% of BW DDGS supplementation (**SUP**). Heifers received treatments for 70 d while grazing then acclimated to and fed a common corn based finishing diet for 109 d. Average daily gain of heifers was greater ($P \leq 0.01$) for SUP treatments, and as a result supplemented heifers had heavier final BW ($P \leq 0.03$) while grazing. Heifer performance, including ADG (1.915 ± 0.05 kg/d), G:F (0.15 ± 0.003 kg), DMI (12.65 ± 0.20 kg), and final BW (573.6 ± 7.43 kg) were not different ($P \geq 0.13$) during finishing study. *Longissimus* muscle area (81.30 ± 1.24 cm^2), 12^{th} rib fat thickness (1.25 ± 0.10 cm), and KPH (1.85 ± 0.08%) were not different ($P \geq 0.50$) between treatments. There were no differences ($P \geq 0.24$) between treatments in yield grade (2.9 ± 0.10) or marbling (492 ± 22.3; $Small^{00}$ = 400). Results from Warner-Bratzler shear force indicated that steaks from SUP heifers tended (P = 0.07) to have increased tenderness compared to CONT steaks (3.33 vs. 3.74 ± 0.12 kg, respectively). Inclusion of 0.6% BW supplementation during grazing increased (P = 0.01) steak L*compared to CONT steaks (46.52 vs. 45.51 ± 0.27, respectively). Steaks from heifers supplemented DDGS during grazing were more tender (P = 0.02) than CONT steaks (5.87 vs.

5.51 ± 0.11; 8-point scale). Supplementation of DDGS during grazing improved ADG of yearling heifers with no effect on feedlot performance or carcass characteristics, but did improve tenderness and steak sensory attributes.

Introduction

Supplementation during grazing becomes an important management strategy when forage quality and quantity is typically lowest during the summer period when cool-season grasses are maturing and prior to fall regrowth of lush plant material (Caton and Dhuyvetter, 1997). Distillers dried grains with solubles (**DDGS**) is a co-product of ethanol production in which protein, fat, fiber, and phosphorus concentrations are increased 3-fold when compared to corn (Klopfenstein et al., 2008); therefore, has been extensively researched as supplemental form of energy and protein. Distillers dried grains with solubles can offset the nutritional deficiencies in the animal and improve performance while grazing (Morris et al., 2006; MacDonald et al., 2007).

Inclusion of DDGS in finishing diets has been shown to decrease a* values (muscle redness) during retail shelf life (Gill et al., 2008; Depenbush et al., 2009). Zerby et al. (1999) correlated a* values to consumer acceptance of the product, with increased a* values correlating to increased consumer acceptance. Distillers dried grains with solubles increases the formation of PUFA in meat leading to a faster oxidation during retail shelf life (Leupp et al., 2009), which may deter consumer's purchase. Research is needed to evaluate DDGS supplementation during grazing and the comprehensive impacts DDGS has on animal performance and meat quality throughout the entire management system. Therefore, our objective was to evaluate the effects of supplemental DDGS provided to heifers on animal performance during both grazing and subsequent feedlot production, as well as carcass characteristics, steak color and sensory

attributes. Our hypothesis was that supplementation of DDGS to grazing heifers would increase average daily gain, without affecting finishing performances, carcass characteristics or meat quality.

Materials and Methods

All animal care and handling procedures followed protocols approved by the North Dakota State University Animal Care and Use Committee prior to initiation of study. Procedures using human subjects for sensory panel were approved by the North Dakota State University Institutional Review Board before initiation of the panel.

Grazing Study

This study was conducted at Central Grasslands Research and Extension Center (**CGREC**) located in south-central North Dakota, approximately 14 kilometers northwest of Streeter, North Dakota. The study was located on township 138 north range 70 west, with the native range pastures (six, 16.6 ha each) located in section 25. This region of North Dakota is near the eastern edge of the Missouri Coteau, an area of young morainic hills formed from recent glaciation (Lura, 1985; Schauer et al., 2004). Climate of the study area is characterized by seasonal variations in both temperature and precipitation (Schauer et al., 2004). The south central region of North Dakota experiences approximately 120 frost-free days with a range of average high and low monthly temperature from -17°C in January to 27°C in July (North Dakota Agricultural Weather Network, 2012). Annual rainfall of 39.68 cm is seasonal with over 74% occurring from May through September (29.35 cm; North Dakota Agricultural Weather Network, 2012).

Kentucky bluegrass (*Poa pratensis* L.) was the most prevalent species on study site (Neville and Patton, unpublished data). Other important forage species in the area include blue

grama (*Bouteloua gracilis* [H. B. K.] Lag. Ex Griffiths), needle and thread (*Hesperostipa comatae* [Trin. & Rupr.] Backword), sun sedge [*Carex inops* L. H. Bailey spp. *heliophila* (Mack.) Crins], and western snowberry (*Symphoricarpos occidentalis* Hook.) (Hirschfeld et al., 1996).

Eighty-two heifers (319.5 ± 1.03 kg) were utilized in a completely random design. Heifers were stratified by BW and then randomly assigned to one of six groups for a 70 d grazing study starting on June 6th. Groups were assigned randomly to one of two treatments: 1) 0% DDGS supplementation (**CONT**) or 2) 0.6% of BW DDGS supplementation (**SUP**). Pastures served as the experimental unit (n = 3 pastures per treatment). Stocking rates were 1.0 animal unit/1.6 ha. Heifers were allowed continuous access to water, trace-mineralized salt blocks (American Stockman Hi-Salt with EDDI; North American Salt Company, Overland Park, KS), and mineral blocks (Purina Mineral Block 12:12 HI-SE; Purina Mills, LLC, St. Louis, MO). Supplemental DDGS were pro-rated; hand-delivered to feeders in treatment pastures at 0800 h 5 d/week.

Refused feed was removed and weighed before each feeding at 0800 h. Initial and final BW were the average of 2 BW taken on consecutive days, with intermediate BW taken every 14 d to keep supplementation consistent with increasing body weights. Sample forage clippings were taken from pastures at 3 time intervals, starting at the beginning of the experiment, and continuing every 28 d until the end of the grazing study. At each sampling date five 0.25 m^2 plots were clipped per pasture, or 15 total plots per treatment.

Finishing Study

Grazing was terminated during mid-summer on 16 August 2012. Heifers were transported to the CGREC headquarters to begin the 109 d finishing period. Each feedlot pen

coincided to a grazing pasture with heifers maintained in the same groups as during grazing. Heifers were started on a medium concentrate diet (DM basis: 40% corn silage, 29.9% dry rolled corn, 19.9% sainfoin (*Onobrychis viciaefolia* Scop.) hay, 5% barley, 5% liquid supplement, and 0.2% limestone) and were transitioned to a high concentrate diet over 28 d. All heifers received the same corn-based finishing ration (DM basis: 54.8% dry rolled corn, 25% barley, 10% sainfoin (*Onobrychis viciaefolia* Scop.) hay, 5% corn silage, 5% liquid supplement [Sup-R-Lix NC Feedlot 40 R400; Purina Mills, LLC, St. Louis, MO]), and 0.2% limestone. Finishing ration was formulated to meet or exceed dietary NRC requirements. Liquid supplement (DM basis) included 400 g/T monensin, 40% CP, 3% crude fat, 5.5% calcium, 0.3% phosphorus, 2.5% salt, 1.5% potassium, 40,000 IU/lb vitamin A. Refused feed was removed and weighed weekly prior to feeding at 0800 h. Heifers were implanted with Synovex Choice (Fort Dodge Animal Health, Fort Dodge, IA) on d 1 in feedlot. Initial and final BW was the average of 2 BW taken on consecutive days, with continual BW taken every 28 d.

Diet Analysis

Sample forage clippings were dried using a forced air oven (65°C; The Grieve Corporation, Round Lake, IL) for a minimum of 72 h. Dried samples were ground using a Wiley Mill (Arthur H. Thomas Co., Philadelphia, PA) to pass a 2 mm screen. Forage samples were analyzed for DM, ash, CP, phosphorus, calcium, (methods 934.01, 942.05, 2001.11, 965.17, and 968.08, respectively; AOAC, 2010), IVDMD, and IVOMD. Concentrations of NDF (Van Soest et al., 1991; as modified by Ankom Technology, Fairport, NY) and ADF (Goering and Van Soest, 1970, as modified by Ankom Technology) were determined using an Ankom 200 Fiber Analyzer (Ankom Technology, Macedon, NY).

Feed refusals from grazing and finishing period were collected and dried using a forced air oven (65°C; The Grieve Corporation, Round Lake, IL) for a minimum of 48 h. Dried feed refusals were analyzed for DM content. Dried samples from finishing study were used to calculate DMI, ground to pass a 2 mm screen and stored for further analysis.

Carcass Sample Collection

Heifers were transported and humanely harvested at a commercial abattoir (Tyson Fresh Meats Inc., Dakota City, NE). Hot carcass weight was measured within 30 minutes after exsanguination. Following an approximate 24 h chill at -2°C, trained personnel measured LM area and 12th rib fat and visually assessed maturity, marbling score, and KPH. Strip loins (IMPS #180) were removed after carcasses were chilled 24 - 48 h. The loin samples were transported to North Dakota State University for subsequent analysis. Loin samples were in dark storage period for 7 d before being processed into 2.5 cm steaks. Steaks were vacuum packaged individually. One steak was not frozen and prepared immediately for retail display life; with total aging time being 7 d. Steaks used for tenderness determination were aged at 4°C for an additional 7 d, and steaks for trained sensory panel were frozen until further evaluation.

Retail Display Life

One steak from each heifer was used for simulated retail display life analysis. For analysis, all steaks were over-wrapped with oxygen permeable polyvinyl chloride film, and placed under direct soft white fluorescent bulbs (General Electric, Ecolux, Cleveland, OH) at 2°C. Steaks were rotated randomly and evaluated every 24 h by trained personnel for percent metmyoglobin discoloration (expressed as percentage discoloration relative to the surface area of the steak) and objective color evaluation throughout 10 d period. Objective color evaluation was conducted using a colorimeter (Chroma Meter CR-310 Minolta Corp., Ramsey, NJ) equipped

with a 50 mm aperture utilizing a D65 illuminant. Colorimeter was calibrated to white plate over-wrapped with the same polyvinyle chloride film used for retail packaging prior to color evaluation. Color readings measured LM lean L* (muscle lightness), a* (muscle redness), and b* (muscle yellowness) through the overwrap polyvinyl chloride film for each postmortem display day at 1300 h each day.

Tenderness Determination

One steak from each heifer was used for evaluation of tenderness using the Warner-Bratzler shear force (**WBSF**) machine (G-R Electrical Manufacturing Co., Manhattan, KS; AMSA, 1995). Steaks were thawed for 24 h at 4°C, weighed, and then cooked on clamshell-style grills (model GRP99B, Salton Inc., Lake Forest, IL) at 177°C until steaks reached an internal temperature of 70°C. Temperatures were monitored internally in the geometric center of each steak with a copper, constantan, Neoflon perfluoroalkyl insulated wire and temperatures were recorded using an Omega handheld digital thermometer model HH801B (Omega Engineering Inc, Stamford, CT). Steaks were then weighed to determine cooking loss and cooled to room temperature. A minimum of six 1.27 cm diameter cores were obtained from each steak parallel to muscle fibers (AMSA, 1995). Each core was sheared once use a 250 mm/min crosshead speed. The mean of the 6 cores was used in the statistical analysis.

Trained Sensory Panel

Sensory panel analysis was conducted with a trained panel (AMSA, 1995). Steaks were thawed at 4°C for 24 h and cooked as described previously for tenderness determination. Steaks were then cut into pieces of approximately 1.3 x 1.3 x 2.5 cm and served to panelists for evaluation. Panelists were trained to evaluate initial tenderness, juiciness, and flavor intensity (Cross and Dinius, 1978). Panelists scored 9 samples each day using an 8-point scale in which 1

equaled extremely tough, dry, and bland; and 8 equaled extremely tender, juicy, and intense beef flavor. At least 5 panelists evaluated samples each day. After each sample, panelists cleansed their palates using distilled water, unsalted crackers, and ricotta cheese.

Statistical Analysis

All data was analyzed using a completely random design using PROC GLM procedures of SAS (SAS Ins. Inc., Cary, NC). Pasture was used as the experimental unit, and the model for pasture performance, feedlot performance, tenderness determination, and trained sensory panel included the effects of treatment. For trained sensory panel, panelists' evaluations were averaged for the respective sensory attribute, and then averaged for pasture. The model for the retail display life included treatment, day, and treatment x day interaction. Treatment differences were considered significant at an alpha of $P < 0.05$.

Results and Discussion

Analyzed composition of supplemental DDGS averaged 28.28 % CP, 5.36% ash, 29.63% NDF, and 7.01% ADF (DM basis). Heifers assigned to SUP treatment consumed an average of 2.66 kg/d of DDGS (DM basis) over the entire grazing period. Forage nutrient values from June to August are depicted in Table 2.1. As the grazing period progressed, CP and IVOMD values declined while NDF and ADF values increased; which is indicative of cool-season pastures when forage growth ceases and forage quality starts to decrease (Lardy et al., 2004).

Table 2.1. Chemical composition of Northern Great Plains rangeland grazed by yearling heifers[1]

Item	June	July	August
DM, %	93.0	93.7	93.6
CP, % DM	10.2	8.9	8.7
NDF, % DM	64.4	66.6	70.5
ADF, % DM	33.8	37.9	39.9
IVOMD, % DM	64.4	53.3	49.5

[1]Estimates were derived from hand clipped pastures

Energy and protein are often considered as some of the most limited nutrients for grazing livestock (Holechek et al., 1998); therefore supplementation may be considered to help offset these limited nutrients in forage quality and quantity to maintain production demands (Caton and Dhuyvetter, 1997). Determination of when to supplement may be difficult since cattle may select a diet higher in quality than the average standing crop (Paterson et al., 1996). In addition, prediction of energy requirements are severely underestimated for grazing cattle due to the amount of energy expended for increased maintenance and work associated with grazing (Caton and Dhuyvetter, 1997).

Lardy et al. (1996) collected season-long diet samples from subirrigated meadow, predominantly cool-season pastures, and found that degradable intake protein (**DIP**) often becomes limiting as forages mature. Degradable intake protein is vital for effective growth of ruminal microorganisms and stimulation of digestion and forage utilization (Lardy et al., 1996); however, oversupplying DIP has minimal effects on the MP status of the animal, and undegradable intake protein (**UIP**) supplementation may be considered. Similarly to DIP, UIP is highest in actively growing forages (Lardy et al., 2004), and declines with the onset of maturity.

Initial BW was not different between the two treatment groups ($P = 0.09$) and averaged 319.5 ± 1.03 kg (Table 2.2). After the grazing period of the study, final BW and ADG were increased ($P \leq 0.03$) for SUP treatment when compared to CONT treatment. Heifers consuming supplemental DDGS gained 0.21 kg/d more, which equated to 11.2 kg heavier weights coming off pasture than non-supplemented heifers.

A plethora of research has proven that supplementing DDGS during grazing increases ADG and final BW (Stickel, 2009; Buttrey et al., 2012; Lomas and Moyer 2011); however, reasoning behind the increased performance is often contradictory. When grazing a lower

Table 2.2. Effect of distillers dried grains with solubles (DDGS) supplementation to grazing heifers on Northern Great Plains rangeland on animal performance[1]

	Treatment[2]			
Item	CONT	SUP	SEM[3]	*P*- value
Initial BW, kg	321.1	317.9	1.03	0.09
Final BW, kg	359.1	370.3	2.50	0.03
ADG, kg/d	0.54	0.75	0.02	0.002

[1]Means presented are least squares means
[2]CONT = 0% DDGS supplementation; SUP = 0.6% of BW DDGS supplementation
[3]n=3

quality forage (< 7% CP), protein supplementation may negate a MP deficiency by improving forage intake and digestibility (Paterson et al., 1996). In the case of Stickel (2009), protein supplementation was provided as DDGS (1% of BW; DM basis) to steers grazing late season native forage for a 90 d grazing period from August to November, with forage chemical composition averaged 7% CP. Steers supplemented with DDGS had increased ADG and final BW when compared to non-supplemented steers (Stickel, 2009). Stickel (2009) attributed the increase in gain from the supplemented steers to a combination of available DIP in DDGS, increased availability of recycled nitrogen, or increased energy. However, DDGS usually are not fed as a supplement for DIP since exposure to heating during processing renders a larger portion of DDGS protein as undegradable in the rumen (Stickel, 2009). Contrary, MacDonald et al. (2007) supplemented UIP equal to the concentration in DDGS to heifers grazing smooth bromegrass pasture, and found that the additional UIP found in DDGS resulted in one-third of the increased gains. This suggests that increased gains obtained when supplementing DDGS may be due to the heifer's response to UIP meeting a MP deficiency. The reasons for differences in animal responses to supplemental DDGS may in part be due to differences in CP of grazing forage. In the current study, heifers grazed cool-season pastures where active growth is evident during the earlier portion of the grazing period indicated by forage CP values; and UIP is often

highest during these times of active growth (Lardy et al., 2004). When forage quality started to decline in later grazing months, UIP may also have been reduced thus potentially leading to decreased animal performance. Addition of UIP from supplemental DDGS during the later summer months may have negated a MP deficiency in SUP treatment leading to increased ADG and final BW.

During the finishing study, all heifers were fed the same diet for ad libitum intake to examine the effects of supplemental DDGS during grazing on subsequent finishing performance and carcass characteristics. Upon entry into feedlot, SUP heifers had increased initial BW (P = 0.03) when compared to CONT heifers (Table 2.3); which is explained by increased ADG and heavier final BW for SUP heifers at the conclusion of grazing. Performance during finishing and final BW during finishing was similar between SUP and CONT treatments ($P \geq 0.13$; carcass-adjusted performance $P \geq 0.46$).

Table 2.3. Effect of distillers dried grains with solubles (DDGS) supplementation to grazing heifers on Northern Great Plains rangeland on subsequent feedlot performance[1]

	Treatment[2]			
Item	CONT	SUP	SEM[3]	*P*- value
Initial BW, kg	359.1	370.3	2.50	0.03
Final BW, kg	568.9	578.3	7.43	0.42
ADG, kg/d	1.92	1.91	0.05	0.83
DMI, kg	12.9	12.4	0.20	0.13
G:F, kg	0.15	0.15	0.003	0.28
Carcass-adjusted Performance				
Final BW,[4] kg	570.2	578.5	7.55	0.48
ADG, kg	1.93	1.91	0.05	0.78
G:F, kg	0.15	0.15	0.004	0.46

[1]Means presented are least squares means
[2]CONT = 0% DDGS supplementation; SUP = 0.6% of BW DDGS supplementation
[3]n=3
[4]Carcass-adjusted final BW calculated from HCW divided by the average dressing percentage of all treatments

Although finishing performance and final BW between both treatments were similar, SUP heifers maintained weight gained during grazing; which could potentially lead to less time spent in feedlot. Perry et al. (1971) supplemented differing levels of corn (0, 1/3 full feed, 2/3 full feed, or full feed; where full feed is 6.7 kg/h/d) to steers during a 58 d grazing study and found steers fed the highest amount of concentrates during grazing had the least amount of gain during finishing. Perry et al. (1971) estimated that for each additional kg gained during grazing, steers gained 0.2 kg less during finishing; however, steers fed full feed during grazing required fewer days on feed **(DOF**) to reach market weight. Stickel (2009) analyzed finishing performance on steers supplemented DDGS (1% of BW; DM basis) while grazing late season native forage. Control, unsupplemented steers had increased ADG and G:F during finishing while supplemented steers had increased final body weights. Although, supplementation during grazing may lead to no added advantage in finishing performance; supplementation may benefit producers economically by reducing the number of DOF for finishing cattle.

Reuter and Beck (2012) suggested rate of gain playing an integral part of carryover effects from stocker cattle moving into finishing. Felix et al. (2011) fed either corn or DDGS (65% DM in diet) to steers during the growing phase to achieve either 0.9 kg/d or 1.4 kg/d predicted BW gain and analyzed subsequent feedlot performance. Regardless of supplement, steers fed at a lower rate of gain (0.9 kg/d predicted BW) during the growing phase gained 14% faster during finishing; which could be explained by a compensatory response from restricted steers being more efficient during finishing (Felix et al., 2011). In the current study, no compensatory response was seen during the fishing portion of the study for SUP heifers; even though SUP heifers gained 0.75 kg/d while grazing. However, heifers in the current study were

older and heavier upon entering the feedlot which may result in increased ADG and daily feed intake, but less feed efficient (Reuter and Beck, 2012).

Similar to final BW, there were no differences ($P > 0.05$) between treatments (Table 2.4) in HCW ($P = 0.47$; 336.4 ± 4.39 kg). *Longissimus* muscle area (81.30 ± 1.24 cm^2), 12^{th} rib fat thickness (1.25 ±0.10 cm), and KPH (1.85 ± 0.08%) were not different ($P \geq 0.50$); therefore, no differences ($P = 0.30$) were observed for yield grade (2.9 ± 0.10).

Table 2.4. Effect of distillers dried grains with solubles (DDGS) supplementation to grazing heifers on Northern Great Plains rangeland on subsequent carcass characteristics[1]

	Treatment[2]			
Item	CONT	SUP	SEM[3]	*P*- value
HCW, kg	334	339	4.39	0.47
LM area, cm^2	81.94	80.65	1.24	0.50
12^{th} Rib Back fat, cm	1.2	1.3	0.10	0.57
Marbling score[4]	470	514	22.3	0.24
KPH, %	1.85	1.85	0.08	0.99
Quality grade[5]	10.2	10.6	0.25	0.28
Yield grade	2.8	3.0	0.10	0.30
Dress, %	58.7	58.3	0.33	0.86

[1]Means presented are least squares means
[2]CONT = 0% DDGS supplementation; SUP = 0.6% of BW DDGS supplementation
[3]n=3
[4]Marbling score based on 400 = $Small^{00}$
[5]Quality grade based on Low Choice (Ch^-) = 10, High Prime (Pr^+) = 15

Stickel (2009) assessed the impacts of supplementing DDGS at 1% of BW to steers grazing late season native forage and the impact of differing DOF on animal performance during finishing and carcass characteristics. Steers supplemented with DDGS during grazing had heavier HCW and increased LM area, although there were no differences ($P > 0.05$) seen in USDA yield grades, marbling scores, KPH or quality grades (Stickel, 2009). Heavier HCW and increased LM area were attributed to increased gains while grazing since DDGS steers were heavier at the conclusion of grazing and maintained this live weight advantage throughout finishing.

No differences ($P = 0.24$) were observed between treatments for marbling, which averaged 492 ± 22.3 (Small[00] = 400). Although not statistically different, in the present study heifers receiving 0.6% of BW DDGS supplementation had numerically more marbling compared to 0% DDGS supplementation (514 vs. 470; respectively). Stickel (2009) found that increasing DOF for yearling cattle during finishing increased marbling scores and decreased the percentage of carcasses grading Select, concluding marbling is optimized around 110 to 120 DOF during finishing.

Steaks from heifers consuming supplemental DDGS had lower L* ($P = 0.01$) color values when compared with steaks from heifers consuming no supplemental DDGS during grazing (Table 2.5). No differences were found between treatments for a* ($P = 0.47$) or b* ($P = 0.11$) color values. There was no treatment x day interaction for L*, a*, and b* ($P \geq 0.99$).

Table 2.5. Effect of distillers dried grains with solubles (DDGS) supplementation to grazing heifers on Northern Great Plains rangeland on steak shear force, color analysis, and sensory characteristics[1]

	Treatment[2]			
Item	CONT	SUP	SEM[3]	*P*- value
Steaks, n	40	40	---	
Shear force, kg	3.74	3.33	0.12	0.07
Cooking loss[4], %	21.37	18.73	0.62	0.04
Color[5]				
L*	45.51	46.52	0.27	0.01
a*	21.59	21.48	0.11	0.47
b*	9.41	9.30	0.05	0.11
Sensory characteristics[6]				
Tenderness	5.51	5.87	0.11	0.02
Juiciness	5.51	5.64	0.07	0.20
Flavor	5.41	5.44	0.05	0.70

[1]Means presented are least squares means
[2]CONT = 0% DDGS supplementation; SUP = 0.6% of BW DDGS supplementation
[3]n=3
[4](Weight loss during cooking/weight before cooking) x 100
[5]L* = white to black (100 = white, 0 = black); a* = red to green (35 = red, -35 = green) b* = yellow to blue (35 = yellow, -35 = blue)
[6]Tenderness (8 = extremely tender, 1 = extremely tough); juiciness (8 = extremely juicy, 1 = extremely dry); flavor (8= extremely flavorful, 1 = extremely bland).

In muscle, lipid oxidation is referred to as the oxidation of unsaturated fatty acids in phospholipids and triacylglycerols; and subsequently enhances myoglobin (color) oxidation (Scollan et al., 2006; Faustman et al., 2010). Meat color is vital when making meat purchasing decisions due to consumer's association of color as an indicator of freshness during retail display life (Mancini and Hunt, 2005). Zerby et al. (1999) correlated a* (muscle redness) color values to consumers acceptance of the product, with increased a* color values correlating to increased consumer acceptance. Distillers dried grains with solubles have higher values of PUFA leading to a faster oxidation during retail display life, reduced a* color values, and decreased consumer acceptance (Scollan et al., 2006; Segers et al., 2011).

Leupp et al. (2009) included 30% DDGS during growing and finishing periods (treatments: 0:0, 30:0, 0:30, 30:30; respectively) and found when included only in growing periods (treatment 30:0), L* and b* tended to be reduced; however, DDGS inclusion in both growing and finishing periods (treatment 30:30) reduced a* color values throughout retail display life. Several authors are in agreement with Leupp et al. (2009) when including DDGS during finishing reducing a* color values (Depenbusch et al., 2009; Segers et al., 2011). Depenbush et al. (2009) found that as dietary levels of DDGS increased (0, 15, 30, 45, 60, and 75%, DM basis), concentration of PUFA linearly increased; suggesting that lipid oxidation and color stability are influenced more by the ratio of PUFA to saturated fatty acids (**PUFA:SFA**) than the actual amount of PUFA. Segers et al. (2011) fed either DDGS, SBM, or CGF (25% DM basis) to steers from weaning until slaughter and found steaks from DDGS steers had increased PUFA as well as a greater ratio of PUFA:SFA; which is likely due to the increased concentrations of corn oil in the DDGS diet.

Stickel (2009) supplemented DDGS (1% of BW; DM basis) to steers grazing late season native forage and found supplementation did impact fatty acid composition, specifically PUFA, or L*, b*, and a* color values. Even at a higher inclusion rate (1% of BW; DM basis) than the present study, Stickel (2009) found that supplementation of DDGS during grazing may not be detrimental to retail display life, and more so a* values.

Warner-Bratzler shear force values of steaks from heifers fed supplemental DDGS during grazing tended ($P = 0.07$) to be lower than steaks from heifers fed no supplemental DDGS (3.33 vs. 3.74 ± 0.12 kg; respectively). In addition, cooking loss was less ($P = 0.04$) for SUP compared to CONT treatments (18.73 vs. 21.37 ± 0.62%; respectively).

Tenderness is one of the most important factors affecting consumer's perception of palatability (Morgan et al., 1991); with 78% of consumers willing to pay a higher price for the same USDA quality grade if the retailer guarantees the steak's tenderness (Miller et al., 2001). Miller et al. (2001) conducted a consumer survey for establishing tenderness thresholds and suggested threshold classes of < 3.0, 3.0 to 4.3, and > 4.9 kg WBSF resulting in customer satisfaction of 100, 93, and 25%; respectively. In the current study, steaks from both treatment groups would have fit into the threshold of 3.0 to 4.3 and would have satisfied 93% of consumers on tenderness when based on Miller et al. (2001) established thresholds.

Leupp et al. (2009) included 30% DDGS during growing and finishing periods (treatments: 0:0, 30:0, 0:30, 30:30) to steers analyzing meat quality attributes and found no differences in WBSF or cooking loss across treatments. Segers et al. (2011) fed steers DDGS, soybean meal (**SBM**), or corn gluten feed (**CGF**) (25% DM basis) from weaning until slaughter and found after 7 d of aging steers fed SBM were tougher than the other two treatments. However, after steaks were aged between 14 and 21 d there were no differences between

treatments for WBSF (Segers et al., 2011). This implies that aging steaks may be able to overcome finishing nutritional regime. Contrary, no differences in WBSF values were seen when DDGS were supplemented at 1% of BW to steers during grazing (Stickel, 2009).

Results from sensory panelists indicated no differences ($P \geq 0.20$) in juiciness or flavor between treatments which averaged 5.58 ± 0.07 and 5.43 ± 0.05, respectively (8-point hedonic scale). Taste panelists detected steaks from heifers supplemented DDGS during grazing were more tender ($P = 0.02$) then steaks from non-supplemented heifers (5.87 vs. 5.51 ± 0.11; respectively). Steaks from SUP heifers may have increased tenderness due to the slight increase in the amount of marbling in the SUP carcasses. Research has shown little evidence of a strong influence of marbling on tenderness; marbling may act as a lubricant during mastication easing the process of swallowing and improving apparent tenderness (Aberle et al., 2001). Stickel (2009) found that supplementation of DDGS (1% of BW; DM basis) to steers grazing late season native forage did not affect myofibrillar tenderness, connective tissue amount, overall tenderness, juiciness, beef flavor intensity, or off-flavor intensity. However, in the present study SUP treatment held a slight increase in marbling when compared to CONT treatment (514 vs. 470 ± 22.3; 400 = Small^{00}) while Stickel (2009) found no increase in marbling between supplemented and control treatments (399.6 vs. 387.6 ± 9.08; 400 = Small^{00}). This may account for the differences seen between the two studies in taste panelist's perceived tenderness.

Depenbusch et al. (2009) fed differing levels of DDGS (0, 15, 30, 45, 60, and 75%, DM basis) to heifers during finishing and found myofibrillar and overall tenderness increased linearly as dietary level of DDGS increased from 0 to 75%. Steaks from heifers fed DDGS at 45% and 60% were rated greatest by panelist in beef flavor intensity and least for heifers fed no DDGS. However, juiciness, off-flavor intensity, and TBARS were not different among treatments

(Depenbusch et al., 2009). Similarly, Leupp et al. (2009) found no differences in tenderness from trained panelists when supplemented 30% DDGS during growing or finishing (treatment 30:30); however steaks from steers fed 30% DDGS during the finishing (treatment 0:30) tended to be juicier and more flavorful than steaks from control steers.

Conclusions

This research found that supplementation of distillers dried grains with solubles to cattle grazing Northern Great Plains rangeland increased average daily gain while grazing with no differences between treatments on finishing performance. Research has shown that distillers dried grains with solubles may be detrimental to retail display life by deteriorating the redness of steaks, deterring consumers from purchasing retail products. In the current study, supplementation during grazing proved to have no effects on retail display life, more specifically redness of steaks. Supplemental distillers dried grains with solubles increased tenderness of steaks for Warner-Bratzler shear force and sensory panelists were able to detect the same difference in tenderness. This research demonstrated that supplementing distillers dried grains with solubles during grazing to stocker cattle may improve grazing performance with no detrimental impacts on subsequent finishing performance, carcass characteristics, or meat quality attributes.

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