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Effects Of Distillers Grains Plus Solubles And Monensin Supplementation On Yearlings Grazing Smooth Bromegrass

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Supplementing cattle on grass is an effective way of increasing animal efficiency and grass utilization. Distiller grains plus solubles (DGS) supplementation has been repeatedly proven as an effective supplement by providing ruminally undegradable protein (RUP), fat, and highly digestible fiber. The effects of monensin supplementation on grazing cattle are variable. Although some research has shown a decrease in forage organic matter intake (FOMI), the popular belief is monensin increases ADG while maintaining DMI in a grazing situation. Two experiments were designed to observe the effects of DGS and monensin supplementation on cattle grazing smooth bromegrass. In the first study, ADG and modified distillers grains plus solubles (MDGS) intake were measured for cattle grazing smooth bromegrass. Steers were supplemented MDGS at 0.05, 0.4, 0.6, or 0.8% BW and were either given 0 or 200 mg monensin. In the second study, FOMI was estimated when cattle grazing smooth bromegrass were supplemented with MDGS at 0.4% BW was given 0 or 200 mg monensin. In the first study, monensin did not affect ADG ($P = 0.53$). There was a monensin x MDGS intake interaction ($P = 0.05$). Monensin decreased MDGS consumption only when supplement was offered at 0.8% BW ($P = 0.01$). In the second study, monensin tended to decrease FOMI by 9% ($P = 0.10$).

Table of Contents

Introduction

The foundation of cattle biology and the beef industry is the utilization of fiber that is indigestible to humans and converting it into protein. Grazing cattle on grassland is beneficial to both cow/ calf producers and feeders. Prior to entering the feedlot, growing cattle on grass is a practical and economical practice with benefits that continue into the feeding phase. Unfortunately, grazing resources for cattle are continually threatened by drought and the economic incentives to convert grassland for grain production. Maximizing the potential use of the grass available is becoming increasingly important.

The ethanol industry has provided a practical tool to better utilizing grazing resources. Distiller grains plus solubles (DGS) is a byproduct that is a good source of protein and energy. Distiller grains plus solubles is high in CP (30.9% DM; U.S. Grain Council. 2012) of which 63% is ruminally undegraded protein (RUP % of CP; Lopez, 2012). Even though immature grass is considered sufficient in CP, most (82-89% of CP; Mitchell et al., 1997) of the protein is ruminally-degraded protein (RDP). Consequently, the first limiting nutrient for growth in grazing cattle is metabolizable protein (MP), which is required as RUP. Distiller grain plus solubles supplementation meets this need while providing extra energy. Consequently, ADG is increased when grazing cattle are supplemented DGS (Greenquist, 2009; Morris et al. 2005; Morris et al. 2006; Watson et al. 2012). Supplementation also replaces a small portion of forage in the animal's diet, and allows the stocking rate to increase (Corrigan et al., 2009b; Gustad et al., 2006; Loy et al., 2003; Greenquist, 2009; Morris et al. 2005; Watson et al. 2012)F.

The antimicrobial ionophore monensin is a feed additive used in feedlots across the country. The effects of monensin include lower intake variation and increased feed efficiency (Duffield et al., 2012). An increase in feed efficiency is due to a decrease in acetate: propionate ratio (Raun et al., 1976; Richardson et al., 1976; Goodrich et al., 1984, Dinius et al., 1976). The use of monensin in forage diets can potentially shift the VFA profile to be more similar to that of a steer on a concentrate diet.

Theoretically, providing both DGS and monensin will meet metabolizable protein requirements and increase feed efficiency. Consequently, stocking rates could be increased while maintaining or improving performance. Many studies have been conducted to observe the effects of DGS supplementation on cattle grazing smooth bromegrass. These studies focus on performance, nitrogen retention, forage savings, and economics. Monensin has also had extensive research conducted looking at DMI, performance, and changes in ruminal pH, N, and volatile fatty acids. The effects of monensin on protein requirements in forage diets have also been investigated.

The purpose of this review is to document literature, which evaluates the importance of grazing with supplementation of DGS and monensin to meet metabolizable protein requirements, increase animal efficiency, and maximize grass resources.

Literature Review

Smooth Bromegrass

Background

Smooth bromegrass, *Bromus inermis* Leyss, is the most widely used of the cultivated bromegrasses (Casler and Carlson, 1995). Smooth brome was introduced to the United States from Europe in the 1880s, and was growing in the Midwest by the late 1890's. The aggressive reproduction, either through self- seeding or vegetative spread, provides conservation value for establishment of plant cover but also causes smooth brome to be classified as weeds in some situations (Casler and Carlson, 1995). Consequently, smooth brome was a primary survivor in the Midwest following the drought of the 1930s, and continues to be used by many producers to this day.

Plant Characteristics

The smooth bromegrass plant is a leafy, tall-growing, sod forming perennial (Casler and Carlson, 1995). Like all *Bromus* species, smooth bromegrass is a cool-season grass. Cool- season grasses make their principal growth during the spring and have maximum rates of photosynthesis when air temperatures are between 18-24^{o} C (Volesky, 2003). Yet, smooth bromegrass survives periods of drought and extreme temperatures (Casler and Carlson 1995). These characteristics, including winter hardiness, make smooth bromegrass very suitable for central and eastern Nebraska.

Production

Smooth bromegrass is very productive because of the rhizomes of the plant, which are the primary means of vegetative growth. Forage yields can be exceptional -

6.7 to 9.0 mT/ha or more- with good management when rainfall is adequate (Lamond et al., 1992). When compared with orchardgrass (Dactylis glomerata L.), reed canarygrass (Phalaris arundinacea L.), and tall fescue (Festuca arundinacea Schreb.), smooth bromegrass was the most winter-hardy species and usually the highest-yielding species in the spring (Casler and Carlson, 1995). Regrowth after grazing is competitive to other grasses when managed properly. Volesky (2007) found that smooth bromegrass had greater DM production than orchard grass and meadow bromegrass at a 21-cm stubble height. Smart (2006) determined that Smooth bromegrass had higher overall herbage and leaf yields than wheatgrass.

Management

Production of smooth bromegrass is dependent on factors that can't be controlled, especially in non-irrigated pastures, such as temperature and rainfall. Regardless, like most agronomic operations, nitrogen application is a practice that can have significant implications on yield. Spring application of 90 to 168 kg/ha N usually produces the highest economic return. For fall grazing, 34- 45 N kg/ha should be applied in late August or early September (Roberts and Kallenbach, 2000).

The carrying capacity of smooth bromegrass pastures depends on precipitation, fertilization, and season. Spring stocking rate needs to be adjusted to compliment the summer grazing strategy. Spring stocking rate should be higher compared to the dryer summer season when growth is hindered. Stocking rate should be managed so the pasture is not grazed under a stubble height of ten centimeters (Lamond et al., 1992). The grazing system should optimize both animal and forage production over a long-term period (Ohlenbusch and Watson, 1994).

Rotational grazing is a management practice that attempts to harvest more forage per acre and reduce patch grazing by increasing stocking rate and animal competition, which in turn decreases selectivity. Grazing pastures multiple times throughout the season have higher harvest efficiency. Schlueter (2004) observed smooth bromegrass and smooth bromegrass - birdsfoot trefoil mix plots grazed for three days, four times throughout the growing season had approximately 50% utilization. This system does not increase forage production, but rather better utilizes the forage supply (Lamond et al. 1992). Rotational grazing also gives the pasture periods of rest and recovery. Once livestock are moved from a pasture, regrowth is quicker and more uniform compared to continuous grazing (Lamond et al. 1992).

Nearly half (40-55%) of the seasonal growth of smooth bromegrass occurs by mid- May (Schlueter, 2004). The high growth period in the early spring is complimented by an intensive rotational grazing system with short grazing periods. The quick rotations of early spring prevent the smooth bromegrass from extensive stem growth and the loss of palatability (Baleseng, 2006). As the season continues into the summer grass growth slows. Consequently the rotations should be slowed to allow longer rest periods. Regrowth will be observed in the fall due to the cooling weather.

Research comparing rotational and continuous grazing systems has shown increase in animal gain/ hectare is greater in a rotationally grazing system. Walton et al. (1981) showed gains per hectare of a brome-alfalfa- creeping red fescue mix pasture were nearly double in a rotational grazing system. From the forage standpoint, comparing rotational and continuous grazing, research has generally

concluded that rotational grazing has little to no effect on defoliation patterns. However, this research has been conducted using small paddocks, usually less than 25 ha and often less than 5 ha (Teague and Dowhower, 2002). Teague and Dowhower's (2002) study provides evidence that in large paddocks (1858-1295 ha), rotational grazing allows recovery and reduces degradation caused by patch overgrazing, and concluded that rotational grazing is a key tool for managing sustainability in grazing systems.

Forage Quality

Forage quality is defined as the potential of forage to produce the desired animal response (Collins and Fritz, 2003). Smooth bromegrass has proven to be high quality forage by superior ADG of cattle and sheep compared to orchardgrass, tall fescue, reed canarygrass, perennial ryegrass, alfalfa, and timothy (Casler and Carlson, 1995). The performance of the animal is a simple and practical approach to measuring forage quality. However, the factors that affect forage quality are more complex. The digestibility (energy) and crude protein of the plant and the voluntary intake of the grazing animal ultimately determines forage quality (Collins and Fritz, 2003).

Digestibility in itself is a complicated characteristic with many variables. Digestibility is different for every plant, plant part, and maturity level. Volesky (2007) found smooth bromegrass to have a greater IVDMD than orchardgrass, creeping foxtail, and meadow bromegrass throughout the grazing season.

The nutritive value of smooth bromegrass is greatest in the spring and decreases as the grass matures into the summer until regrowth in the fall (Casler and Carlson, 1995; Baleseng, 2006; Volesky, 2007). In the spring, the DMD of all plant

parts is high with few differences among components. As the plant matures, the differences in DMD between different fractions become more significant (Minson, 1990). As the plant matures, the DMD of the stem and other structural parts decrease more rapidly compared to the leaf. There is also a decrease in the fraction of leaf lamina and CP, and an increase in the percentage of cellulose, hemicellulose, and lignin (Minson, 1990; Baleseng, 2006). The total DMD of smooth bromegrass will increase until mid-bloom, while the percentage of digestible protein declines beyond this stage (Casler and Carlson, 1995).

Schlueter (2004) found CP content of immature fertilized bromegrass in early May was 17.3% and declined to 14.6% as the grass matured by mid July. Similarly, NDF content increased during the same time period from 54.4% to 66.6%. However, Baleseng (2006) reported an increase in CP as the plant went into the cool weather of the fall.

Forage CP is comprised of three fractions: nonprotein N, digestible protein N, and indigestible N (Collins and Fritz, 2003). The digestible protein N is made up of two types of protein; ruminally degraded protein (RDP) and ruminally undegraded protein (RUP). Ruminally undegraded protein is the portion of CP that bypasses ruminal degradation by microbes and is absorbed in the small intestine and metabolized by the animal (NRC, 1996). Forages are poor sources of RUP. The RUP of smooth bromegrass over a year ranged from 0.97% – 2.52% DM (Mitchell et al., 1997). Ruminally undegraded protein was observed at 1.32% - 2.03% DM by Watson et al. (2012) and Buckner et al. (2013), respectively. MacDonald (2006) found that smooth bromegrass RUP (% DM) increased from 2.76% to 2.83% from May to June.

At the same time RUP digestibility decreased from 54.3% to 49.0%. Further research by Haugen et al. (2006) observed as the plant matures from June to July the RUP (% DM) remains constant at 1.82% and 1.71%. However a decrease in RUP digestibility (% DM) from 38.6 % to 28.1% simultaneously occurred between the same two months.

Forage quality is also affected by grazing behavior, which is influenced by stocking rate and pasture plant culture. As grazing pressure increases the forage quality available decreases. Taylor et al. (1997) concluded when grazing pressure is not managed, high quality forage may be overgrazed. This is advantageous for competing plants that are less palatable and lower quality. Over time, this will decrease the forage quality available to the animal. Senft et al. (1985) determined that cattle grazing selection is highly correlated to preferred plant communities and aboveground standing nitrogen (CP). These pasture characteristics can be managed for optimum forage quality. Taylor et al. (1980) found in high competition grazing system, preferred forage and plant CP decreased over the grazing season. However, in a low competition grazing system Taylor et al. (1980) determined that the CP remained constant over the grazing season, and CP digestibility was greater than the CP digestibility of the high competition system.

When sampling to determine forage quality, cattle grazing behavior must be taken into consideration. The nutritive properties of the species actually consumed are more important than the properties of all species of the pasture (Senft et al., 1985). Torell (1954) and Campbell (1968) observed significant nutrient differences between diet samples taken by a fistulated steer and hand clippings of the same pasture.

Analyzing diet quality via fistulated cattle is more accurate than grass clippings taken by hand (Ullerich, 2001).

Ruminant Protein Utilization

Crude Protein

The CP of feed ingredients is determined by quantifying the total amount of N in a sample via Kjeldahl or combustion analysis (AOAC, 1996). However there are differing nitrogenous compounds within the makeup of CP that are metabolized differently and are found in different fractions among ingredients. The CP system does not account for these varying compounds and their differences in utilization by the ruminal microbes and the animal.

Metabolizable Protein System

The metabolizable protein (MP) system fractions crude protein of feed into ruminally degradable protein (RDP) and ruminally undegradable protein (RUP; NRC, 1996). The microbes of the rumen metabolize RDP while RUP goes towards the animal's protein requirement. Metabolizable protein is the true protein absorbed by the intestine, supplied by RUP and microbial crude protein (MCP; NRC, 1996). Microbial crude protein is assumed to be 80% true protein that is 80% digestible in the small intestine, resulting in 64% of the MCP contributing to MP (NRC 1985). The RUP digestibility fluctuates between 50 – 100%, but is assumed to be 80% by the NRC (1996; Haugen, 2006). Crude protein and RUP: RDP ratios also fluctuate between different ingredients. Smooth bromegrass contains 14.2-16.5% CP (DM) with 12.5-14.0 % RUP as % of CP (Buckner et al., 2013). In comparison Buckner et al. (2008) tested (DGS) from six ethanol and plants and concluded DGS contains 31%

CP (DM). In addition approximately 63% of the CP in distillers grains plus solubles (DGS) is RUP (Lopez, 2012). Distillers grains plus solubles has a greater amount of RUP and MP compared to smooth bromegrass.

Determining the MP of feeds to meet the requirements of the animal is important but complex. The availability of MP is affected by protein composition, ruminal protein digestion rate, passage rate, bacterial composition and yield, ruminal pH and postruminal digestibilities (Bach et al., 2005; Sniffen, 1992). Consequently, protein content and degradability estimates are challenging to assess in different feeding situations (MacDonald, 2006). The ruminant's ability to provide RDP to the rumen, through urea recycling, should also be considered when attempting to meet the protein requirements of the rumen microbes. Excess MP can contribute to RDP via urea recycling capabilities of the ruminant. Urea returned to the rumen represents 30-40% of the digested N in cattle (Lapierre and Lobley, 2001). Understanding the conditions and mechanisms that underlie the movements of N within the animal should enhance our ability to manipulate feed and husbandry to improve production efficiency (Lapierre and Lobley, 2001).

Supplementing Grazing Ruminants

Supplementation Management

The goal of optimizing the economic returns of producing cattle on grass can best be met if the first limiting nutrient is identified and supplemented. Otherwise, a positive response to supplementation should not be expected (Klopfenstein, 1996). Pasture nutrients available to the animal are influenced greatly by management, plant culture, and weather patterns. Forages can vary in CP, RUP, RUP digestibility, and

total tract indigestible dietary protein (TTIDP) depending on the forage type, year, and time within year (Buckner et al. 2013). Consequently, the first limiting nutrient may also vary from year to year. Determining if the first limiting nutrient is energy, RUP, RDP, or even a mineral is important when making supplementation decisions.

Supplementing Protein

In grazing situations, the protein found in both warm and cool season grasses is high in RDP compared to RUP. Mullahey (1992) observed the RDP of switchgrass and smooth bromegrass to be 57% and 74% of the CP, respectively. The RDP promotes microbial growth, which in turn increase the MCP fraction of MP. The MCP in grazing situations usually meets the animal's requirement for maintenance (Klopfenstein, 1996). There are situations when both RUP and RDP are low. When grass CP or energy are low due to dry weather or poor growing conditions, no response to RUP supplementation has been observed (Lardy et al. 1999; Hafley et al. 1993). Burroughs (1975) concluded that high-cellulosic feeds (TDN < 60) with less than 7% CP benefited from RDP supplementation. In most grazing cases, especially in the early part of the growing season, grass energy and RDP are sufficient, and RUP supplementation is beneficial.

Karges (1992) found no gain response when steers grazing warm season native range (IVOMD 51.8 – 68.9%) were supplemented RDP in the form of urea. However, grazing steers supplemented RUP in the form of treated soybean meal (SBM) and feather meal (FM) responded with a linear gain increase. A growth response has been observed in grazing cattle supplemented with RUP (Creighton et al., 2003; Karges et al. 1992; Watson et al., 2010).

Hafley et al. (1993) compared supplementing energy to supplementing energy plus RUP to cattle grazing warm season grasses during the summer. The source of RUP was in the form of blood meal (BM) and corn gluten meal (CGM). The RUP was supplemented at 0.1 and 0.2 kg per head daily with the energy supplement. As RUP supplement increased, gain also increased from 0.91 kg ADG to 1.01 kg ADG.

Lardy et al., (1999) found summer calving cows that were supplemented RDP and RDP + RUP more readily maintained body condition and the calves gained more than cattle not supplemented or supplemented energy. In this situation, cattle were grazing warm season range from the summer into the fall. The authors concluded that RDP was the first limiting nutrient for summer calving cattle on warm season range.

Ethanol By-Products and the Grazing System

Dry Milling Process

Distillers grains and solubles are the by-products of the ethanol industry via the dry milling process. Stock et al. (1999). The corn is ground and the starch is fermented by yeast to produce alcohol and carbon dioxide. The fermented mash (alcohol, water, and the remaining corn particles) goes through the distillation process to separate the alcohol from the mash. Once the alcohol is distilled, the mash is called whole stillage with 5-10% DM.

The coarser grain particles are separated from the whole stillage by centrifugation. These coarse grain particles can be marketed as wet distillers grains (WDG), modified distillers grains (MDG), or dried distillers grains (DDG) depending on the extent of drying, if any. Dry matters of each product vary from plant to plant. The liquid remaining after the coarse particles are removed is called thin stillage, and

contains fine corn particles and yeast cells. The thin stillage is evaporated to 20- 35 % DM and is called condensed distillers solubles (CDS; Stock et al., 1999). The CDS may then be added back to the coarse particles to form distillers grains plus soluble (DGS) and marketed as WDGS (34.9% DM), MDGS (46.2% DM), or DDGS (90.4% DM; Erickson et al., 2010).

Supplementing DGS to Grazing Cattle

Previously discussed was the importance of supplementing RUP to meet MP requirements of cattle grazing grass. Distillers grains plus solubles are high in both RUP and energy. Buckner et al. (2008) found WDGS ranged from 10.7% to 13.1% fat (DM-basis). Corrigan et al. (2009a) determined DDGS also contained 36.1% NDF. Hsu (1987) found corn fiber had a total tract digestibility >70%. Corn fiber is at least equal to corn grain as a source of supplemental energy in high roughage diets (Oliveros, 1989).

Loy et al. (2003) evaluated energy supplementation to heifers on a high forage diet. Heifers were supplemented dry rolled corn (DRC), DRC plus corn gluten meal (CGM), or DDGS. The cattle were either supplemented daily or three times weekly. Regardless of supplementation level, heifers fed DDGS had greater gains ($P < 0.01$) and were more efficient ($P < 0.01$) than cattle supplemented DRC. Loy et al. (2003) concluded DDGS had 27% greater net energy value than DRC in forage diets.

Utilizing heifers grazing smooth bromegrass, MacDonald et al. (2007) compared supplements equal to DDGS in RUP or fat. The RUP supplement was in the form of corn bran and corn gluten meal (CGM). Fat supplement was in the form of corn bran and corn oil (OIL). The RUP supplemented cattle gained 38% that of the

DDGS cattle. Cattle supplemented fat saw no improvement over the control cattle supplemented corn bran because MP was the first limiting nutrient. MacDonald et al. (2007) concluded neither RUP nor fat by themselves can explain the significant improvement in cattle supplemented DDGS. Providing a combination of metabolizable protein from RUP and energy from both RUP and protected fat may be responsible for the additional gain observed from DDG supplementation.

Rolfe et al. (2012) conducted a three-year study evaluating the impacts of supplementing MDGS to steers grazing summer range. Steers either grazed native range without supplementation (CON) or were supplemented MDGS at 0.6% BW. The average amount of supplement fed per day was 2.27 kg (DM)/steer daily. Following the grazing season, SUPP steers had 0.30 kg/d greater ($P < 0.01$) ADG than CON cattle. Consequently, SUPP cattle were 48.1 kg heavier ($P < 0.01$) at the end of the study than CON steers.

Watson et al. (2011) found that as digestibility of smooth bromegrass decreases, gain response to DDGS supplementation increases. She concluded that strategic DDGS supplementation might be beneficial. Moore et al. (2013) wanted to determine the effects of DDGS supplementation strategies for yearling steers grazing smooth bromegrass. The alternative strategy was to increase DDGS supplementation levels as grass digestibility decreased. However, the average level of supplementation over the grazing season remained at 0.6% BW. Cattle performance of the strategic supplementation on nonfertilized paddocks (STRAT) was compared with nonfertilized paddocks with daily DDGS supplementation of 0.6% BW (SUPP), fertilized paddocks (90 kg N/ha) with no supplement (FERT), and nonfertilized

paddocks with no supplementation (CONT). There was no difference in ADG between the STRAT and SUPP treatments. However STRAT and SUPP cattle had greater ADG of 1.12 and 1.22 kg compared to FERT and CONT steers gaining 0.90 kg/day ($P < 0.01$). Moore et al. (2013) concluded there was no difference in supplementation strategies but DDGS supplementation significantly improved ADG.

DGS supplementation has been shown to decrease forage intake and simultaneously increase gain (Corrigan et al., 2009b; Gustad et al., 2006; Loy et al., 2003; Greenquist, 2009; Morris et al. 2005; Watson et al. 2012). Loy et al. (2003) demonstrated that heifers supplemented DDG at 0.81% BW consumed less hay than heifers supplemented 0.21% BW. Corrigan et al. (2009b) stated as the DDGS level increased FDMI decreased linearly ($P < 0.01$) and total DMI increased quadratically ($P < 0.01$). Watson et al., (2010) reported forage savings of 6.8% and 17% for the daily supplementation of 0.91 and 2.27 kg (DM) MDGS, respectively.

Watson et al., (2010) measured and compared cattle and smooth bromegrass pasture performance between cattle grazing fertilized pastures, non- fertilized pastures with DDGS supplemented (0.6% BW), and pastures that were neither fertilized nor supplemented. Cattle supplemented DDGS had a greater ADG (0.96 kg) compared to non- supplemented cattle (0.70 kg). As the grazing season continued, forage quality and ADG decreased, but cattle gain response to DDGS supplementation increased. Supplemented cattle replaced approximately 0.45 kg of forage for every 0.45 kg (DM) of DDGS consumed.

Greenquist et al. (2011) also showed how DDGS supplementation could increase pasture production, not only by forage savings, but also by the extra N

excreted by the supplemented cattle. The high urinary excretion of N is due to the protein of DDGS providing more than the MP requirements. The authors observed the differences in DDGS supplementation and N fertilization of smooth bromegrass pasture in terms of N dynamics and N use efficiency both pasture and steer. Supplemented steers consumed less ($P < 0.01$) forage but had greater ($P < 0.01$) total N intake compared to steers grazing fertilized pasture. Supplemented steers retained 31% more ($P < 0.01$) N and excreted more ($P < 0.01$) N than CON or FERT steers. Consequently, pasture retention of N was 31% greater ($P < 0.01$) for SUPP steers than CON or FERT steers. Greater N retention of the pasture equates to greater grass production. Therefore, pastures with cattle supplemented DDGS have greater grass production compared to pastures that are not fertilized and have no DDGS supplementation (Watson et al., 2010).

Watson et al. (2012) summarized five years of cattle and pasture performance from 2005 – 2009, and applied an economic analysis. Treatments were pasture fertilized with 90 kg N/ha (FERT), nonfertilized pasture with daily supplementation of DDGS to cattle at 0.6% BW (SUPP), and pastures that received no fertilizer or supplementation (CONT). Forage production was the greatest with FERT paddocks, lowest for CONT, with SUPP being intermediate ($P < 0.01$). SUPP pastures replaced approximately 0.79 kg of forage for each 1 kg of DDGS supplement, resulting in a higher stocking rate than CONT. SUPP steers gained 40 kg more than either FERT or CONT steers. Consequently, net returns for SUPP, FERT, and CONT were \$17.55, -\$6.20, and -\$8.71 per head ($P < 0.01$), respectively.

Monensin

The demand for low cost beef worldwide continues to push the cattle industry to more efficiently produce beef. Technology has offered many tools to increase our capabilities to produce a safe protein source. Ionophores have been in use in the beef industry since the introduction of monensin in December of 1975 (Elam & Preston, 2004)

Mode of Action and VFA Ratios

Monensin disrupts the ion concentration gradient of gram-positive microbes of the rumen, which causes them to enter a futile ion cycle. The inhibition of the gram-positive microbes is advantageous to the gram-negative microbes, which convert carbohydrates into VFA's that are more efficient to the animal (Hersom & Thrift, 2012). Propionate fermentation is energetically more efficient than either acetate or butyrate fermentations (Wolin, 1960; Hungate, 1966). Baird et al. (1979) observed an increase in heptatic gluclose production following the increase in ruminal propionate production and absorption. Research shows a decrease in the molar proportions of acetic, butyric and valeric acids while increasing the proportions of propionic and isovaleric acids in cattle that were fed monensin in high concentrate rations (Raun et al., 1976; Richardson et al., 1976; Goodrich et al., 1984, Dinius et al., 1976). Horn et al. (1981) found significant decreases of acetate to propionate ratios of 20 to 40% in steers grazing wheat pasture that were supplemented monensin.

Animal Performance and Efficiency

Monensin and other ionophores alter the volatile fatty acid (VFA) balance in the rumen, reducing production of fermentation waste byproducts and increasing the amount of net energy available from feedstuffs (Elam & Preston, 2004). Increasing

available energy results in an increase in cattle gain response (Boling et al., 1977; Duffield et al., 2012). Further, N retention is found to be greater in cattle with lower acetate: propionate ratios (Dinius et al., 1976; Eskeland et al., 1974).

Boling et al. (1977) determined differences in steers grazing Kentucky bluegrass that were supplemented 0, 25, 50, or 100 mg of monensin. Steers that were supplemented with 50 or 100 mg of monensin had greater ($P < 0.01$) ADG of 0.73 and 0.68 kg compared steers supplemented 0 or 25 mg with gains of 0.55 and 0.55 kg, respectively. Ruminal propionate increased ($P < 0.05$) as level of monensin fed increased.

Besides an increase in ADG, the increase in energy available to animal also triggers a chemostatic response on DMI (Raun et al., 1976). Decreases in DMI in a feedlot situation are easier to determine than in a grazing situation. Raun et al. (1976) measured the effect of increasing monensin levels on DMI of steers on a finishing diet. Feed consumption decreased as monensin concentrations increased. Consequently, the increase in gains and decrease in DMI results in improved feed efficiency (FE). Meyer et al. (2009) observed a 0.7 kg decrease in DMI ($P < 0.05$) and an 8% improvement in G: F ($P < 0.05$).

Duffield et al. (2012) conducted a monensin meta-analysis of 40 peer-reviewed articles and 24 additional trial reports of both growing and finishing cattle. He reported a decrease in DMI of 0.27 kg/d ($P < 0.001$) and an improvement in feed efficiency (FE) ($P < 0.001$) when cattle were fed an average concentration of 28.1 mg/kg feed (DM).

Monensin also affects ruminal protein degradation. Faulkner et al. (1985) fed steers high forage diets with monensin levels of 0, 6.1, 12.2, 18.3, or 36.6 mg/kg. The authors found that as monensin increased, bacterial protein concentration decreased quadratically ($P = 0.10$), and the ratio of total N:diaminopimilic acid (DAP) of the rumen contents increased ($P = 0.02$) when monensin was fed. The N:DAP ratio suggests less protein was degraded and/ or less BCP was synthesized. However, there was no significant increase in duodenal flow of nonammonia nitrogen or free amino acids.

Hanson and Klopfenstein (1979) tested the effect of monensin when two different protein sources: soybean meal (SBM) and urea, were fed. Each source was tested at two levels of CP (11.1% vs. 13.1%) and two levels of monensin (0 vs. 200mg/steer daily). Hanson and Klopfenstein (1979) found monensin improved feed efficiency by 8.1% with 11.5% CP compared to 3.2% feed efficiency improvement with the 13.1% CP level. This suggests a possible protein sparing effect due to either decreased degradation of gluconeogenic amino acids in the liver or reduced protein degradation in the rumen (Hanson and Klopfenstein, 1979).

Goodrich et al. (1984) summarized data from six trials to determine the change in protein requirements for cattle fed monensin. He found weight gain of cattle fed monensin was optimized with diets of 11.2% CP when the requirement was 11.6% CP. Goodrich et al. (1984) concluded monensin spares dietary protein from ruminal degradation. Ruminal ammonia, from protein degradation, is lower in cattle fed monensin compared to cattle not fed monensin (Dinius et al., 1976; Chen and Russell, 1991). Chen and Russell (1991) conclude that monensin's inhibition of

gram-positive bacteria significantly lowers the amount of ruminal protein degradation. Due to this inhibition, they found certain types of peptides that are slowly degraded are likely to escape rumen degradation and pass into the lower gut. Increased passage of peptides would increase the RUP and MP values of feed ingredients.

Monensin has been shown to affect grazing cattle differently than cattle on a high concentrate diet. Cattle on pasture had improved daily gains when supplemented monensin (Goodrich et al., 1984; Potter et al. 1976). Goodrich et al. (1984) conducted a summary of 24 trials comparing control cattle to cattle supplemented an average of 154.5 mg/head daily. He found that monensin improved daily gain from 0.609 to 0.691 kg, an average improvement of 13.5% for cattle on pasture. Though increased gain response has been well documented, monensin's effect on forage intake is more variable, and the conclusions are not as clear.

Potter et al. (1976) reported no difference in DMI when cattle were dosed monensin at 200mg or less. However, 300 and 400 mg/ steer daily decreased DMI by 5% below control. Potter went onto hypothesize monensin improves efficiency for both grazing cattle and feedlot cattle but in different ways. Raun et al. (1976) found monensin improved feed efficiency of cattle on high concentrate diets by maintaining ADG but decreasing DMI. However feed efficiency improvement in grazing cattle supplemented monensin is due to an increase in ADG while DMI remains unchanged (Potter et al. 1976). On the contrary, Lemenager et al. (1978) found cows grazing winter range with a soybean meal-based supplement had reduced FDMI by 13.6% and 19.6% when monensin was given at 50mg and 200mg, respectively.

Measuring Forage Intake of the Grazing Ruminant

Factors Affecting Forage Intake

Variation in voluntary intake is the primary determinant of the extent and efficiency of ruminant production. Yet this variation is large and highly unpredictable for grazing ruminants. There are many factors affecting forage intake: physiological stage and/ or maturity of the animal, forage preference, forage availability, and supplementation. However, the primary mechanisms of intake regulation are digestibility, passage rate, and reticulo-rumen fill (Allison, 1985).

Chemical composition of the forage is the major factor determining digestibility and voluntary intake. Chemical composition of the forage differs between the species of grass and different maturity levels. In general, as the plant matures the amount of indigestible fiber and lignin increases. In terms of chemical composition, the only consistent effect that can be observed for all forages is that of the total fibrous fraction (NDF) of the cell- wall constituents: hemicellulose, cellulose and lignin. As NDF increases, voluntary intake decreases with an increasingly negative slope (Van Soest, 1965).

Digestibility can also be affected by the physiological status of the rumen microbes. Basic concepts for ensuring a balanced nutrition for ruminants in forage-based diets include being certain there are no deficiencies in microbial nutrients (Leng, 1990). A deficiency in energy or protein can certainly decrease the microbial activity, and consequently lowers digestibility and passage rate. Inhibited microbial growth not only decreases the availability of VFA's (energy) to the animal but also

decreases the main protein source for the animal. In non-supplemented grazing situations, BCP provides most of the protein to the animal (Leng, 1990).

Estimating DMI of the Grazing Animal

The awareness of the factors effecting forage intake are useful in making management decisions. However, from a research perspective, practically and accurately measuring the forage intake of grazing ruminants has been a challenge. There is a wealth of experimental DMI data of cattle in pen-fed situations, but DMI data is lacking for grazing livestock. The procedures used for measuring intake by animals under grazing conditions have often been disappointing and many have provided unreliable data due to high individual animal variability (Cordova et al., 1978). Cordova et al. (1978) pointed out that the average between- animal coefficient of variation (CV) of intake by sheep ranges from 10% - 16%. Heaney et al. (1968) utilized forage intake data of 2,427 individual sheep/period measurements and documented a CV of 16% and a standard deviation of 9.7 units of intake. The high animal variability is due to differences in diet composition, excretion rate, and fecal composition (Van Dyne, 1969).

Holechek et al. (1986) compared actual forage intake and estimated forage intake via total fecal collection. Forage intake was estimated by dividing total fecal output by forage indigestibility estimated by in vitro procedures. Six out of the nine forages used to estimate intake were not accurate with the actual intake. This problem of estimation is further compounded when fecal output is also estimated with the use of markers.

An internal marker is an indigestible substance that is naturally found in the feed such as lignin. Acid insoluble ash, alkanes, acid detergent fiber (ADF), acid detergent lignin (ADL), in vitro neutral detergent fiber (IVNDF), and in vitro acid detergent fiber (IVADF) have also been used as internal markers. Cochran et al. (1986) instructed using caution when using IVNDF and IVADF. He also concluded among the markers he tested, ADL and ADF exposed to 10-day cellulase incubation were the least acceptable. An external marker is one that is added to the feed and is not found in the feedstuff naturally. Chromium compounds and titanium dioxide (TiO_2) are commonly used as external markers used to estimate fecal out.

Estimating forage intake can be conducted through either ratio techniques or index procedures. Ratio techniques involve the calculation of digestibility and fecal output data through their ratio to an "indigestible" indicator marker (Cordova et al., 1978). Forage intake (OM) is then calculated using the formula: organic matter intake = fecal organic matter output/ % organic matter indigestibility.

Macoon et al. (2003) compared three techniques to estimate forage intake of lactating dairy cows. They compared inference from animal performance, the use of fecal output estimation using a marker, and herbage disappearance methods. Chromium-mordanted fiber was used for the marker treatments. The cows grazed cool -season grass / clover mixture and were supplemented concentrate. The concentrate supplement consisted of hominy, soybean hulls, whole cottonseed, and citrus pulp. The herbage disappearance method and animal performance method were correlated to one another with estimate differences ranging from -4.7 to 5.4 kg/d. Macoon et al. (2003) found that the use of a chromium -mordanted fiber seemed to be

a poor tool in determining fecal output for forage intake estimation. He concluded that pulse marker method generally estimated higher forage DMI (as much as 11.0 kg/d more) and was not correlated to the other methods. Horn et al. (1981) found similar problems with chromic oxide as the estimates were unrealistically high. They concluded that this was due to cattle consuming significant amounts of soil.

Titgemeyer et al. (2001) tested the effectiveness of using TiO_2 as a marker to determine DMI in three studies. In Exp. 1, steers were divided into four treatments. All steers were fed prairie hay ad libitum and were either fed 1) no supplement, 2) 1.6 kg/d (DM) corn, 3) 0.43 kg/d cooked molasses with 30% CP, or 4) 5.0 g/d of Smartamine-M. Daily, all steers were dosed with 10g of TiO_2. Fecal recovery of TiO_2 averaged 93% and was not affected ($P = 0.47$) by supplement (Titgemeyer et al., 2001). There was no difference ($P = 0.15$) between digestibilities calculated by TiO_2 and total fecal collection.

In experiments 2 and 3, Titgemeyer et al. (2001) compared marker recovery and digestibility estimations between TiO_2 and chromic oxide (Cr_2O_3) in corn-based diets. In Exp. 2, average marker recovery was 95% for TiO_2 and 116% for Cr_2O_3. Compared to total fecal collection, digestibility estimates referring to TiO_2 underestimated 1.1% ($P < 0.01$) and Cr_2O_3 overestimated 2.2% ($P < 0.01$). In Exp. 3, average marker recovery was 90% for TiO_2 and 98% for Cr_2O_3. Compared to total fecal collection, digestibility estimates using TiO_2 underestimated 1.6 – 4.3% ($P < 0.01$) and Cr_2O_3 was not different ($P = 0.31$). In conclusion future research is warranted to determine the usefulness of TiO_2 in measuring digestibility in cattle (Titgemeyer et al., 2001).

Myers et al. (2005) utilized ewes, fed diets varying in forage levels, to observe the differences in marker excretion patterns of TiO_2 and Cr_2O_3. Treatments were diets of 100%, 50%, and 25% forage. The markers were both dosed twice daily at 2.5g for a total daily dose of 5g. Both markers were measured in fecal samples and in duodenal digesta sampled at times 0, 2, 4, 6, 8, and 10 h after morning feeding. Myers et al. (2005) found there were diurnal patterns after feeding for both markers. However, there was no significant marker x time interaction. Higher concentrations of TiO2 were recovered in the feces compared to Cr_2O_3. Regardless, TiO2 is an acceptable alternative to Cr_2O_3 for use in site and extent of digestion studies with ruminants (Myers et al., 2005).

Although there is a large amount of criticism of markers from expectations not being met, the us of external markers is one of the most practical choices for measuring forage intake. Despite imprecision in marker procedures, inherent variation may be small relative to other sources of variation (e.g., gut physiology, diet, environment, and feed intake) (Owens & Hanson, 1992). Markers may provide imprecise absolute values, but the estimates are usually reliable in yielding direction and extent of kinetic changes induced by treatments (Owens & Hanson, 1992).

Summary and Research Objectives

An abundance of research has focused on supplementing grazing cattle. The supplementation of DGS has proven to increase ADG while decreasing forage intake (Corrigan et al., 2009b; Gustad et al., 2006; Loy et al., 2003; Greenquist, 2009; Morris et al., 2005). Monensin supplementation has been shown to improve gains of cattle grazing pasture (Goodrich et al., 1984; Potter et al., 1976). The decrease in

DMI has not been clearly demonstrated in the grazing scenario like it has in the feedlot for cattle fed high-energy diets. Potter et al. (1976) theorized there is no decrease in DMI when monensin is supplemented to grazing cattle due to the energy of a forage diet, which is comparatively lower than feedlot finishing diets. Supporting that monensin does not decrease forage intake is challenging due to researcher's inability to practically measure the intake of a grazing animal. The attempts of estimating forage intake of grazing cattle have been far short of acceptable. There is no sure way of measuring the forage intake of a grazing animal that is practical. The best option in this day and age is the use of an external marker in the ratio technique. Despite the challenges, investigating the effect of DGS with monensin supplementation on grazing cattle efficiency is warranted due to the demand for affordable beef. Therefore, our objective is to determine how FOMI and ADG of cattle grazing smooth bromegrass are affected by supplementing DGS and monensin.

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Effect of Monensin and Distillers Grains plus Solubles Supplementation on Performance of Steers Grazing Smooth Bromegrass

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Abstract

Two groups of cattle were utilized to evaluate cattle performance and profitability when supplemented with modified distiller grains plus solubles (MDGS) while grazing smooth bromegrass. In Exp. 1, crossbred yearling steers (n=45, BW= 352 ± 12 kg) rotationally grazed smooth bromegrass paddocks. Steers were assigned randomly to one of three treatments; nonfertilized pasture and no supplement (CON), pasture fertilized with 90 kg N/ha without supplement (FERT), or nonfertilized pasture with supplementation of MDGS at 0.6% BW (SUPP). In Exp. 2 steers were utilized in a 4 x 2 factorial treatment structure. The first factor was 4 rates of MDGS supplement, and the second factor was 0 or 200 mg/steer daily of monensin. Crossbred yearling steers (n= 60, BW= 334 ± 32 kg) rotationally grazed smooth bromegrass paddocks and were individually supplemented (MDGS) at 0.05, 0.4, 0.6, or 0.8% BW. Within each rate of MDGS, steers were fed 0 or 200 mg/steer daily of monensin. In Exp. 1, SUPP steers gained 0.50 kg/day more ($P < 0.01$) than FERT and CONT cattle. In Exp. 2, gain increased quadratically *(*$P < 0.01$) as MDGS level increased. Maximal ADG (1.34 kg/d) was predicted when supplementing at 0.48% of BW. There tended to be a MDGS supplementation level x monensin interaction ($P = 0.12$). Monensin increased ADG ($P = 0.04$) when supplemented with MDGS ≤ 0.05% BW. Monensin did not affect ADG when supplemented with MDGS ≥ 0.04% BW (*P*

= 0.53). A MDGS level x monensin interaction was observed for MDGS intake. Monensin decreased MDGS consumption (P = 0.01) when MDGS was supplemented at 0.8% BW. Monensin had no effect on MDGS consumption (P = 0.67) when supplemented with MDGS ≤ 0.06% BW. Economic analysis compared daily MDGS supplementation at 0, 0.91, and 2.27 kg/d (DM) when MDGS was priced from $145.89 to $312.51/mT (DM). When cattle ownership was retained through the feeding period, MDGS supplementation was profitable. Supplementation at 0.91 kg (DM) was more profitable than 2.27 kg (DM) when MDGS was above $292.81 mT (DM).

Key words: monensin, modified distillers grains plus solubles, supplementation, rotational grazing

Introduction

Drought and grain price incentives to convert pasture to cropland can deplete grass resources severely for grazing cattle production. This challenge has created the need to maximize grazing resources. Supplementation of distiller grains plus solubles (DGS) is an effective tool in managing forage supply without sacrificing cattle performance. The ruminally undegradable protein (RUP), which is digested directly by the animal as metabolizable protein (MP), is the first limiting factor for yearling steers grazing native range and smooth bromegrass (Creighton et al., 2003; Karges et al. 1992; Watson et al., 2010). Distiller grains plus solubles meet MP requirements with approximately 30.9% CP (% of DM; U.S. Grain Council. 2012) and 63% RUP (% of CP; Lopez, 2012). Supplementing DGS also provides energy through digestible

NDF (NDFD 70% of NDF; Kononoff and Page et al., 2007; Corrigan et al., 2009; Hsu et al., 1987) and 10.7 – 13.1% fat (Buckner et al., 2008) . Previous research determined dried distiller grains (DDGS) to be 127% the energy value of dry rolled corn in forage diets (Loy et al., 2003). Research has shown DGS supplementation allows growers to increase stocking rate and ADG (Corrigan et al., 2009; Gustad et al., 2006; Loy et al., 2003; Greenquist, 2009; Morris et al. 2005; Watson et al. 2012). However, an increase in DGS prices may impact the optimum supplementation level. Likewise, optimum levels may differ between achieving maximum animal performance and achieving maximum profitability.

The supplementation of monensin, an ionophore feed additive, to grazing cattle has also been used to increase the efficiency of grazing cattle. When supplemented to grazing cattle, monensin increases ADG in grazing cattle (Boling et al., 1977; Goodrich et al., 1984; Horn et al., 1981; Potter et al. 1976). The improvement in efficiency by feeding monensin is believed to be due in part by a protein sparing effect. Hanson and Klopfenstein (1979) concluded that monensin either decreased degradation of gluconeogenic amino acids in the liver or reduced protein degradation in the rumen. Improvement in cattle efficiency from monensin is also because of the increase in ruminal production of propionate (Raun et al., 1976; Richardson et al., 1976; Goodrich et al., 1984; Dinius et al., 1976). Due to the gluconeogenic nature of propionate, there is an increase in the hepatic gluconeogenic flux when ruminal propionate production increases (Baird et al., 1980).

The objective of this study was to determine the effects of modified distillers grains plus solubles (MDGS) and monensin on the performance of cattle grazing smooth bromegrass.

Materials and Methods

Experiment Site

This project was conducted at the University of Nebraska- Lincoln Agricultural Research and Development Center near Mead, Nebraska in 2012. In the year of the experiment, the climate at the site of research consisted of temperatures ranging between a low of -8.3°C in February to a high of 33.3°C in July. Total precipitation from January to September was 40.2 cm, with a monthly high of 10.8 cm in June and a low of 0.7 cm in July (NCDC, 2014). Soil type of the study type is primarily Sharpsburg silty clay loam. The pastures were composed of a monoculture of smooth bromegrass. The pastures have been used for studies utilizing rotational grazing from 2005- 2011.

Treatments

In Exp. 1, crossbred steers (n=45, BW= 352 ± 12 kg) were utilized in a 3 block, 3 treatment RCBD to evaluate the effect of MDGS supplementation and pasture fertilization on performance of cattle grazing smooth bromegrass. Pasture was the experimental unit. Each steer was assigned randomly to one of the following pasture treatments: nonfertilized and nonsupplemented (CONT), fertilized at 90 kg N/ha and nonsupplemented (FERT), or nonfertilized and supplemented with MDGS at 0.6% BW (SUPP) (Table 1). Nitrogen fertilizer in the form of urea was applied March 17, 2012 to the FERT pastures. Fed in bunks, SUPP cattle were supplemented MDGS

daily, in their respective paddock.

In Exp. 2, crossbred steers (n= 60, BW= 334 ± 32 kg) were utilized in a 4 x 2 factorial design experiment to compare the effects of MDGS and monensin supplementation on performance of steers grazing smooth bromegrass. The first factor was the supplementation of MDGS at levels of 0.05, 0.4, 0.6, and 0.8% BW. The 0.05% BW level acted as the control. Due to the need for a carrier to administer the monensin, the control cattle were supplemented DDGS at 0.05% BW. The second factor was the supplementation of monensin at either 0 or 200 mg/steer daily. Steers were assigned randomly to one of the 8 treatments (Table 2). Utilizing a Calan gate system, treatments were applied to each steer in an individual feeding barn daily between 0700 h and 0900 h.

A premix of DDGS, salt, and Rumensin 90 was formulated to administer the monensin to steers on the monensin treatment. A second premix was also made with DDGS and salt for steers not receiving monensin to maintain consistency between treatments. When supplemented, the premix was first measured into a feed pan followed by the assigned amount of MDGS. The feed pan was then flipped upside down into the feed bunk so that the premix was on top and would be consumed first. Following the 2.5 hours cattle were allowed to consume their assigned supplement, the steers were returned to the smooth brome pastures and orts were collected and weighed.

Grazing Management

Exp. 1 had 3 pastures within each block, one for each treatment. Each pasture was divided into 6 paddocks by single wire electric fence. The CONT cattle were

stocked at 6.8 AUM/ha, and the FERT and SUPP cattle were stocked at 9.9 AUM/ha. Historically, the CONT pastures were stocked lower than FERT or SUPP due to less forage production and replacement of forage DMI with MDGS supplement (Greenquist et al., 2011; Watson et al., 2010). Therefore, because equal grazing pressures were desired, CONT stocking rate was adjusted. A detailed description of the pasture management of Exp. 1 is further described by Greenquist et al. (2011).

Each treatment in Exp. 1 was on a 136 day, 6 paddock grazing rotation from April 27, 2012 to September 11, 2012. The grazing season was divided into 5 cycles. A cycle was complete when the 6th and final paddock was grazed. Cycle grazing length was adjusted according to precipitation and relative grass production. Cycles 1 and 3 were 24 days. Cycles 2, 4, and 5 were 36, 34, and 18 days, respectively. During cycle 4, cattle on trial were removed from the research paddocks to another pasture to avoid limited intake due to grass shortages. However, SUPP cattle continued supplementation at 0.6% BW MDGS.

In Exp. 2, cattle were on a 120-day grazing rotation using 6 paddocks from April 27th, 2012 to August 24th, 2012. Cattle were rotated through 3 pastures. Each pasture was split into 2 paddocks by single wire electric fence. They were stocked at 6.77 AUM/ha. There were 4 grazing rotation cycles. Cycle 1 was a 24-day grazing cycle, and cattle were rotated every 4 days. Cycles 2 and 3 were each 36-day grazing cycles, and cattle were rotated every 6 days. Period 4 was a 24-day grazing cycle, but dry weather resulted in a shortage of grass on the designated paddocks. During period 4 cattle were placed in an extra pasture and continuously grazed for the 24-day period, and individual supplementation was continued.

Data Collection & Analysis

Performance

Five days prior to day 1 of the trial, both Exp. 1 and Exp. 2 steers were limit fed (2.0% BW) a common diet of 48% alfalfa hay, 48% wet corn gluten feed, and 4% supplement (DM basis). The three following days (-1, 0, and 1) individual weights were taken and then averaged for initial BW to reduce weight inaccuracy due to gut fill variation (Stock et al., 1983; Watson et al., 2013). During day 1 weighing, steers were also implanted with Revalor G (Merck Animal Health, De Soto, Kansas). Cattle weighed at the completion of each cycle and adjusted with a 4% shrink BW to compensate for gut fill. Exp. 1 interim weights were taken on days 24, 60, 84, and 118. Exp. 2 interim weights were taken on days 24, 60, and 96. The first day following the last grazing cycle cattle were limit fed a common diet of 48% alfalfa hay, 48% wet corn gluten feed, and 4% supplement (DM basis) for five days followed by three days of weighing. The three-day weights were averaged to establish end BW.

The differences in ADG were analyzed for Exp. 1 and Exp. 2. However, performance of both Exp. 2 and CONT steers of Exp. 1 were used to create a regression equation to estimate ADG in relation to the amount of MDGS actually consumed. The regression equation was developed using MDGS consumption and calculated ADG.

Efficiency improvements due to daily MDGS supplementation at 0, 0.91, and 2.27 kg/steer (DM) were calculated. These supplementation points were utilized because previous research had established these amounts were practical for producers. Performance and actual MDGS consumption were analyzed using the SAS

MIXED procedure (SAS, Inc., Cary, N.C.). For Exp. 2, steer was the experimental unit and supplementation level was the fixed effect. Maximal gain was also determined by using the first derivative of the quadratic response from actual MDGS intake and ADG data.

Diet Quality

Diet samples were collected utilizing six ruminally fistulated steers. Diet samples were taken at the midpoint of the 4 or 6 day grazing rotation for accurate representation of grass quality (Baleseng, 2006). The midpoints of the 4 and 6-day rotations were considered the morning of day 3 and 4, respectively. Diet sampling was taken from a pasture from Exp. 2, while the cattle of Exp. 2 were being individually supplemented. Following 12 hr fasting, the fistulated steers were ruminally evacuated at 0800 h. Steers were then allotted a 20 min grazing period to accumulate the sample. The fresh rumen samples were then collected and iced. Pre-evacuated rumen contents were then returned to the rumen. Following collection, the cooled samples were transferred to the lab where the entire sample was weighed. The liquid and solid fractions were separated using a food grade colander and then weighed to determine the ratio of solid to liquid. A sub sample of the solid fraction was analyzed for dry matter and the remainder of the samples were then stored at −4°C.

For lab analysis, the liquid fraction was oven dried (60°C) and then ashed (600°C; 6 hours) to determine DM and OM. The remaining lab analysis refers only to the solid fraction. The solid fraction samples were lyophilized (−50°C) and ground separately through a 2-mm screen using a Wiley mill (Thomas Scientific,

Swedesboro, NJ). A subsample was then ground through a 1-mm screen. Organic matter was determined after an ashing (600°C) time of 6 hours. Diet crude protein was determined by the combustion method (method 4.2.10; AOAC, 1996) using a combustion N analyzer (FP-528, Leco Corp., St. Joseph, MI).

Neutral detergent fiber was measured using the reflux method (Van Soest & Marcus, 1964) with a calculation adjustment for the liquid portion. The liquid portion was considered 100% soluble OM. Therefore, NDF was determined by the % NDF of the solid fraction multiplied by the percentage the solid portion was of the entire diet sample on a OM basis.

In vitro organic matter disappearance (IVOMD) was determined following the Tilley and Terry method (Tilley and Terry, 1963) with an addition of 1 g/L of urea to the McDougall's buffer (Weiss, 1994). Diet sample components were analyzed using the MIXED procedure of SAS (SAS, Inc., Cary, N.C.). Model effects included period, steer, and measurement (NDF, CP, IVOMD). Probabilities of linear and quadratic trends were determined using orthogonal polynomial contrasts.

Economic Analysis

Presuming retained cattle ownership through the feeding period and finished steers priced at $2.86/kg, profitability differences (partial budget) were calculated for supplementing MDGS to steers at 0, 0.91, and 2.27 kg of DM/day during a 120-day summer grazing period. Performance data from previous DGS supplementation research conducted by Morris et al. (2005; 2006) were combined with performance data of Exp. 2 to add power and precision to the economic analysis. Morris et al. (2005) determined ADG of heifer calves (n=90, BW 286 kg) when supplemented

dried distillers grains plus solubles (DDGS) at 0, 0.7, 1.4, 2.0, or 2.7 kg DM with either brome or alfalfa hay. Morris et al. (2006) determined ADG of 56 steers (n=56, BW 311 kg) while supplemented with DDGS at 0, 0.26, 0.51, 0.77, or 1.03% BW while grazing summer Sandhill native range. The assumption was made that in the feedlot, DMI would be similar and weight gain would be retained from cattle supplemented 0.91 and 2.27 kg MDGS (Morris et al. 2006, Rolfe et al. 2012).

Pasture rent base price was set at $0.80/animal daily. Previous research suggests forage savings is 6.8 and 17% for 0.91 and 2.27 kg (DM) MDGS supplementation, respectively (Watson et al., 2010). Correspondingly, stocking rate increases and rent cost/animal decreases. Therefore, the assumed pasture rent for the 0.91 and 2.27 kg (DM) MDGS supplementation is $0.75 and $0.66/animal daily. Delivery cost of supplementation for both amounts was $0.10/steer daily.

Supplementation was priced at 100% of corn with corn priced from $0.16 /kg to $0.34/kg (DM basis). Consequently, the costs of MDGS, on DM basis were $160.75, $222.00, $283.22, and $344.47/mT. The as-is price of MDGS would depend on the DM content of the MDGS.

Results and Discussion

Performance

The SUPP steers in Exp. 1 gained more ($P < 0.01$) weight (1.20 kg/d) than FERT and CONT steers (0.68 and 0.74 kg/day, respectively). There was no difference in ADG between FERT and CONT ($P = 0.23$). Cattle supplemented on smooth bromegrass gained 41% more weight per day compared to nonsupplemented cattle. Consequently, end BW for SUPP, CONT, and FERT was 520, 456, and 447 kg

respectively. Watson et al. (2012) evaluated five years of data collected with similar methods and observed similar ADG differences for SUPP, CONT, and FERT cattle gaining 0.94, 0.67, and 0.68 kg/day, respectively. Greater gains for supplemented cattle are due to supplying (RUP) from DGS, thus meeting the metabolizable protein requirements of the animal. Further, the DGS provided additional energy from fat (Buckner et al., 2008) and digestible fiber (Corrigan et al., 2009). The increased gain due to RUP, fat, and digestible fiber in DGS was demonstrated by MacDonald et al. (2007).

In Exp. 2, a quadratic increase ($P < 0.01$) in ADG was observed as actual MDGS intake increased. Griffin et al. (2012) also observed a quadratic gain increase as the level of DGS increased when cattle were fed forage in a confined scenario. On the contrary, the authors observed a linear gain increase when DGS was supplemented to cattle on pasture. Morris et al. (2005) observed a linear increase in ADG as the amount of DGS increased from 0 – 1.0% BW when cattle were individually fed low or high quality forage. Morris et al. (2006) also observed a linear increase in ADG for cattle on native range as DGS supplementation increased from 0 to 1.03% BW. The reason of differences in the observed trend of the current study and those of Griffin et al. (2012) and Morris et al. (2005, 2006) is unknown. Speculatively speaking, the differences may be due to the variance in levels of DGS evaluated between the studies.

In terms of ADG, there tended to be an interaction between monensin and MDGS level ($P = 0.12$; Figure1). Monensin did not effect ADG when supplemented with MDGS $\geq$ 0.4% BW ($P = 0.53$; Figure 1), which disagrees with the summary of

Goodrich et al. (1984). However when feeding MDGS at 0.05% BW, monensin increased (P = 0.04; Figure1) ADG by 0.15 kg/day. The gain increase observed at 0.05% BW MDGS due to monensin, reveals the advantage monensin provides through the protein sparing effect (Goodrich et al., 1984; Hanson & Klopfenstein, 1979) and the increase of ruminal propionate (Boling et al., 1977; Dinius et al., 1976; Duffield et al., 2012; Raun et al. 1976, Richardson et al., 1976). However, there was no performance difference observed due to monensin when MDGS supplementation increased. Speculatively, there is no improvement in gain from monensin when fed with MDGS because the benefits of monensin are small relative to the response from RUP and energy of MDGS.

A regression equation based on ADG and MDGS intake was created using cattle that were not supplemented monensin (n=30, BW 400± 39 kg). Since monensin increased ADG when MDGS was fed at 0.05% BW and its effect on forage intake was unknown, cattle fed monensin were excluded from developing the regression equation. Based on the regression equation developed using Exp. 2 cattle ADG and MDGS offered ($y = -0.9363x^2 + 1.2693x + .8803$ $R^2 = 0.64$), the maximal gain response of 1.31 kg/day occurred when cattle consumed MDGS at 0.68% BW. The maximal gain response when cattle are supplemented DGS at 0.68% BW is similar to past research (Griffin et al., 2012). Griffin et al. (2012) evaluated pasture cattle supplemented DGS between 0 – 0.8% BW, 0.6 had the greatest ADG of 0.93 kg. However, the results from Griffin et al. (2012) and the regression equation previously explained are based on the amount of MDGS offered, not actual MDGS consumed. The advantage of the Calan gate system was that we could observe each individual,

and it was observed that steers offered 0.8% BW MDGS rarely consumed above 0.6% BW.

Therefore another regression equation was developed replacing MDGS offered with MDGS consumed. The addition of the CONT cattle from Exp.1 were included because they were on similar pasture and we knew each animal consumed 0 kg MDGS. Control cattle from Exp. 1 and the non-monensin steers of Exp. 2 (n=45, BW 401± 38kg) were used to develop the regression equation ($y = -2.4582x^2 + 2.3474x + 0.7823$ $R^2 = 0.72$) to estimate maximal ADG based on actual MDGS intake data (Figure 2). The actual MDGS intake based regression calculated a maximal ADG of 1.34 kg/day at MDGS supplementation of 0.48% BW. When Griffin et al. (2012) evaluated pasture cattle supplemented DGS between 0 – 0.8% BW, 0.6% BW had the greatest ADG of 0.93 kg. The differences in estimated optimal DGS level for maximal gain between the regression based on actual MDGS intake and Griffin et al. (2012) may be due to year to year variation on grass quality, grass source, and whether DGS intake was measured or assumed.

A gain improvement of 14 % was calculated when MDGS supplementation increased from 0 to 0.05% BW (0.18 kg MDGS/steer/day). This increased gain response is due to the fulfillment of the metabolizable protein (MP) requirement of the steer via the high RUP (63% of CP; Lopez et al., 2013; Creighton et al., 2003; Karges et al. 1992; Watson et al., 2010).

The regression equation was used to estimate the ADG of a 341kg steer when supplemented MDGS amounts of 0, 0.91, and 2.27 kg. The estimated ADG for 0, 0.91, and 2.27 kg DGS were 0.78, 1.23, and 1.25 kg, respectively. An increase of

MDGS supplementation from 0 to 0.91 kg resulted in a 57.7% improvement in gain. Again this improvement is due to meeting the MP requirement of the animal. However, a smaller improvement of an additional 1.6% was observed between 0.91 to 2.27 kg MDGS/steer. The small increase between 0.91 to 2.27 kg MDGS/steer reveals the improvement is no longer from meeting the MP requirement, but from the additional energy as MDGS increased (Buckner et al.,2008; Corrigan et al., 2009; Hsu, 1987; Oliveros,1989).

Supplement DMI

The analysis of the actual MDGS intake of Exp. 2 resulted in differences between levels of MDGS offered *(P* < 0.01). Though the difference in MDGS intake is not surprising, we observed cattle offered 0.8% BW MDGS rarely consumed over 0.6% BW. A level x monensin interaction was observed for MDGS intake (*P* = 0.05; Figure 3). The supplementation of monensin had no effect on MDGS intake when MDGS was supplemented at 0.05, 0.4, and 0.6% BW (*P* = 0.99, 0.35, and 0.41 respectively). However, when monensin was supplemented with 0.8% BW MDGS, consumption of the MDGS was lower (*P* = 0.01) with an intake of 0.59% BW compared to 0.63% BW. This interaction suggests monensin may have a negative impact on MDGS supplement intake as the amount of MDGS offered increases. The biological mechanism is not clear.

The MDGS intake decrease is also observed in high concentrate feedlot diets as it triggers a chemostatic response due to a decrease in acetate: propionate ratio (Duffield et al., 2012; Raun et al. 1976). Theoretically, as we increase the concentrated energy intake of the animal there is a greater chance of a chemostatic

response, especially with the addition of monensin. A steer (BW 401 kg) eating MDGS at 0.8% BW would be consuming 3.2 kg of MDGS and 4.8 kg smooth bromegrass daily. Comparatively, the same steer with no supplementation would be consuming 8.0 kg DM smooth bromegrass. Assuming smooth bromegrass is 62% TDN (MacDonald & Klopfenstein, 2004) and MDGS is 108% TDN (Watson, 2011), then the supplemented and nonsupplemented steers would be consuming diets of 81% and 62% TDN, respectively. Consequently, supplemented steers gained 1.3 kg/day and nonsupplemented steers gained 0.8 kg/day. However, Owens et al. (1997) listed a feedlot diet TDN at 89% with an ADG of 1.5 kg. The question arises; is there enough energy at the high level of MDGS supplementation for monensin to have a significant effect on the acetate: propionate ratio and impact DMI? Klopfenstein et al. (2007) stated that the lipid in DGS might also decrease DMI. Speculatively, the supplementation of 0.8% MDGS with monensin to steers grazing bromegrass may decrease MDGS DMI due to the high lipid level, the initiation of a chemostatic response or both.

Diet Quality

The Exp. 2 cattle were moved to an extra pasture due to a shortage of rain and consequently a shortage of grass. Therefore, the August diet sample was taken in the extra pasture. Overall, diet sample NDF did not change over the season (P = 0.12), but tended to increase quadratically (P = 0. 06; Table 3) as the grazing season progressed. Crude protein decreased (P = 0.05; Table 3) quadratically from May to August from 15.9% to 14.3% DM. Smooth bromegrass CP was the lowest for July at 10.5 % DM. Apart from year to year variation, Schlueter (2004) observed a similar

pattern as CP content of immature fertilized smooth bromegrass in early May was 17.3% and declined to a low of 14.6% as the grass matured by mid July. However, Shclueter et al. (2004) also observed an increase in CP in September of 19.2% CP on DM basis. Similarly, Baleseng (2006) reported an increase in CP as the plant went into the cool weather of the fall. Corresponding to the CP observations, IVOMD decreased quadratically (P = 0.05; Table 3). Comparably to CP, smooth bromegrass IVOMD was the greatest in May at 62.5 % and decrease to 54.5 % in August with the low being in July at 54.0 %.

Economics

Analysis of the combined data resulted in 1.00 kg/d ADG for cattle supplemented with DGS while non-supplemented cattle gained 0.70 kg/day. When sold as fat cattle, supplemented steers had $43.17 to $93.17 more gross profit than non-supplemented cattle (Figure 4). Watson et al. (2012) observed a $44.01 gross profit advantage for cattle consuming 2.4 kg DDGS when compared to nonsupplemented cattle. Watson et al. (2012) went on to calculate a $17.55 / steer net return for cattle supplemented DDGS, and a net loss of $7.46 / steer for nonsupplemented cattle.

When MDGS was $160.75 mT DM, supplementing 2.24 kg DM MDGS had a return of $233.77 and supplementing 0.91 kg DM returned $209.15; a difference of $24.62 per head (Figures 4 and 5). However, as the price of MDGS increased, the profitability of 2.24 kg MDGS supplementation decreases quicker (slope = -16.7; Figure 5)) than 0.91 kg MDGS supplementation (slope = -6.67; Figure 5). Therefore,

supplementing 0.91 kg DM MDGS became $0.37 more profitable per head than supplementing 2.24 kg DM MDGS when MDGS price reached $313.86 mT (Figure 5). When the price of MDGS reached $344.47 Mt DM supplementing 0.91 kg DM MDGS became $5.38 more profitable than supplementing MDGS at 2.24 kg DM (Figure 5). Depending on the price of corn and the price of DGS to corn, these data suggest supplementation to the maximum gain is not always the most profitable. However, supplementing to maximum gain for cattle on grass was more profitable most of the time. In every scenario evaluated, supplementing MDGS to growing cattle on grass was always more profitable than not supplementing.

Implications

Supplementing MDGS increases performance of cattle grazing smooth bromegrass. Supplementing at 0.48% BW DM to cattle grazing smooth bromegrass resulted in maximal gain response of 1.34 kg/day. When adding monensin to the MDGS supplement there was no increase in gain unless fed at 0.05% BW DM or lower. Without affecting ADG, monensin started to decrease MDGS DMI when MDGS was fed at 0.8% BW DM. Profitability of supplementing MDGS to grazing cattle is affected by many factors, but when ownership is retained through the feedlot and cattle are sold at $1.30, growing cattle supplemented DGS were more profitable than cattle not supplemented. Supplementing 2.44 kg DGS DM was more profitable when DGS price was below $292.8 mT. Supplementing DGS to grazing cattle has valuable performance benefits. Adding monensin may have subtle effects on performance and DGS DMI when supplemented to grazing cattle. However, when cattle are supplemented with DGS, monensin's effect on forage intake is unclear.

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Table 1. Exp. 1 Treatments

	[3]Treatments		
	CONT	**SUPP**	**FERT**
[1]**N, kg/ha**	**0**	**0**	**90**
[2]**MDGS, %BW**	**0**	**0.6**	**0**
MDGS, kg/d	**0**	**2.6**	**0**
[4]**AUM**	**6.8**	**9.9**	**9.9**

[1]Nitrogen fertilizer applied March 17, 2012

[2]MDGS was supplemented daily in a portable bunk in the pasture

[3]Treatments: nonfertilized and nonsupplemented (CONT), or nonfertilized and supplemented with MDGS at 0.6% BW (SUPP), fertilized at 90 kg N/ha and nonsupplemented (FERT)

[34]1 AUM= 680 kg of forage 100% DM basis

Table 2. Exp. 2 Treatments

	Treatments							
[1]MDGS level, % BW	0.05		0.4		0.6		0.8	
[2]Monensin level, mg.day	0	200	0	200	0	200	0	200
Experimental Units, n	9	9	7	7	7	7	7	7

[1]MDGS was supplemented daily at 4 levels in an individual feeding barn using the Calan gate system.
[2]Monensin was administered at 10g/day in a premix of DDGS (84%), Rumensin 15% and salt 1%.

Table 3. Smooth bromegrass quality changes over grazing season.

	Cycle				Probabilities[1]	
	1	2	3	4 [3]	Linear	Quadratic
Month	May	June	July	August		
Factor, % DM						
CP	15.9	13.4	10.5	14.3	0.05	0.05
[2] NDF	62.8	68.3	63.8	62.7	0.34	0.06
[3] In Vitro OMD	62.5	56.3	54.0	54.5	<0.01	0.05

[1] Probablilities of linear and quadratic trends determined with orthogonal polynomial contrasts.

[2] Neutral detergent fiber was adjusted for organic matter.

[3]Cattle from Exp. 2 were moved to an extra smooth bromegrass pasture in August due to drought – caused grass shortages. Values from the August diet sample are from a different pasture than the first three months.

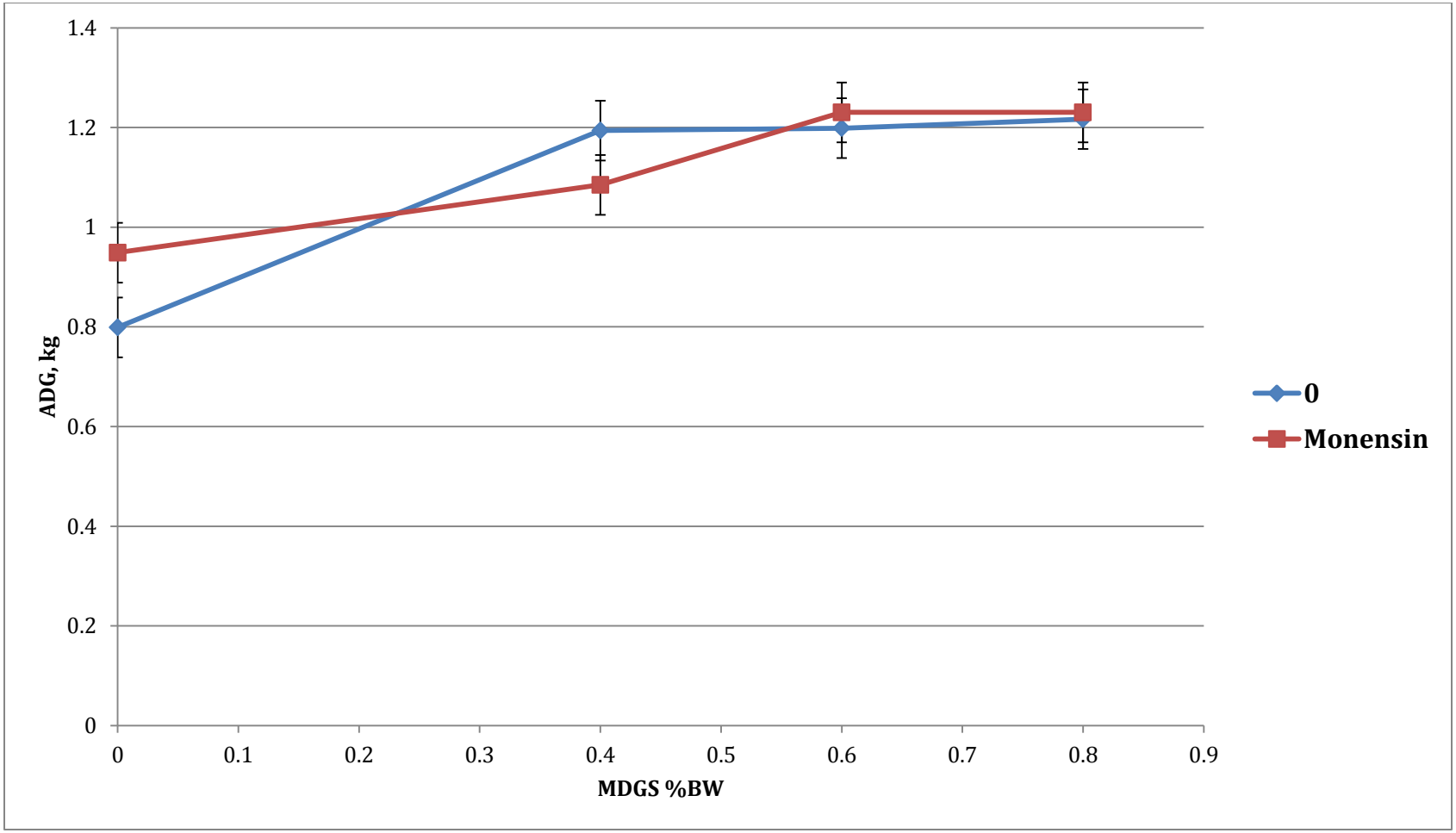

Figure 1. The effect of MDGS and monensin supplementation on peformance of grazing steers of Exp. 2. There tended to be an interaction between monensin and MDGS level (*P =0.12)*. Monensin did not effect ADG when supplemented with MDGS ≥ 0.4% BW (*P*=0.53. However, when feeding MDGS at 0.05% BW, monensin increased (*P*=0.04, Figure1) ADG by 0.15 kg/day.

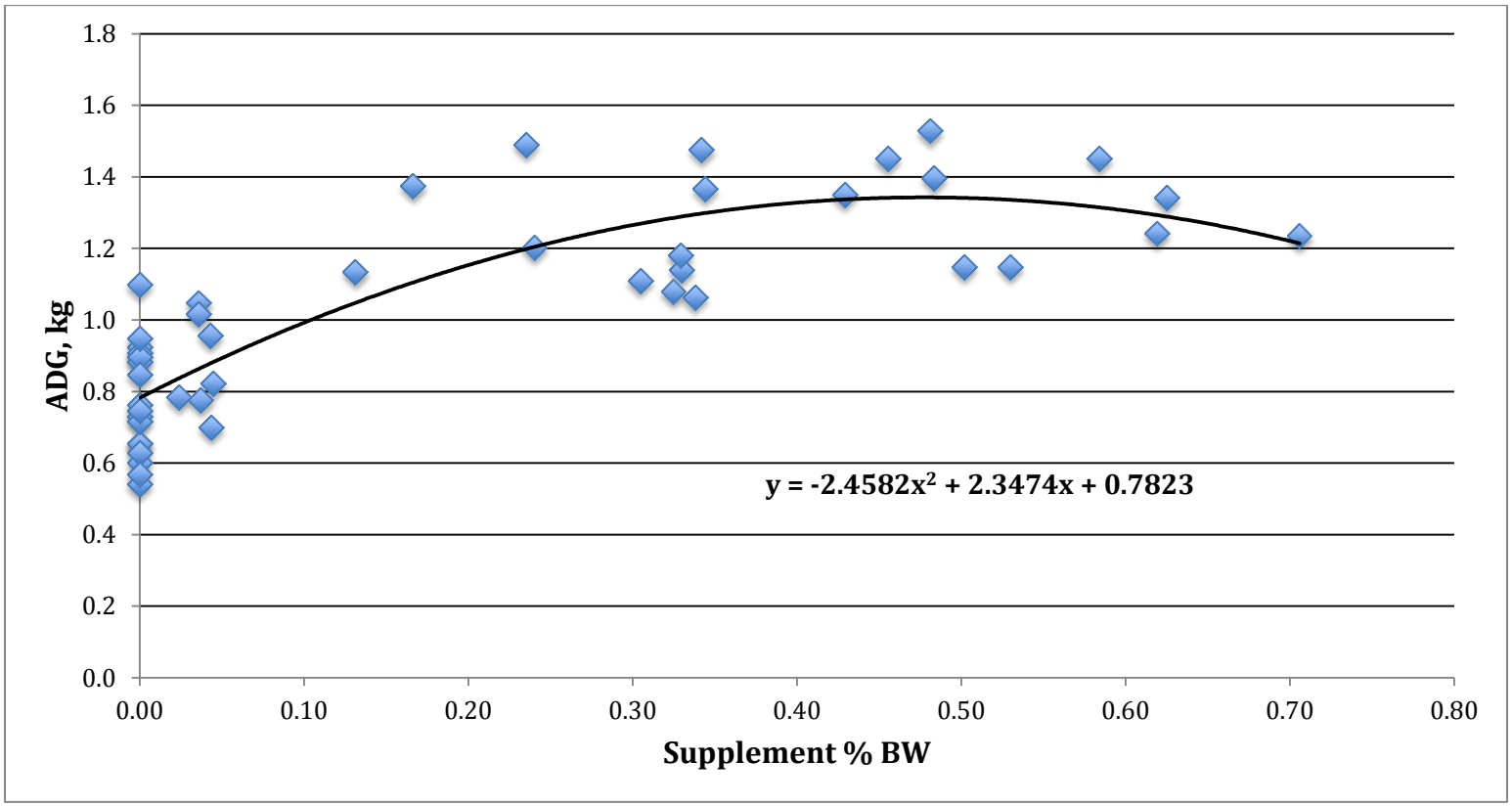

Figure 2. Effect of actual MDGS supplement intake on grazing steer ADG. Actual MDGS DMI and ADG data from CONT of Exp. 1 and steers supplemented MDGS without monensin of Exp. 2. The gain response increased quadratically ($P < 0.01$) as MDGS DMI increased ($R^2 = 0.72$).

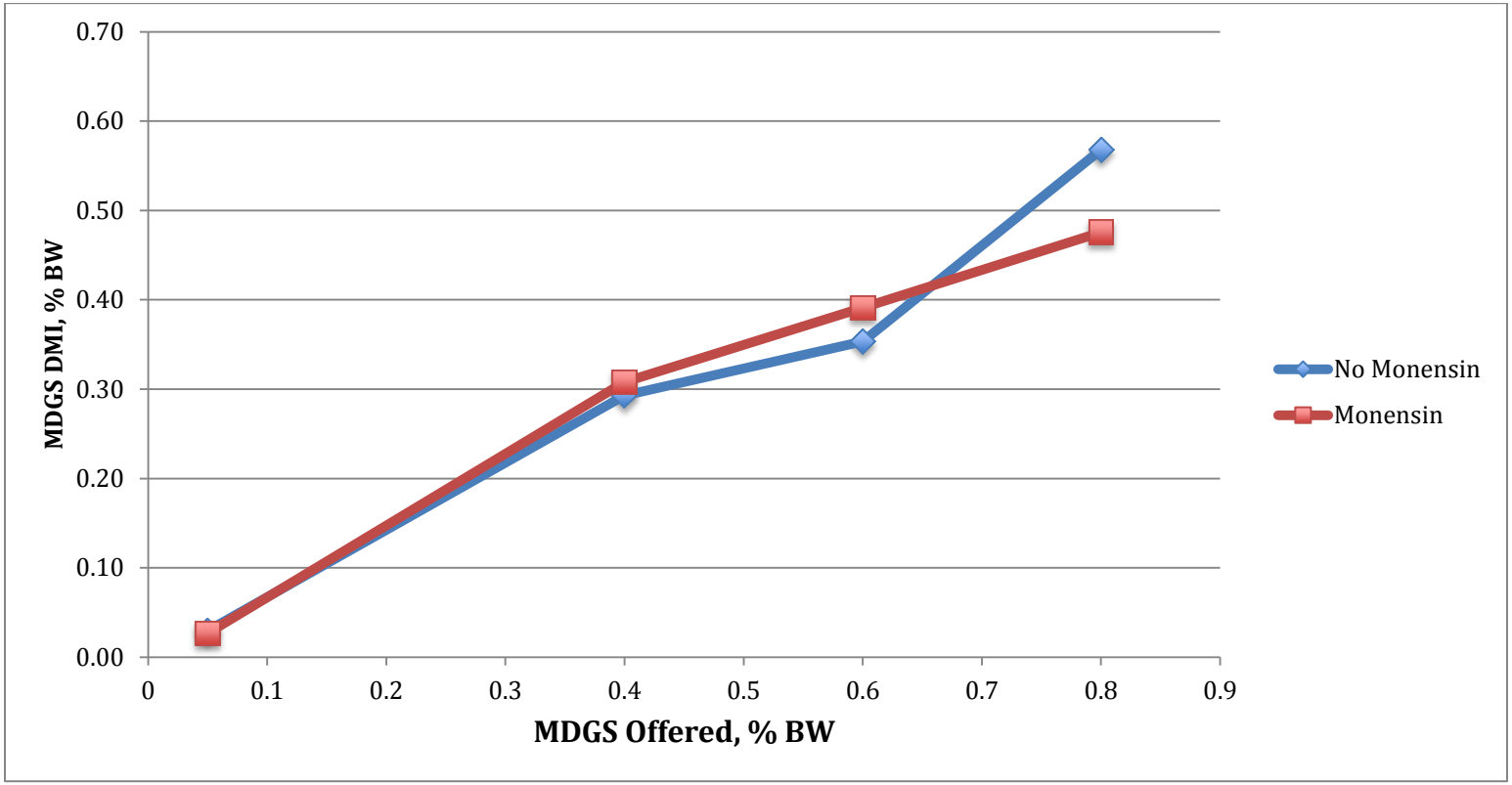

Figure 3. Effect of monensin on MDGS supplement intake. MDGS DMI was not affected by supplementing monensin (P = 0.67; SE = 0.009). A significant interaction between MDGS level and monensin (P = 0.05; SE= 0.01) was observed. Monensin only suppressed MDGS DMI (P = 0.01) when MDGS was offered at 0.8% BW.

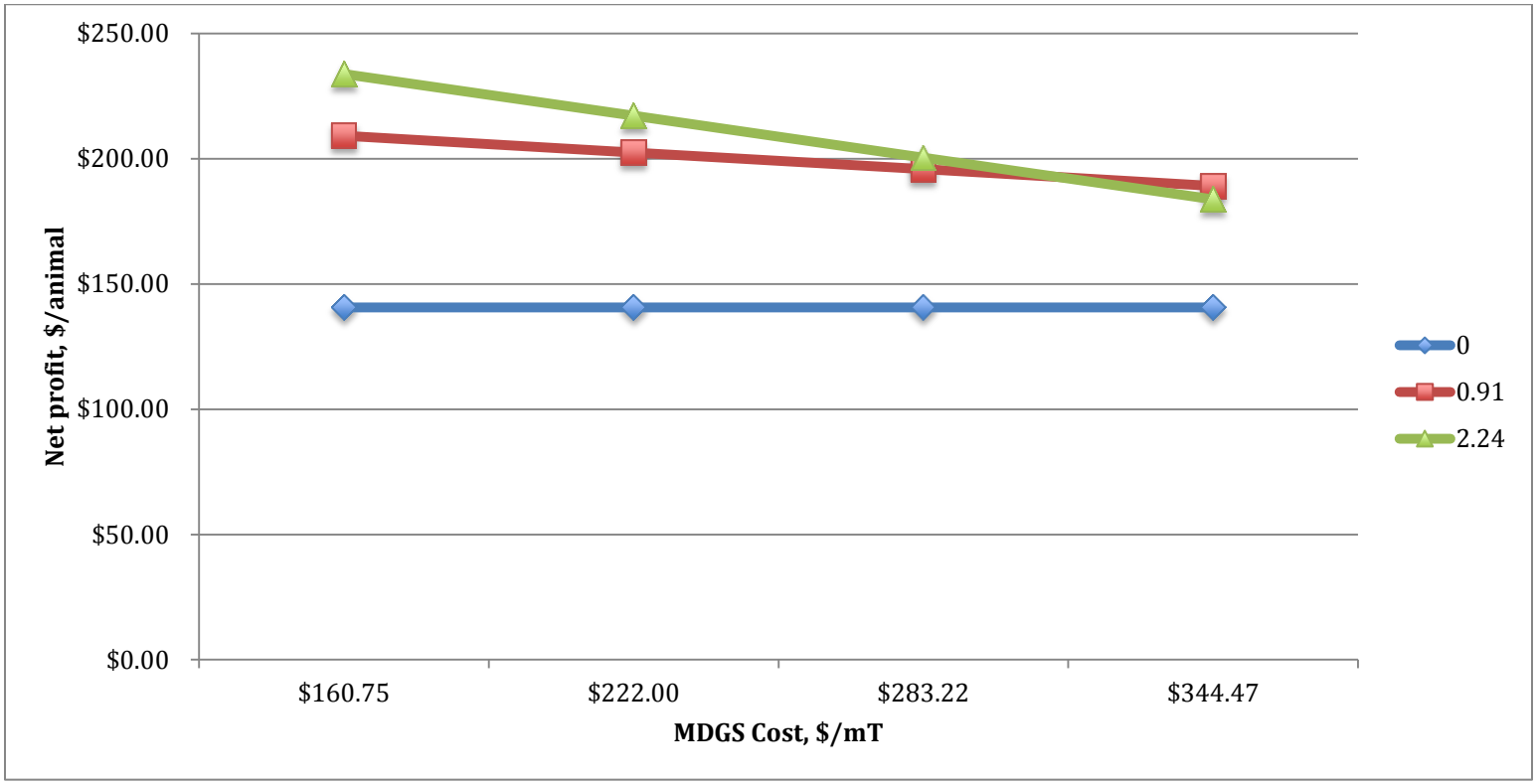

Figure 4. The net return of supplementing 0, 0.91, and 2.24 kg MDGS DM compared to no MDGS supplement. Supplemented steers were $43.17 to $93.17 more profitable than non-supplemented cattle. Presumptions of cattle ownership retained through the feeding period and sold as finished cattle.

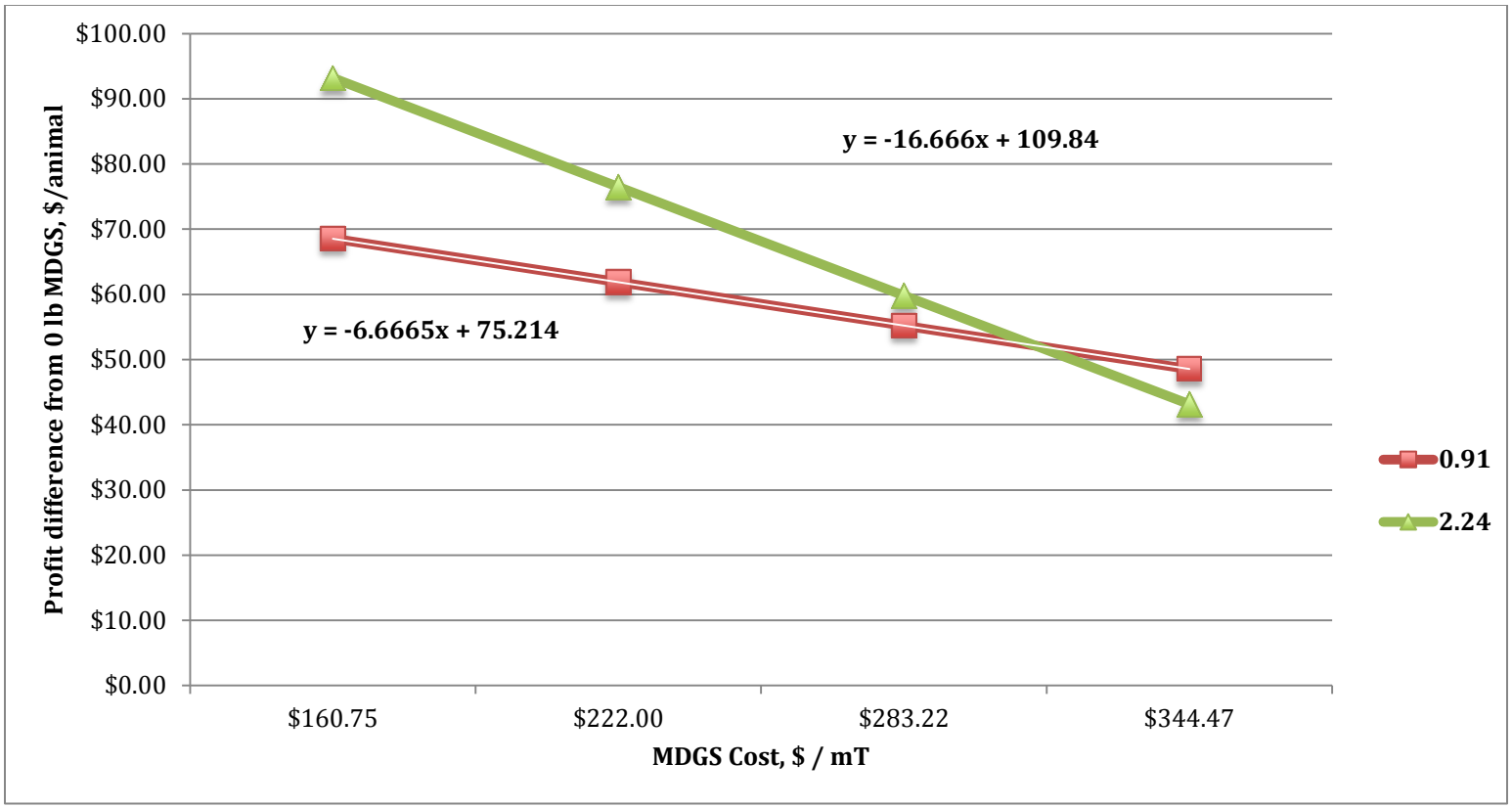

Figure 5. The profit difference of supplementing 0.91 and 2.24 kg MDGS DM compared to no MDGS supplement. Scaled at $0.00 profit for cattle not supplemented MDGS. Presumptions of cattle ownership retained through the feeding period and sold as finished cattle at $2.86/kg. Supplementing .091 kg MDGS DM becomes more profitable than 2.24 kg MDGS DM when MDGS is ≥ $313.86 mT DM. As the price of MDGS increases the profitability of 2.24 and 0.91 kg DM MDGS supplementation decrease at rates of -16.7 and -6.7 respectively. Supplementing 0.91 kg DM MDGS became $0.37 more profitable per head than supplementing 2.24 kg DM MDGS when MDGS price reached $313.86 mT.

Effects of Monensin Supplementation on Forage Organic Matter Intake of Steers Grazing Smooth Bromegrass

T.L. Hasenauer, T. J. Klopfenstein, J. C. MacDonald, R. G. Bondurant, D. B. Burken

Abstract

Cannulated steers (n=6; BW= 394 kg) were utilized in a switchback design experiment to determine the effects of monensin supplementation on forage organic matter intake (FOMI) of grazing steers. The steers were assigned randomly to one of 2 treatments: supplementation with 0 or 200 mg monensin. Steers were individually supplemented with 1.4 kg modified distiller grains plus solubles (MDGS) DM (0.4% BW). Daily, steers were given 200 mg monensin via bolus inserted into the rumen. Titanium dioxide was used as a marker to estimate fecal output and was ruminally dosed daily at 10g. There were six, 21- day grazing periods from May 3, 2013 to September 13, 2013. At the end of each period fecal samples, rumen samples, and diet samples were collected to estimate fecal output, VFA ratios, and digestibility. Estimated fecal output and smooth bromegrass IVOMD were used to calculate FOMI. Steers supplemented monensin had a decrease in FOMI from 7.34 kg to 6.70 kg (P = 0.10). Supplementation of monensin tended to decrease FOMI by 9% (P = 0.10).

Keywords: fecal output, forage organic matter intake, modified distillers grains plus solubles, monensin, titanium dioxide

Introduction

The importance of the cattle industry's ability to efficiently produce beef becomes more and more important as the national cattle herd remains at historically low numbers (USDA NASS, 2014) and the global demand for protein continues to rise (Trostle and Seely, 2013). Efficiency in all areas of the cattle industry must be increased, including grazing. The ability of cattle to graze forage and convert cellulose and hemicellulose to protein is the foundation of the beef industry. The opportunity to use this advantage is challenged in times of drought and by the conversion of pasture to cropland. The supplementation of distillers grains plus solubles (DGS), a byproduct of the dry milling industry, has significantly improved producers' ability to increase grazing efficiency in grazing cattle by economically providing ruminally undegradable protein (RUP) (Creighton et al., 2003; Karges et al. 1992; Watson et al., 2010) and energy in the form of digestible fiber (Creighton et al., 2003; Karges et al. 1992; Watson et al., 2010) and fat (Buckner et al., 2008). The supplementation of DGS decreases forage intake and increases ADG (Corrigan et al., 2009; Gustad et al., 2006; Loy et al., 2003; Greenquist, 2009; Morris et al. 2005; Morris et al. 2006; Watson et al. 2012).

Monensin is an ionophore used to increase feed efficiency of cattle. Duffield et al. (2012) reported an improvement in ADG ($P < 0.01$) and a decrease in DMI ($P < 0.01$) in feedlot cattle when fed monensin at 28.1mg/kg of diet DM. When supplemented to grazing cattle monensin has been shown to increase ADG in grazing cattle (Boling et al., 1977; Goodrich et al., 1984; Potter et al. 1976). The decrease in the acetate to propionate ratio caused by monensin leads to the improved efficiency of cattle. This is based on the gluconeogenic structure of propionate and an increase in

hepatic gluconeogenic flux when ruminal propionate production increases (Baird et al., 1980). In finishing diets the increase in glucose production triggers a chemostatic inhibition of DMI (Raun et al., 1976). The chemostatic suppression of DMI is clearly observed in feedlot cattle (Duffield et al., 2012). In contrast to the ease of measuring DMI in pen-fed scenarios, estimating the intake of grazing cattle is more challenging. Results have been variable in the findings of the effect of monensin on forage organic matter intake (FOMI) of grazing cattle. Potter et al. (1976) stated monensin improves efficiency of both pasture cattle and feedlot cattle but in different ways: pasture cattle increase ADG while maintaining DMI and feedlot cattle decrease DMI while maintaining ADG. On the contrary, Hasenauer et al. (2014) found supplementing monensin with DGS did not affect ADG of steers grazing smooth bromegrass. Further, monensin has been shown to decrease forage DMI when supplemented to cows on native range (Lemenager et al., 1978). Therefore, the objective of this experiment was to determine the effects of monensin with DGS supplementation on forage intake of steers grazing smooth bromegrass.

Materials and Methods

Experiment Site

This project was conducted at the University of Nebraska- Lincoln Agricultural Research and Development Center near Mead, Nebraska in 2013. In the year of the experiment, the climate at the site of research consisted of temperatures ranging between a low of -20.0°C in February to a high of 37.2°C in May and September. Total precipitation from January to September was 58.7cm, with a monthly high of 16.3 cm in May and a low of 1.5 cm in July (NCDC, 2014).

Treatments and Experimental Design

Measurements needed in this study to determine FDMI were fecal output, which was estimated by using the external marker titanium dioxide (TiO_2), and diet digestibility. Ruminally fistulated steers (n=6; BW=394 kg) were assigned randomly in a switchback designed experiment to one of two treatments: supplementation with 0 or 200 mg monensin. The steers continuously grazed a fertilized smooth bromegrass monoculture pasture from May 3, 2013 to September 13, 2013. Steers were individually supplemented 1.36 kg MDGS on a DM basis (0.4% BW) daily at 0700 h. Steers were supplemented MDGS at 0.4% BW with the assumption monensin would not affect ADG (Hasenauer et al. 2014) and instead induce an effect on FOMI. Individual feeding was facilitated in the pasture by a custom pen structure with one alley and six individual pens. While the steers were consuming the MDGS supplement, a bolus with 10 g TiO_2 with or without 200 mg of monensin was inserted through the cannula plug. The bolus method was used to ensure that all monensin and TiO_2 was dosed correctly.

The switchback designed experiment consisted of six, 21- day periods. Immediately following the end of each period, steers were administered the opposite treatment of what they were receiving in the previous period. On day one of each period, dosing of TiO_2 and monensin began.

Sample Collection and Analysis

Rumen samples were taken at 0800 on day 15 of the current period and day 1 of the following period. The rumen fluid samples were taken to analyze volatile fatty

acids (VFA) to determine efficacy of the monensin and to assure there was no residual monensin impact on steers that had been switched to the non-monensin bolus on the day of the switchback. Rumen fluid was squeezed by hand from the rumen sample into a 50 ml conical centrifuge tube and dropped into liquid N to be transported and stored at - 4^{O}C until lab analysis. Once samples were thawed, they were prepared for gas chromatography described by Erwin et al. (1961).

Neutral detergent fiber digestibility by in situ technique (Vanzant et al. 1998) was determined to observe monensin's effects on digestibility. Diet samples from similar smooth bromegrass pastures and similar dates of the summers 2010-2012 were composited to provide a sample of smooth bromegrass averaged over three years. Composited samples were then matched up to corresponding periods by date. Five by 10 cm Dacron bags (Ankom Technology, Fairport, NY) with a pore size of 50 μm were filled with 1.25 g of the composited sample. Five Dacron bags were then placed in a mesh bag with weights. On day 21 of each period, the mesh bag with the five samples was placed in the rumen through the cannula at 0800 for 24 h incubation. On day 1 of the following period, the mesh bag was pulled from the rumen at 0800. The bags were then iced and transported to the lab. Dacron bags were removed from the mesh bags and place in a washing machine where they were rinsed and spin dried three times (Whittet et al., 2003). The bags were then bulk refluxed in neutral detergent solution using an Ankom fiber analyzer (Ankom Technology, Macedon, NY), dried at 60°C, and weighed.

Diet samples were taken at the end of each period using the 6-fistulated steers that were on trial. The steers were fasted for 12 hours starting in the evening of day

21. Then, at 0800 h on day 1, steers were ruminally evacuated. Steers were allotted a 20 min grazing period to collect the sample. The fresh rumen samples were then collected and iced. Pre-evacuated rumen contents were then returned to the rumen. Following collection, the cooled samples were transferred to the lab and stored at −4°C. The sample was divided into a liquid and solid fraction to determine the liquid to solid ratio. Then the two fractions were merged to the corresponding ratio. The separation and remerging of the sample was to ensure a representative sample was taken. When sampled by hand, the liquid fraction immediately decreased as it seeped from the sample. By separating the liquid from the solid and weighing the two fractions, the exact ratio of liquid to solid was determined and a representative sample was taken. The sample was then lyophilized (−50°C). The dried samples were ground through a 2-mm screen using a Wiley mill (Thomas Scientific, Swedesboro, NJ). A subsample was further ground through a 1-mm screen. The 1-mm sample was oven dried (60°C) to determine DM. Organic matter was measured by an ash oven (600°C) time of 6 hours. Diet crude protein was determined by the combustion method (method 4.2.10; AOAC, 1996) using a combustion N analyzer (FP-528, Leco Corp., St. Joseph, MO). Neutral detergent fiber was measured using the reflux method (Van Soest & Marcus, 1964). In vitro organic matter disappearance (IVOMD) was determined following the Tilley and Terry method (Tilley and Terry, 1963) with an addition of 1 g/L of urea to the McDougall's buffer (Weis, 1994).

Fecal output was estimated using TiO_2 as a marker. As previously stated, 10 g of TiO_2 were dosed daily through the cannula. Fecal samples were collected at 0700 for 5 consecutive days: 18, 19, 20, 21, and 1. Samples were transported on ice and

stored at -4^{O}C. Samples were then composited by steer for each period and lyophilized at -50^{O}C. The dried samples were then ground separately through a 1-mm screen using a Wiley mill (Thomas Scientific, Swedesboro, NJ). Samples were then prepared as described by Myers et al. (2004) to determine TiO_2 concentration through spectrophotometry. The concentration was then used to calculate the estimated fecal output per day.

Once total fecal output was estimated, feces from the MDGS were subtracted. The digestibility of MDGS was presumed to be 87.6% (Corrigan et al., 2009). Fecal output was then estimated by the equation: MDGS DMI x 0.13 = MDGS fecal output. Using the period appropriate forage IVOMD, forage dry matter intake (FOMI) was calculated by the following: fecal output/ 1- IVOMD = FOMI. Forage dry matter intake and diet sample components were analyzed using the MIXED procedure of SAS (SAS, Inc., Cary, N.C.). Model effects included period, steer, and measurement (NDF, CP, IVOMD). Probabilities of linear and quadratic trends were determined using orthogonal polynomial contrasts.

Results and Discussion

When steers were supplemented monensin, estimated FOMI decreased 9% (*P* = 0.10; Figure 1). Cattle consumed 6.70 kg forage (1.70% BW) when supplemented monensin and 7.34 kg (1.86% BW) forage when monensin was not given. These results are similar to Lemenager et al. (1978) with cows grazing winter range with soybean meal supplementation and given 0, 50, or 200 mg of monensin. Compared to

the cows given 0 mg monensin, intakes decreased by 13.6% and 19.6% when given 50 or 200 mg monensin, respectively.

Lemenager et al. (1978) also found cows grazing winter pasture with a soybean meal –based supplement at 0.3% BW did not differ in ADG when given 200 mg monensin. In previous research (Hasenauer et al., 2014) ADG was not affected when grazing steers were supplemented monensin with 0.4% BW MDGS or higher. This led to a hypothesis that monensin was increasing efficiency by decreasing forage intake. A decrease in DMI without a loss in ADG is a similar response observed in the feedlot when monensin is added into the diet (Duffield et al., 2012). The addition of MDGS with monensin appeared to stimulate an efficiency response in the cattle that was contrary to prior observations by Potter et al. (1976). This may be due to the added energy the MDGS provides through fat, digestible fiber, and ruminally undegradable protein (RUP), making the diet and the efficiency response more similar to that of a feedlot animal. Further, we hypothesized this suppression in forage intake was due to the decrease of acetate: propionate ratio when monensin was supplemented.

The decrease in acetate: propionate (A: P) ratio of grazing cattle caused by supplementation of monensin has been demonstrated in past studies (Horn et al., 1981; Lemenager et al., 1978). However, in the present study the only significant difference in acetate: propionate ratio was by period. Acetate: propionate ratios changed cubically across the grazing season ($P < 0.01$, Figure 2). Monensin had no effect on A: P ratio ($P = 0.68$). Numerically, monensin decreased the A: P ratio. Monensin supplemented and non-supplemented steers had A: P ratios of 4.47 and

4.39, respectively. The insignificant differences in A: P ratios were unexpected. Horn et al. (1981) found cattle supplemented with 200 mg monensin/day while grazing wheat pasture had A: P ratios 20-40% lower ($P < 0.05$) than cattle given supplement without monensin. Similarly, we hypothesized monensin would increase the amount of propionate production, which would increase the hepatic gluconeogenic flux and incur a chemostatic response on DMI (Baird et al., 1980). The reason we did not observe an effect of monensin on A:P ratios may be due to the timing of rumen fluid sampling. Rumen fluid sampling was taken once a day at 0800. Steers were free to graze ad libitum when rumen fluid sample taken on day 15. There may not have been enough fermentation time between early morning grazing and rumen fluid sampling for the monensin to affect the A: P ratio. Hanson and Klopfenstein (1979) took rumen samples 5 hours post feeding and observed a decrease in A:P ratio when cattle were given 200 mg monensin. Another error occurred when rumen fluid samples were taken on day 1 of each period. Steers were fasted for 12 hours (for diet sampling) before the rumen fluid sample was taken. The 12-hour fast could have also affected the A:P ratios. Therefore, timing of rumen fluid sampling may have compromised the VFA results.

Though we did not observe A: P ratios effected by monensin, we still observed a decrease in forage intake. This raises the question; what decreased the FOMI? Hasenauer et al. (2014) observed interactions with monensin and MDGS. They found monensin had no effect on ADG when MDGS supplementation was ≥ 0.4% BW ($P = 0.53$), but increased ($P = 0.04$) ADG when MDGS was supplemented at 0.05% BW. The authors also observed no effect ($P = 0.67$) of monensin on MDGS

DMI when MDGS was offered at < 0.6% BW, but monensin decreased ($P = 0.01$) MDGS DMI when MDGS was offered at 0.8% BW. Consequently, interactions with monensin and the level of MDGS were observed. This leads to the question does the monensin and DGS interaction continue into A: P ratio and FOMI? Apart from speculative questions, the reason monensin did not decrease A: P ratios but still decreased FOMI is unknown.

Neutral detergent fiber tended to increase ($P = 0.19$, Figure 3) as the season progressed. In vitro OMD and NDFD decreased linearly ($P < 0.01$, Figure 4) throughout the grazing season. In vitro OMD estimates averaged 17% higher than NDFD values. Derived from the summative equation of Van Soest (1967): {(1-NDF) x .98 + NDF x NDFD / OM – 12.5}, the digestibility was determined of the composited diet samples used to determine NDFD. Digestibilities estimated by summative equation were compared to IVOMD. Summative estimates differed by only 5% compared to IVOMD (Figure 4). The small difference between IVOMD and the summative equation is intriguing considering the estimation derives from a composite of diet samples from different years.

Monensin had no effect on NDFD ($P = 0.72$) after 24-hour in-situ incubation. Dinius et al. (1976) also saw no effect ($P > 0.10$), both in-vitro and in-vivo, on cotton fiber digestibility when monensin was blended with forage diets at 0, 11, 22, and 33 ppm. In-vivo digestion was not different for forage dry matter, crude protein, hemicellulose, and cellulose among the monensin treatments (Dinius, et al., 1976). Monensin's ineffectiveness on fiber digestion further pushes the question; why did

we observe a decrease in FOMI when steers were supplemented 200 mg of monensin?

Implications

Supplementing monensin with MDGS decreased FOMI. The reason for decreased FOMI is not clear. In the case where monensin is supplemented with a nutritionally dense supplement such as DGS, the increased efficiency may not come as increased ADG but as decreased FOMI. Supplementing monensin and DGS is an effective way to decrease FOMI and increase stocking rate and grazing efficiency.

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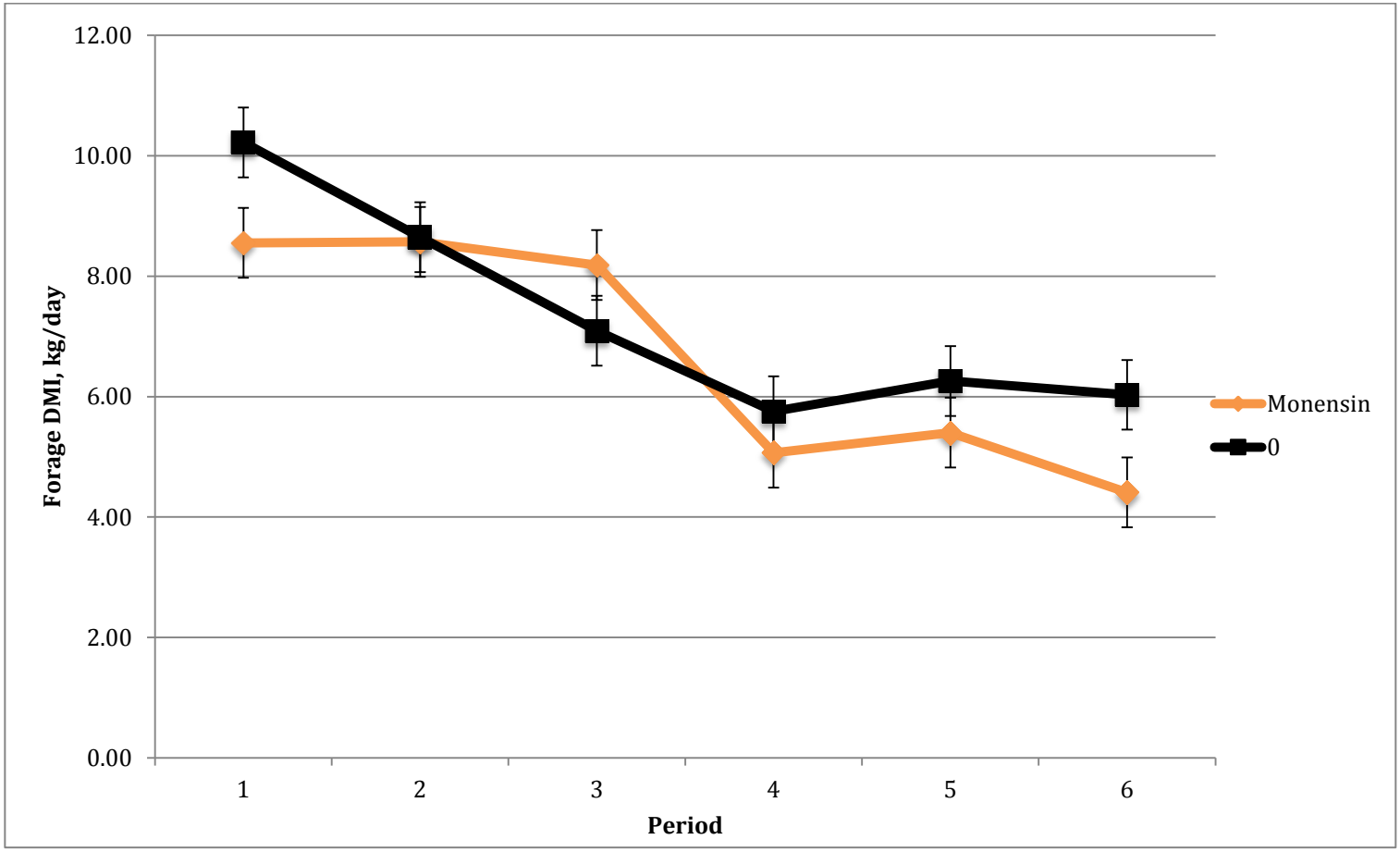

Figure 1. Estimated forage organic matter intake (FOMI) by period. Each period was 21 days. Cattle were supplemented 1.4 kg MDGS daily. Two treatments were administered: 200 mg monensin or 0 mg monensin. When cattle were supplemented monensin FOMI decreased 9% (P = 0.10, SE = 0.58).

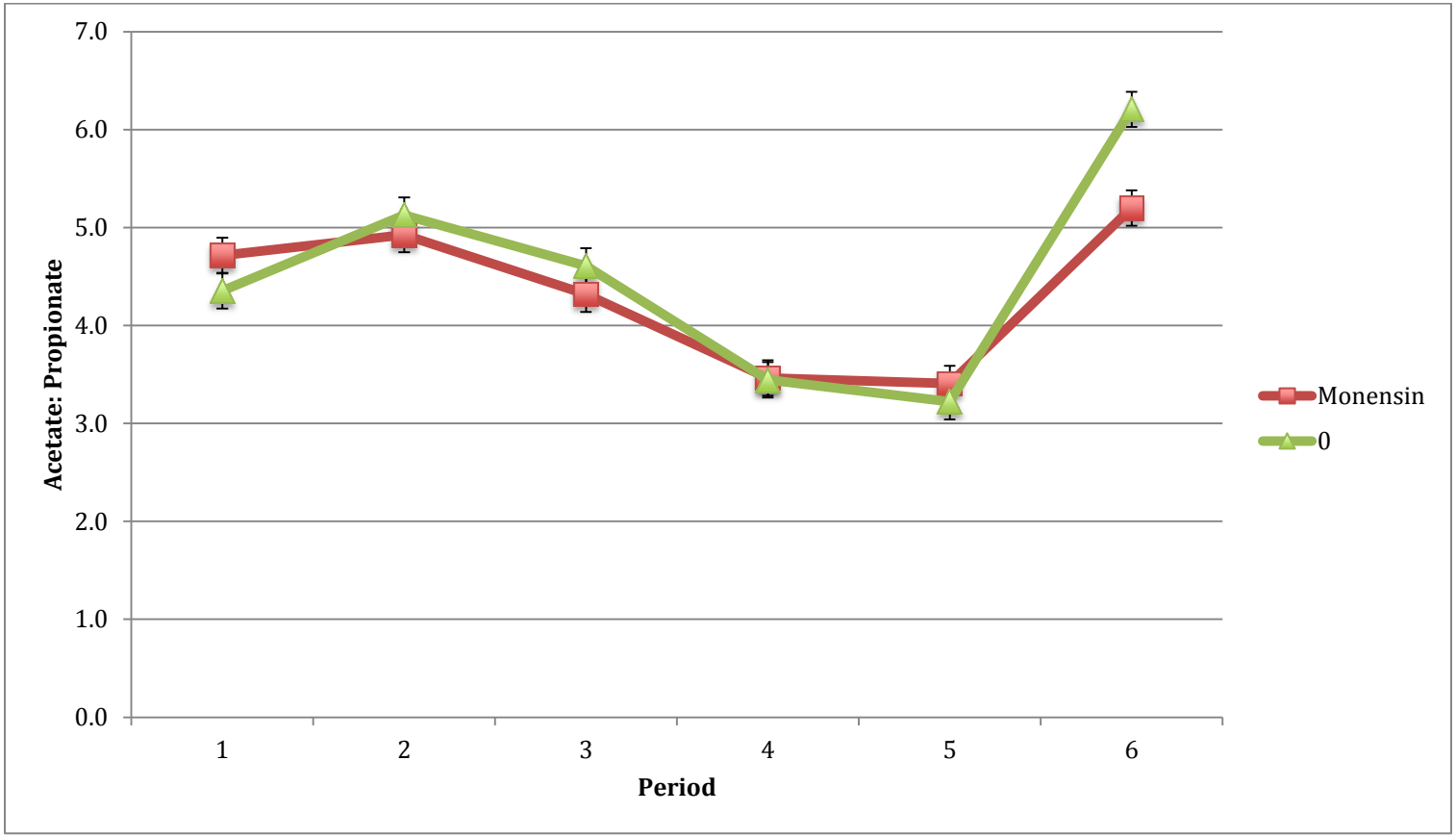

Figure 2. The acetate: propionate ratio was not affected by monensin supplementation (P = 0.75; SE 0.18). The A:P ratio changed cubically across periods (P = 0.01).

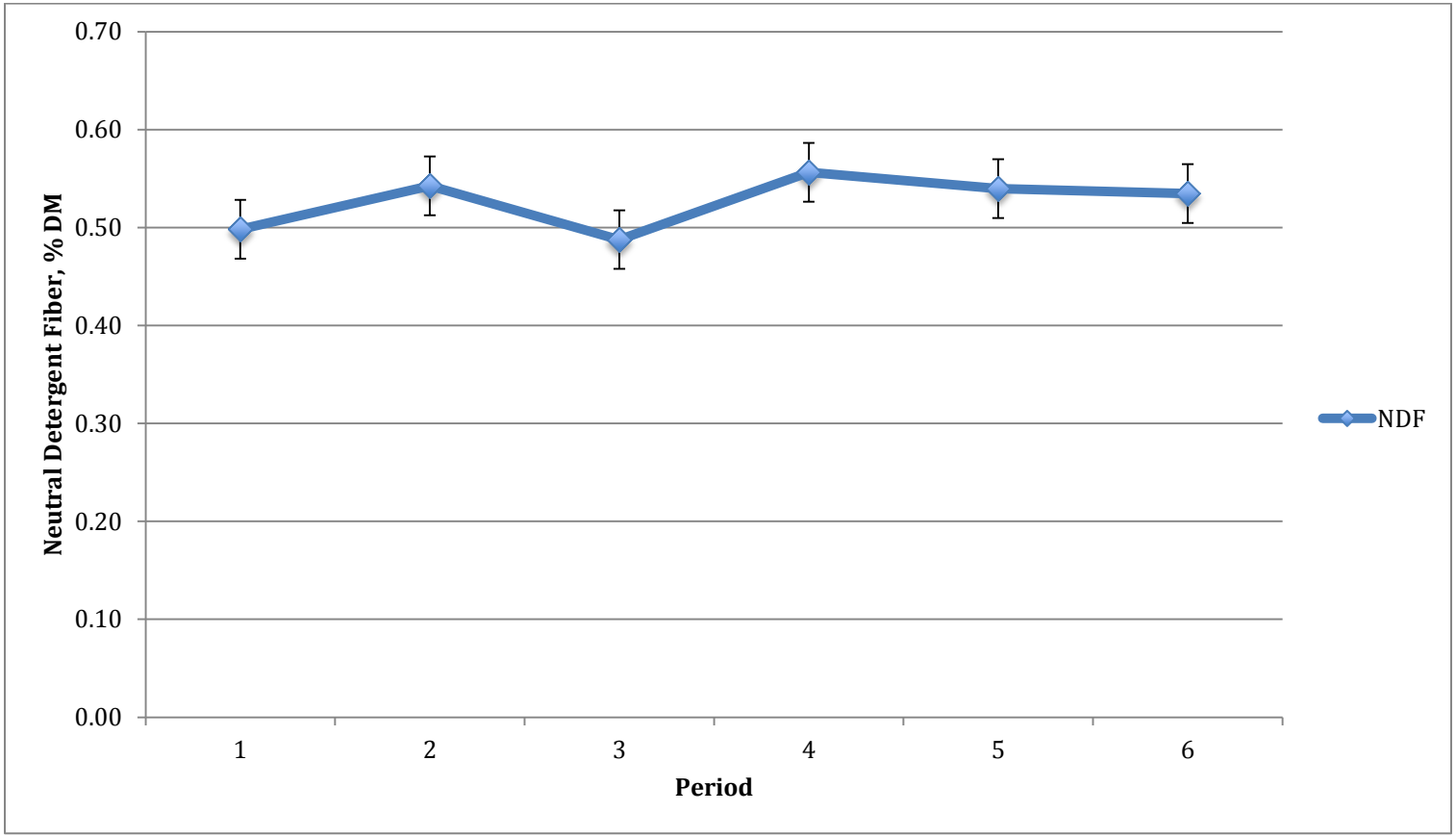

Figure 3. Smooth bromegrass neutral Detergent Fiber (NDF) tended to increase over the grazing season (P = 0.19; SE= 0.03).

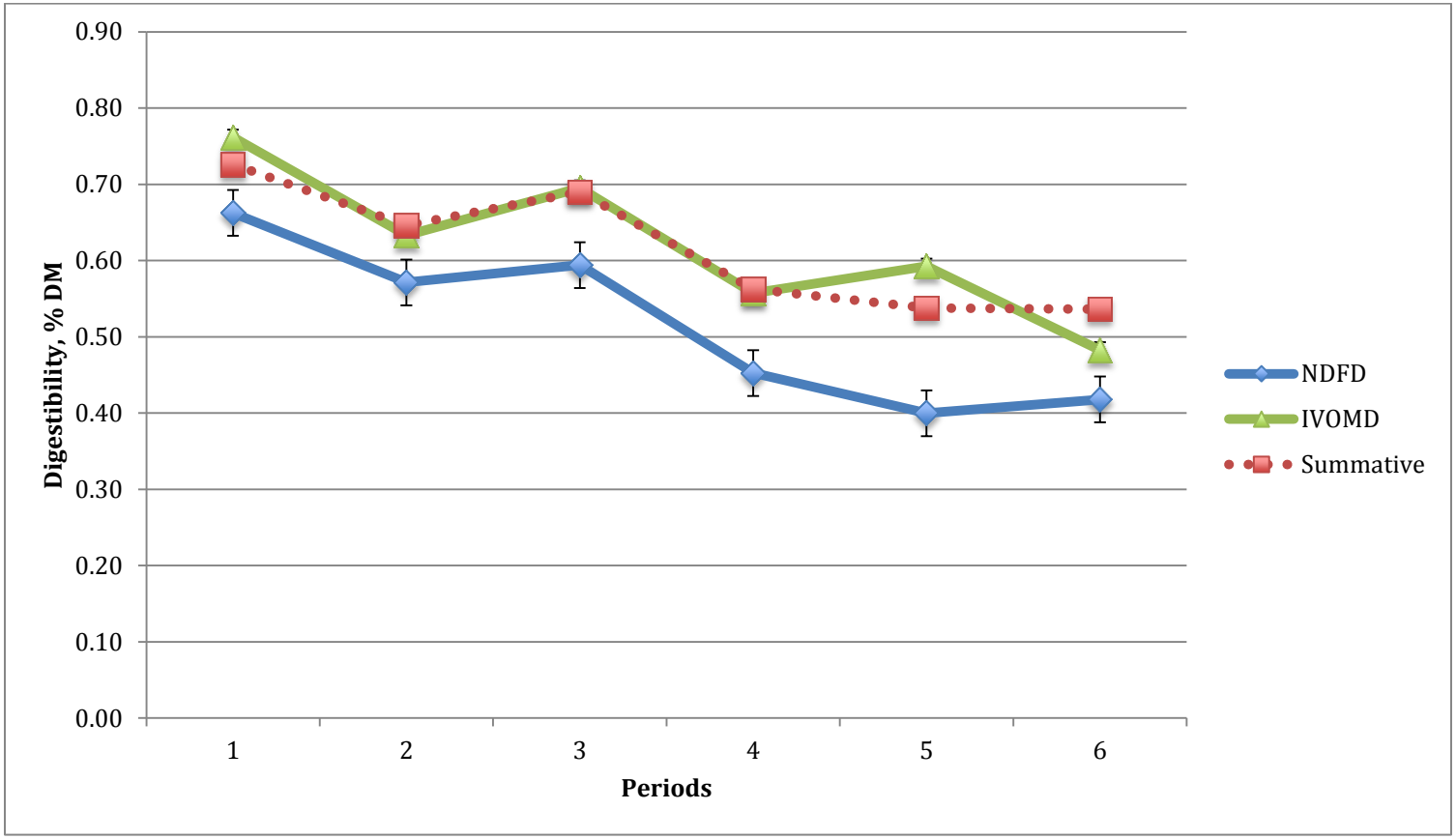

Figure 4. Smooth bromegrass in vitro organic matter digestibility (IVOMD) and neutral detergent fiber digestibility (NDFD) decreased linearly (*P* > 0.01; SE =0.01; SE= 0.03, respectively) over the grazing season. Summative estimates were 5% different from IVOMD. Monensin had no effect on NDFD (*P* = 0.73; SE= 0.05) after 24-hour in-vivo incubation.