EVALUATION OF CRUDE PROTEIN SUPPLEMENTATION TO BEEF CATTLE GRAZING LATE GROWING SEASON NATIVE RANGE

by

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B.S., West Texas A&M University

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

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Canyon, Texas

2016

Abstract

Two experiments evaluated the effects of altering dietary protein on beef cattle performance and nutrient excretion. In the first study, concurrent experiments were conducted to evaluate the effect of protein supplementation to beef cattle grazing warm-season shortgrass forage during the late growing season. For all Exp., treatments consisted of a supplemented group (1.32 kg of a 39% CP fed 3 times a week) and a non-supplemented control group. In Exp. 1, cow final BW (P = 0.24) and ADG (P = 0.38) were not affected by treatment. There was no difference (P = 0.97) in cow final BCS regardless of treatment. Calf ADG (P = 0.54) and weaning weight (P = 0.45) were not affected by treatment. In Exp. 2, cow final BW (P = 0.39) and final BCS (P = 0.81) did not differ between treatments. Cow ADG (P = 0.07) tended to be greater when supplemented with 0.22 kg CP per day. Calf ADG (P = 0.50) and weaning weight (P = 0.11) did not differ between treatments. In Exp. 3, heifer final BW (P = 0.17) was not different between treatments. Heifer ADG (P = 0.02) was greater for supplemented heifers. Supplementing protein to cattle grazing late season medium quality forage is advantageous for increasing ADG in replacement heifers and potentially beneficial to improve condition in lactating primiparous cows. In a separate study, a commercially available condensed tannin (CT) extract (ByPro; Silva Team, Ontario, CA) was included in a cereal grain-based diet at 3 levels (0, 1, or 2% of diet, DM basis). No group by treatment interactions was detected ($P \geq 0.18$) among the response variables. Provision of CT did not affect ($P \geq 0.64$) DM intake or apparent total-tract DM digestion. Nitrogen intake was not affected ($P = 0.58$) by inclusion of CT in the diet, but fecal N output increased ($P = 0.04$) at 2% CT inclusion compared with control. However, there was no difference ($P = 0.36$) in urine N output among treatments. Nitrogen retention was less than ($P = 0.03$) with 2% CT than 0 or 1% CT. Proportion of total N excreted in urine decreased ($P = 0.03$) with CT supplementation at 1 or 2% in the diet. Similarly the proportion of total N excreted in feces increased ($P = 0.03$) with 1 or 2% CT inclusion. Site of N excretion was shifted away from urine and toward feces when CT was included in a complete diet fed to beef cattle.

Acknowledgements

I would like to thank Dr. Eric Bailey for helping me throughout my degree and for always being there with advice. Dr. Bailey was gracious enough to take me under his wing and try his hardest to make me a successful scientist and student. I have learned very much under his tutelage about ruminant nutrition and how to be a good student and scientist. Moreover though, Dr. Bailey has been a great friend and was always able to separate work and pleasure, for which I am very thankful. Also, a big thanks Dr. David Lust for taking a chance on me, even though I was not exactly what he sought after in a graduate student. I thank him for allowing me to teach some of his labs, something I greatly enjoyed. I am thankful for the opportunity to manage the Nance Ranch during my time in graduate school. I have learned so much just from this endeavor alone, experiences that I will carry with me forever. Dr. Tim Steffens was another person who helped me in more ways than he knows. Not only did he serve on my committee, but his office door was always open when I needed to visit. Joshua Zeltwanger helped complete my supplementation trial, and was an immense help during the lab analyses of both projects. He was irreplaceable during graduate school. I could always count on him to show up ready to help, night or day. I worked with some very awesome student workers at the ranch, Colton Meyer, Logan Canterbury, Luis Franco, and Kody Anderson. These guys helped keep the ranch running smoothly when I was busy with school and research. They all also assisted in many different facets during my research projects. To the many graduate students I had the pleasure of working with at West Texas A&M, thank you for the fun times and the help with projects and school throughout. I want to take the time to mention one in particular, Pake Ebert. Pake and I did a lot of things together during our times at WT, from helping each other with research to blowing off some steam on the weekends. There were times I am unsure I would have kept going without the help of a good friend like Pake. To my family, thank you, thank you, thank you. You all have prayed for me so very much. For this I am eternally thankful. You all kept pushing me on when the road seemed like it would never end. Thank you mom and dad for making me the man I am today. I owe my success in life to the lessons that you taught me growing up and continue to teach me. To my wife Kristen, there have been times you have wanted to strangle me, thank you for not doing so. Thank you for putting up with my waking you up at 4 am every morning, and sometimes not getting back till 1 or 2am in the morning. Without your love and support I would not be where I am today. You continually encourage me and support me. Thank you, and I look forward to starting our own little family with the arrival of our daughter in October. Finally, I need to thank my Lord and Savior Jesus Christ. Without him I would be nothing. I owe all my accomplishments and success to him.

There are so many things that I could say about the people I have mentioned, and stories I could tell. I just want everyone to know how truly grateful I am that you all are a part of my life, Thank you. Thank you to all I have not mentioned who are too many to

name. It has been quite the journey and I look forward with anticipation to what the next chapter in life holds for me and my family.

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CHAPTER I

Review of Literature

Effects of Crude Protein Supplementation to Beef Cattle Consuming Low Quality Forages

Beef producers are faced with a myriad of management challenges such as meeting nutrient requirements when the diet consists mainly of low quality forage (CP < 7%). Low quality forages can be an adequate source of nutrients if voluntary forage intake and digestion is not limiting. Optimization of voluntary forage intake and digestion can be achieved via the supplementation of crude protein.

The goal of supplementation is to offset nutrient deficiencies, which may occur more often throughout a native rangeland-based beef cattle production system than producers currently manage for.. It would be beneficial to know when (time of year; stage of maturity) forage nutrients become insufficient to meet animal requirements and what type of supplement, energy or protein, would be best to supplement in these situations. Researchers (DelCurto et al., 1990; Köster et al., 1996; Moore et al., 1999) have evaluated the effectiveness of providing protein and/or energy supplements to cattle grazing native range. Providing supplemental protein appears to be of more benefit than supplemental energy when cattle are consuming low quality forage. Significant differences in animal performance can be observed when animals are supplemented CP while consuming forages below approximately 7% CP (Bowman et al., 1995; Cochran, 1995).

Low Quality Forage

Forage quality is commonly based upon animal performance by producers, as they can monitor growth or animal condition in order to make supplement decisions. However this process is flawed because once animal performance begins to decline the decision to supplement is overdue. Forage quality is most precisely estimated by chemically analyzing its nutritive composition. Crude protein has been identified as the most limiting nutrient (McCollum and Galyean, 1985) in grazing ruminant diets.

Understanding when forages decline in quality could help cattle managers determine when animals should be supplemented. Funk et al. (1987) evaluated the nutrient composition and digesta kinetics of steers grazing blue grama rangeland near Clayton, NM. Forage quality was evaluated during four 11 d periods throughout the summer. Early growing season (EGS) measurement was June 2 to June 13; early summer dormancy (ESD) June 22 to July 3; Late summer dormancy (LSD) July 21 to August 1; Late growing season (LGS) August 25 to September 5. Periods were determined based on historic precipitation patterns and growth characteristics of rangeland plants in the area. Dietary composition of forages were calculated from esophageal masticate samples collected on days 1 and 2 of each period. Forage CP content (% OM) was 11.6, 8.1, 7.1, and 11.1 for EGS, ESD, LSD, and LGS respectively. They noted that according to the NRC (1984), growing steers need forage with a protein content of 9 to 11% (DM) to achieve 0.5 to 1.0 kg/d gain. During periods ESD and LSD the steers on study did not have adequate CP to achieve desired performance. The decline in forage quality from June 22 to August 1 was attributed to the lack of rain during this period in the region.

In contrast McCollum et al. (1985) found CP content of forage similar to Funk et al. (1987) to be notably greater in the late growing season. Three esophageal-cannulated beef cows and 6 rumen-cannulated steers, all grazing, were used to measure diet changes as the season advanced. The study included four periods that lasted 8 days each; Early August (EAug) August 9 to August 17; Late August (LAug) August 23 to September 1; Late September (LSep) September 23 to October 1; Late October (LOct) October 23 to October 31. Esophageal samples were taken on d 2 of each period. The CP content (percent OM) of the diet samples were 18.4, 17.6, 12.7, and 11.7 for EAug, LAug, LSep, and LOct respectively. While a substantial drop in CP content was measured between August and September, September's value is well above the critical limit of 7% CP. This could have been attributed to the proportion of forbs in the diet which was nearly 20% which would allow for greater measured CP content as forbs have a greater N content than grasses. The proportion of grasses to forbs was similar during the first three periods (82% grasses to 18% forbs). However in the last period that proportion reversed (22.7% grasses to 77.3% forbs).

As most forages mature the CP content of the forage declines. Plant species, growth stage, and grazing management affect forage quality. Nelson and Moser (1994) describe how forage grazed by animals is not a homogeneous product. Throughout a pasture one may have few or many species of grasses, legumes, and forbs. Development of these plants under varying environmental conditions will determine forage quality.

One such example of this is temperature, at lower temperatures cell wall constituents deposited are less lignified and have a greater digestibility than those components deposited at high temperature (Nelson and Moser, 1994). Cell wall components deposited at higher temperatures have a greater lignin content which decreases the digestibility of the forage.

Plant maturity trumps all environmental factors when considering forage quality (Nelson and Moser, 1994). Forage quality decline is marked by a decrease in the leaf to stem ratio as leaves are defoliated. As the plant matures the proportion of lignin begins to increase in the stem decreasing the proportion of digestible carbohydrates and CP. Leaves do not show the marked increase of lignification of cell wall components. When measuring forage nutrient composition through whole-plant clipping, nutrient composition will be reported at a lower quality than the animal will select because the predominant proportion of the clipping sample will be stem (Coleman and Barth, 1973). Temperature and maturity drive forage quality, as greater temperatures are recorded and the plant matures, greater amounts of lignin in the cell wall reduce plant digestibility.

Alternate theories have been proposed to quantify low quality forage with varying success. Moore et al. (1999) performed a meta-analysis of 66 publications containing 444 comparisons between supplemented treatment and un-supplemented control evaluating the effect of supplementation on voluntary forage intake. Forage types varied from introduced forages, harvested and fed in bunk, to low quality native forages grazed in the pasture. Equations to predict changes in voluntary forage intake were developed by regressing the various forage components reported in the individual studies. These equations were created to find the level of forage CP and TDN where voluntary forage intake decreased. The effect of supplementation on voluntary forage intake varied throughout the dataset. However, supplements increased forage intake when the TDN:CP ratio of the forage was > 7. This would indicate that there is a relationship between N and energy content of forages. Consequently, a supplement that is high in energy will actually decrease forage intake in animals consuming low quality forages, which has been demonstrated experimentally (Olson et al., 1999). Protein supplementation, alternatively, would decrease the TDN:CP ratio, theoretically increasing forage intake.

Understanding when, why, and how forage quality decreases, one then needs to know how forage quality correlates to animal performance. Determining whole plant forage nutrient composition can be a useful management tool; however, understanding the nutrient composition of the forage in relation to grazing livestock is of greater use. Coleman and Barth (1973) determined the quality of diet selected by grazing animals in relation to actual forage nutrient composition. Esophageally-fistulated steers grazed in pairs in eight different pastures containing diverse grass species. Four of the eight pastures (1.25-ha pastures) contained a mixture of Tall Fescue and Korean Lespedeza; the other four were comprised of Orchardgrass and Ladino Clover. Forage samples were collected at 2 week intervals during the months of May through November for 3 consecutive years. Esophageal-fistula samples were collected simultaneously to hand-clipped forage samples. The authors hand-clipped samples from the aerial portions of the plants and attempted to clip samples that contained similar species proportion to that of the entire pasture. The nutrient composition (% DM) of the hand-clipped forage across the collection years averaged 15.8 CP, 37.6 ADF, and 46.5 NFE+EE. The nutrient composition (% DM) of the diet selected by the animal across the collection years averaged 20.5 CP, 48.5 ADF, 30.9 NFE+EE. Crude protein was greater in the selected diet by 4.7 percentage points. Authors speculated that the greater appreciations of ADF could be attributable to the loss of NFE+EE during the esophageal sampling process. Since the dietary components reported are on a percentage basis, the loss of NFE+EE during sampling may increase proportion of ADF. In respect to CP quantity in the diet of grazing steers, this study reports that the diet selected by the animal is greater in quality than that of the hand-clipped samples.

Understanding how different forages, warm or cool season, affect animal performance when being supplemented CP could be useful. Bohnert et al. (2011) supplemented CP to steers consuming low quality warm or cool season forages. The ability to observe animal performance differences in forages below 7% CP is predominantly observed in research using warm season forage (McCollum et al., 1985; DelCurto et al., 1990; Köster et al., 1996). In contrast, observing a performance difference in animals consuming cool season forages with CP content less than 7% is less apparent (Bohnert et al., 2002). Steers consuming cool and warm season forages (Bohnert et al., 2011) responded favorably to CP supplementation; however, steers consuming warm season forage showed the greatest proportional response in regard to forage intake when supplemented CP, compared to steers consuming cool season forage. However, un-supplemented cool season steers consumed a greater amount of forage than supplemented warm season steers. The magnitude of increase due to CP supplementation was greater in the warm season forages as compared to cool season forages, due in part to the greater overall digestibility of the cool season forages. Regardless of supplementation, digestibility of the cool season forage was greater than warm season forage. Cool season grasses are generally more nutritious than warm season grasses at the same stage of maturity as they have greater nonstructural carbohydrates and less fiber. The steers consuming cool season forage were able to meet nutritional needs due to greater un-supplemented intake, and therefore showed a smaller response to CP supplementation. Warm and cool season forages differ in many aspects, mainly though, cool season forages may meet animal requirements at a lower CP content than their warm season counterparts.

DIP Supplementation

Improving voluntary forage intake of low quality forages is attributed to an increased rate of ruminal digestion (McCollum and Galyean, 1985). Improvement of ruminal digestion can be altered through supplementation of degradable intake protein (DIP).

Generally speaking, when low quality forage availability is not limiting, increased forage intake, beneficial to animal performance, is best mediated through CP supplementation (Campling, 1970). More specifically, cattle consuming low quality forage are most deficient in DIP (Köster et al., 1996). Animal performance while grazing native rangeland is maximized through efficient forage intake and digestion. A diet consisting primarily of low quality forage lacks DIP and will be slowly digested. Inadequate digestion leads to forage remaining in the rumen longer leading to decreased intake (McCollum and Galyean, 1985).

Bandyk et al. (2001) evaluated the effect of ruminal or post-ruminal administration of DIP (casein) in beef steers consuming low quality forage. Steers were dosed 400 g/d of casein either in the rumen (DIP) or abomasum (UIP). Casein was used as the protein source because it is similarly digestible by rumen microbes and ruminants. The objective of the experiment was to see if the benefit of supplemental protein in animals consuming low quality forage was due to an animal requirement for dietary protein or a microbial need for N. Organic matter and NDF digestion were not different between casein dosing strategies but were greater than control regardless of supplement. However, ruminal administration of DIP elicited a greater forage intake response. Ruminal administration of DIP also resulted in greater ruminal ammonia levels. The results suggest that supplemental DIP would elicit a greater voluntary forage intake response than UIP when overall dietary protein is deficient.

Increased ammonia concentrations in the previous experiment are important because increased ammonia levels in fermenters leads to a more productive microbial population (Satter and Slyter, 1974). Satter and Slyter (1974) reported that the majority of rumen microbes use ammonia as their source for N. Ammonia is one of the by-products of ruminal protein degradation, along with peptides and amino acids. It was found that as ruminal ammonia concentrations increased from 0 mM to 5 mM microbial efficiency improved (Satter and Slyter, 1974). Above 5 mM ammonia, no increase in microbial efficiency was observed. Microbial efficiency used here is relating to microbial activity and their ability to use DIP to increase forage digestion. It is reported that at low concentrations (< 20 mM) of ammonia in the rumen, fiber digestion is depressed (Orskov, 1982).

Köster et al. (1996) observed intake and digestion characteristics of beef cows consuming low quality forage when supplemented increasing amounts of DIP (casein). Ruminal and duodenaly cannulated beef cows were used. Cows had *ad-libitum* access to low quality (1.94% CP) tallgrass prairie hay. Increased DIP intake provided increased flow of N at the duodenum quadratically, with peak N flow being greatest at 540 g DIP/d. Köster et al. (1996) noted that providing a DIP source to mature beef cows consuming low quality forage improved low quality forage intake and digestion. Based on a regression analysis of DIP and TDN intake, authors concluded that in order to maximize low quality forage intake and digestion, supplements should be formulated where DIP is 11% of total TDN intake.

Olson et al. (1999) evaluated the efficacy of starch and/or DIP supplementation to beef steers fed low quality tallgrass prairie hay (4.9% CP). Thirteen steers were used in a 13 treatment, four period experiment. Treatments consisted of four different levels (0.03, 0.06, 0.09, and 0.12% of initial BW) of DIP being fed with three levels (0, 0.15, and 0.3% of initial BW) of starch along with an unsupplemented negative control. All supplements were dosed intraruminally daily. Forage intake was greatest when steers were supplemented DIP alone. Conversely, the addition of starch to supplements linearly decreased intake. Digestion, extent and rate, increased linearly in response to DIP supplementation and decreased linearly in response to starch supplementation. Greater levels (0.09 and 0.12% of BW) of DIP appeared to reduce the extent to which starch supplementation affected forage intake. Supplementation of DIP alone was enough to maximize forage intake, starch supplementation would be of minimal benefit without adequate DIP.

Looking to build on the work of Olson et al. (1999) Klevesahl et al. (2003) performed a similar experiment. Beef steers were used in a 14 treatment, 2 period crossover design using 1 of 2 levels of starch (0 and 0.3% of initial BW) and 1 of 7 levels of DIP (0, 0.015, 0.051, 0.087, 0.123, 0.159, and 0.195% of initial BW), and examined their effects on low quality forage (4.9% CP) utilization and ruminal characteristics. Animals were intraruminally dosed supplements daily. Klevesahl et al. (2003) differed from Olson et al., (1999) in that the current experiment evaluated a much broader range of starch and DIP levels to look for a plateau in forage intake and digestion effects from each supplement type. All levels of DIP supplementation elicited a positive response in relation to forage intake and digestion. In general, starch supplementation had negative effects on intake and fiber digestion with the exception of the three greatest levels of DIP. At the three greatest levels of DIP supplementation, starch supplementation had little effect on NDF digestion; however, intake was still negatively affected by starch supplementation even when combined with the greatest level of DIP. Overall the value of additional energy gain from starch supplementation is limited. However, once again, positive responses to supplemental DIP were observed even at the lowest levels in cattle consuming low quality forage.

Ruminants have the ability to recycle N in order to conserve it and allow the body to use it in times of N deficiency. This ability to recycle N to meet ruminant requirements is noted by a linear increase in N between the mouth and the duodenum as dietary N decreases (Kropp et al., 1977). Understanding how to synchronize N recycling with protein supplementation in animals consuming low quality forage would lessen the cost of supplementation. Instead of providing large amounts of protein, reduced supplemental protein coupled with the animal's ability to recycle N, could meet microbial N requirements. Wickersham et al. (2008) dosed DIP (casein) to beef steers consuming low quality (4.9% CP) forage and measured intake, digestion, and urea kinetics. The greatest level of DIP supplemented (177 mg of N/kg of BW) was chosen based on the findings of Köster et al. (1996), who suggested that forage utilization is maximized when DIP is 11% of TDN (DM basis). Forage digestion and intake increased linearly with increasing levels of DIP. Urea synthesis in the liver increased in a linear fashion as the level of DIP dosed increased. Between one-fourth and one-third of N utilized by rumen microbes was from recycled urea. The proportion of urea produced that was recycled to the gut for all groups was approximately 98%, pointing to the ability of cattle to conserve N by urea recycling when they are experiencing a dietary N deficiency.

In the aforementioned studies all cattle being supplemented DIP were fed a diet consisting of low quality forage, in all studies the addition of DIP to the rumen positively influenced forage intake and digestion. However, in animals consuming forage that is not low quality, response to CP may not be detectable. Mathis et al. (2000) observed beef steers response to DIP while consuming different qualities of forage. In three independent experiments, steers consumed forages of varying species and CP content. In the first experiment steers were fed Bermudagrass (8.2% CP), in experiment two, lower-quality Bermudagrass (5.9% CP), and in experiment three low-quality forage sorghum (4.3% CP). In all experiments casein was the source of DIP, and each experiment had three levels of DIP and an unsuppplemented control. When the forage consumed was 8.2% CP, supplemental DIP did not affect forage intake or digestion. In the 5.9% CP forage, supplemental DIP linearly increased the rate and extent of forage digestion but not forage intake. However, in the 4.3% CP forage, intake and digestion improved when animals were supplemented regardless of level of DIP.

Degradable intake protein supplementation is very effective at improving consumption and digestion of low quality forage. Forage intake is affected by forage digestion; increased forage digestion is improved through increased microbial activity. However, under situations where cattle are grazing various forage types (Bohnert et al., 2011; Mathis et al., 2000) optimizing intake and digestion may depend on more than just CP quantity, this is apparent in variations between forages.

CP Supplementation to Beef Cattle

In feeding situations where DIP supplementation is warranted, commercially available CP supplements such as cottonseed meal (CSM) and soybean meal (SBM) based products are natural sources that contain appreciable content of DIP. Cottonseed meal and SBM are approximately 60-65% DIP (NRC, 1996). Natural protein sources such as CSM and SBM not only provide more CP per lb. of supplement than most other commercially available products, but their large proportion of DIP makes them ideal for supplementing cattle consuming low quality forage. In an extension report from Oklahoma State University, Lalman and Gill (1999) suggest that intake, digestibility, and ADG of beef cattle grazing low quality forage are reported to be positively influenced with as little as 1lb of a high CP (38% - 42%) supplement daily.

McCollum and Galyean (1985) studied the effect of cottonseed meal (CSM; 37% CP, DM basis) on voluntary intake, rumen fermentation, and rate of passage of low quality forage in beef steers. Treatments consisted of 800 g/d of CSM dosed intraruminally or no supplement. Prairie hay offered to steers contained 6.1 % CP (DM basis). Intake of prairie hay increased from 16.9 g dry matter/kg body weight to 21.5 g dry matter/kg of body weight with the provision of cottonseed meal. Ruminal passage rate was also greater in the supplemented animals. Increased passage rate is another indicator of improved ruminal digestion. McCollum and Galyean. (1985) concluded that supplementation of oilseed meals to ruminants consuming low quality forage increased voluntary intake and ruminal passage rate.

Guthrie and Wagner (1988) evaluated CP supplementation of steers consuming low quality forage. Angus steers (n = 15) were used in an incomplete 3 x 5 Latin square to determine the effect of increasing levels of SBM on intake and digestion characteristics. Treatments consisted of increasing amounts of SBM (0, 121, 241, 362, and 603 g fed once daily) supplemented to steers consuming prairie hay (5.2% CP). Hay intake, DM intake, and total DM digestibility increased in a linear fashion in respect to increasing amounts of SBM.

Supplements with appreciable CP content (> 30% CP) improve intake and digestibility of low quality forage. Supplements containing smaller amounts of CP would be beneficial if they could improve intake of low quality forage, when pricing favors their usage. Hannah et al. (1990) evaluated the influence of protein supplementation with feedstuffs containing a moderate concentration of CP (12-27%, DM basis) on the site and extent of digestion of low quality (2.3% CP) dormant bluestem forage. Treatments consisted of a non-supplemented control, 1.8 kg/d of a 12.8% CP supplement (LowCP), 1.8 kg/d of a 27.1% CP supplement (ModCP), and 2.7 kg/d of dehydrated alfalfa pellets containing 17.5% CP (Dehy). Dry matter intake was greatest in the steers fed ModCP and Dehy when compared to the DM intake of CON and LowCP. Both apparent and true ruminal OM digestibility was greater in the ModCP and Dehy vs the CON and LowCP groups. Total tract OM digestibility was greatest in the ModCP steers and least in the

CON steers, LowCP and Dehy being intermediate. Rumen fill, passage rate, flow, and rate of DM digestion were all greatest in the ModCP and Dehy treatments, and least in CON. The inability to observe a positive effect from the LowCP group can be attributed to additional starch in the supplement. Grain sorghum and SBM were used to formulate the LowCP and ModCP treatments so that they had equal energy densities but different protein levels. The additional starch needed in LowCP group in order to yield a reduced protein level very well could have caused this decrease in intake and digestion as seen in previously reviewed work (Olson et al., 1999; Klevesahl et al., 2003).

Stafford et al. (1996) evaluated several different supplementation schemes to improve performance of beef steers consuming low quality (1.9% CP) forage. Four treatments were used in addition to a non-supplemented control, moderate CP (17.5% CP; MOD) concentrate, high CP (32.7%; HIGH) concentrate, long stem alfalfa hay (17.5% CP; LSAH), and alfalfa pellets (16.3% CP; AP). All supplements were fed at three (0.05, 0.10, and 0.15% BW CP/d) different levels. The moderate and high CP treatments were a mixture of sorghum grain and soybean meal. Moderate CP (MOD) supplement contained 63% starch, and the HIGH 34% starch. Forage intake and digestibility were greater in supplemented groups when compared to control with the exception of LSAH. Intake was greater in HIGH treatments than MOD. A substitution effect was observed, intake decreased as levels of MOD and LSAH increased in the diet. Also a decrease in passage rate was observed at the highest level of MOD and LSAH. A forage intake and digestion plateau was not observed in the HIGH treatment which authors hypothesized. This is most likely due to the additional starch in the diet from sorghum; more starch in the diet may require greater dietary CP to elicit a forage intake and digestion plateau.

Pitts et al. (1992) observed the effect of CP supplementation to steers grazing Tobosagrass in the spring and summer. The three-year study evaluated weight gain, blood urea nitrogen (BUN), and fecal nitrogen (FN). Blood urea nitrogen and FN were measured to evaluate their usefulness at determining protein status of the animal. Steers were observed from April until early July all three study years. Treatments consisted of two different amounts (as-fed basis) of cottonseed meal (CSM; 41% CP), 0.34 kg/head/day, and 0.68 kg/head/day, and a non-supplemented control. Steers supplemented 0.68 kg/head/day CSM consistently had greater BUN and FN levels than the non-supplemented counterparts. The authors however were unable to tie these observations to other literature to determine a point that signified the animal was N deficient. In regards to performance, in years one and three steers reportedly had a greater ADG when supplemented CP regardless of level; However, in year two steer ADG did not differ regardless of treatment. Forage samples indicate that in years one and three forage CP content was greatest in early May but declined to around 7% CP in July. In year two forage CP again was greatest in early May but did not decline as severely and was measured to be approximately 8.1% in July. In this study (Pitts et al., 1992) cattle grazing forage that declined throughout the grazing season to approximately 7% CP responded favorably to CP supplementation during the spring-summer grazing season.

Cow and Calf Performance when Supplemented CP

The literature has many examples of positive responses to supplementing CP to steers grazing low quality forage. Many studies have been done studying the same effect in beef cows; however, few have been published that look at lactating beef cow performance and how calf performance could be improved through CP supplementation to their dam.

Rutledge et al. (1971) evaluated the influence of milk yield and age of dam on the weaning weight of beef calves. In a two-year study in North Carolina eighty-six Hereford cows and their calves were observed. Calving season began approximately January 1 of both study years and concluded around March 31. All calves were sired by bulls of similar in genetic composition to ensure a high degree of genetic similarity among calves. Milk yield was measured once each month for seven months using the weigh suckle weigh method. All calves were weaned at 205 d ± 10 d. Milk yield of the dam was the major factor contributing to weaning weight. Dams that produce greater amounts of milk, wean heavier calves in a 205 d weaning system.

Marston and Lusby (1995) studied the effects that energy or protein supplementation had on beef cows pre-partum and post-partum. Cows (n =32, yr. 1; n = 42, yr. 2) consumed low quality prairie hay while being observed for intake and digestibility. Supplementation began approximately 120 d prior to calving (calving began March 1) in both years. Two 14 d periods in each year were the observation windows for intake and digestibility, one during late gestation, and the second during early lactation. In year one two supplemental treatments were used, PROTEIN (40% CP SBM supplement; 0.55 kg/d CP) and ENERGY (20% CP soybean hulls; 0.55 kg/d CP). However, in the second year the authors added a third supplement, HIGH PROTEIN (40% CP SBM supplement; 1.10 kg/d CP). Supplemental CP, regardless of level, improved forage intake and extent of digestion during gestation and lactation. Milk yield was similar among treatments.

Llewellyn et al. (2006) observed the effectiveness of protein supplementation during the fall, in spring calving beef cows. Cows received supplement from August 14 to December 14 in two consecutive years. Treatments consisted of a non-supplemented control, pre and post-weaning supplementation (Pre+Post; August 14 – December 14), and supplementation only post-weaning (Post; October 16- December 14). Supplemented cows received 0.61 kg/d of a 45% CP supplement. Regardless of supplemental treatment, cows receiving protein had an improved nutritional status as observed in the greater preservation of BCS and BW than non-supplemented cows through the next year's calving season. The authors were unable to verify that this was due to greater forage intake using ruminally cannulated steers in a concurrent experiment. Reproductive performance of cows was not significantly different among treatments; however, the percentage of cows cycling before May 20 was numerically greater in the supplemented groups (Pre+Post 88%; Post 93%) than the control (85%). The BW, on May 20, of calves born in the spring following the first fall of supplementation was greatest from cow's supplemented pre and post-weaning. Calf BW change from birth until May 20 was greater in calves from cows that had been supplemented the prior fall.

A study was conducted to determine CP supplementation effects on lactating beef cows grazing tall fescue (Forcherio et al., 1995). Spring-calving mature beef cows were allotted to 5 treatments, 1 of 2 energy sources (cracked corn or soybean hulls) in combination with 1 of 2 levels of CP (100 g/d or 200 g/d), and a non-supplemented control group. Dams of three male calves and three female calves were allotted to each treatment. All cows grazed a single 8.1 ha pasture from late May until late July. Crude protein of the tall fescue being grazed was estimated to be 9.8% (DMB) on July 11 of the study year. Cow ADG was not different among CP treatments. However, calf ADG was greatest when CP was supplemented at the 100 g/d level vs the 200 g/d level. Milk intake of calves (determined on July 16 of the study year) was greater from calves nursing supplemented cows. Milk intake was not different between energy types; however, the 100 g/d calves had greater milk intake than the 200 g/d calves. Neither intake nor BW change of the cows being supplemented differed throughout the duration of the study. However, differences in calf ADG and milk consumption suggest that CP supplementation to dams can benefit calf growth even when the forage is not considered low quality.

In the search for the first limiting nutrient for summer calving cows, Lardy et al. (1999) supplemented lactating cows grazing native rangeland and measured effects on body weight changes and calf performance. Concurrent studies were conducted over three consecutive years using cattle grazing warm season native grasses. In Exp. 1, forty-eight lactating, summer calving cows were randomly assigned to one of four supplemental treatments; non-supplemented control, energy, DIP, and DIP + UIP. Supplements were not isonitrogenous, but were formulated to meet the calculated DIP and MP requirements laid forth in the NRC (1996). Cows were supplemented from September 4 until November 4, this was repeated for three years. In Exp. 2, 40 lactating, summer calving cows were assigned to the same treatments as in Exp. 1. The difference being that in Exp. 2 cows were supplemented and observed for performance variables from November 5 until January 10 for 3 consecutive years. Milk production was determined using the weigh suckle weigh technique in both observed calf crops. Forage CP content, obtained from esophageal masticate samples, in Exp. 1 ranged from (% OM) 8.5 (September average) to 6.5 (average for November). In Exp 2. the average concentration of CP in the forage was 6.2% (OMB). In Exp. 1, BCS was greater when animals where supplemented, regardless of supplement, when compared to control. Cow final body weight was greatest when supplemented either form of protein when compared to energy and control. Milk production was greater when cows were supplemented regardless of treatment. Calf weight gain was greatest in the protein supplement groups and least in the control groups, energy being intermediate. In Exp. 2, the only significant performance variable observed was cow final body weight which was greatest in the protein supplemented groups, least in the control, and intermediate in the energy group. Although the authors state that there was no significant difference, when studying the standard error in milk production there appears to be a difference (more than 2X SE) in the DIP +UIP group as it has the numerically greater milk yield. Lactating cows grazing late growing season forage increased final cow BW, milk yields, and improved calf performance.

Crude protein supplementation consistently increases cow performance and milk yield. Increased milk yield reportedly increased calf performance. The ability to benefit both the cow and calf, while only supplementing the cow seems beneficial logistically and would reduce costs over other systems.

Frequency of CP Supplementation

Labor costs associated with delivery of CP supplements can be significant if daily provision of supplement is required. Bohnert et al. (2002) evaluated supplementation frequency and CP degradability effects on beef steers consuming low quality forage (5% CP). Supplements were provided daily (D), every third day (3D), or every sixth day (6D). In each of the three frequencies, steers were either fed UIP (blood meal + SBM) or DIP (SBM) at rate of 0.1% of BW/d. No forage intake or digestibility differences were observed regardless of treatment. No differences were observed among treatments for N intake or the extent of digestion, indicating that ruminants consuming low quality forage are able to effectively use supplemental CP regardless of frequency and protein degradability.

Beaty et al. (1994) studied the effect of frequency of CP supplementation in beef cattle consuming low quality forage. Pregnant Angus x Hereford beef cows (n = 128) were used to evaluate the effect of different levels of protein and the frequency of supplementation on BW and BCS change throughout late gestation and into early lactation. Cows were then randomly allotted into 1 of 4 treatments (10, 20, 30, or 40% CP supplement) in 2 frequencies (3X, supplemented 3 times per week; 7X, supplemented 7 times per week). Regardless of frequency, all cows received 14.1 kg/week of the respective supplement, or an average of 2.01 kg/d. All cattle were gathered daily when the 7X groups were supplemented to be sure that there would be no variation in grazing time or stress associated with gathering. Supplements were fed from November 20 until calving (average calving date = March 4). Cumulative weight loss until calving decreased as CP level increased. After calving there was no difference in weight loss between protein levels. Cumulative weight loss at calving time was greater in the 3X frequency groups. While 3X cows lost more weight prior to calving than 7X cows there was no difference in the percentage of cows that became pregnant at breeding. Subsequent calf

ADG or weaning weights weren't different between either of the frequency groups. The performance variables of beef cows that are of importance are capability to become pregnant and calf performance. While individual cow BW decreased more in the 3X group than the 7X group, calf performance and subsequent pregnancy rates were not affected. Supplementing cows three times per week reduced labor costs with minimal effects to cow performance.

Schauer et al. (2005) evaluated CP supplementation frequency on cows grazing low quality forage and its effect on performance and grazing behavior over a three-year period (August through November of each year). Authors wanted to evaluate grazing behavior as they noted that daily supplementation in other studies reduced grazing time. Treatments consisted of a non-supplemented control (CON), a CP supplement fed daily (D), and CP supplement fed once every 6 d (6D). Regardless of frequency, all cows receiving supplement consumed 5.46 kg of a 43% CP supplement every 6 d. Additionally, twelve cows were used in the same periods and treatment structure to evaluate distance traveled, grazing time, and maximum distance from water using GPS collars. Cattle were assigned to one of three 810-ha pastures and the supplemented groups were group fed. Cow distribution and behavior was measured using neck mounted GPS collars. Regardless of feeding frequency, cows that were supplemented CP gained more weight, and had a greater positive BCS change than their non-supplemented counterparts. Grazing time was greatest in the CON group vs the supplemented groups. There was no difference in distance traveled, or maximum distance from water regardless of treatment. No differences were observed in any variable between daily supplementation and every 6 d throughout the entire 3-year study. Infrequent CP supplementation to beef cows grazing low quality native range resulted in similar performance to cattle being supplemented daily.

Cappellozza et al. (2015) observed infrequent CP supplementation in normally-cycling, open, non-lactating beef cows. Daily (D) CP supplementation was compared to infrequent (three times a week, 3WK; once a week, 1 WK) supplementation and its effect on uterine pH and P_4 production. Cows consumed low quality forage (4.7% CP) and were supplemented SBM (54.1% CP) at a rate of 1 kg/cow-day (as-fed). It was hypothesized that increased plasma urea nitrogen (PUN) levels would cause a decreased uterine pH impairing reproductive performance. This hypothesis was derived from literature as it had been observed prior (Elrod and Butler, 1993; Hammon et al., 2005). However, it would be unexpected due to urea's alkaline properties; its addition would be expected to elicit an increase in uterine pH if any changes were observed. While a greater PUN was observed at all time points in the 1WK treatment no difference in uterine pH was observed. Another hypothesis was that the larger meal size of the 1WK treatment would cause decreased levels of plasma P_4, the hormone that aids in creation and maintenance of pregnancies (Spencer and Bazer, 2002). No differences were observed in plasma P_4 concentration among treatments. Vascocelos et al. (2003) fed dairy cows 1 meal a day and reported a decrease in P_4 production. Likewise, Cooke et al. (2007) observed a reduction in P_4 production when beef cows were fed an energy supplement infrequently. Cappellozza et al. (2015) did not find a difference due to meal size presumably due to diet. Cows in this study had ad-libitum access to forage and CP may not have the same effect on P_4 production as the energy supplementation in Cooke et al. (2007). Infrequent CP supplementation in open, non-lactating beef cows would not impede their reproductive capability. However, further studies observing the effects of infrequent CP supplementation in lactating beef cows are needed.

Conclusion from Literature

Crude protein supplementation to beef cattle consuming low quality forage increases animal performance. Increased performance is mediated through increased rate of digestion which in turn increases passage rate and subsequently, forage intake. Infrequent supplementation of CP does not decrease animal performance, even when supplemented as infrequently as every 6 d. In situations where calves are suckling dams that are being supplemented, calf performance increased. Increased calf performance may be an effect of increased milk yield of the dam.

Forage with insufficient nutrients to meet animal requirements can be observed several times throughout the year. While many external factors make it difficult to know exactly when forage quality is limiting, 7% CP is generally considered low quality. Advances in measuring forage quality using the measure of energy as well as CP content will be useful to determine when forage quality will affect animal performance.

Literature Cited

Bandyk, C. A., R. C. Cochran, T. A. Wickersham, E. C. Titgemeyer, C. G. Farmer, and J. J. Higgins. 2001. Effect of ruminal vs. postruminal administration of degradable protein on utilization of low-quality forage by beef steers. J. Anim. Sci. 79:225-231.

Beaty, J. L., R. C. Cochran, B. A. Lintzenich, E. S. Vanzant, J. L. Morrill, R. T. Brandt, and D. E. Johnson. 1994. Effect of frequency of supplementation and protein concentration in supplements on performance and digestion characteristics of beef cattle consuming low-quality forages. J. Anim. Sci. 72:2475-2486.

Bohnert, D. W., T. DelCurto, A. A. Clark, M. L. Merrill, S. J. Falck, and D. L. Harmon. 2011. Protein supplementation of ruminants consuming low-quality cool- or warm-season forage: Differences in intake and digestibility. J. Anim. Sci. 89:3707-3717.

Bohnert, D. W., C. S. Schauer, M. L. Bauer, and T. DelCurto. 2002. Influence of rumen protein degradability and supplementation frequency on steers consuming low-quality forage: I. Site of digestion and microbial efficiency. J. Anim. Sci. 80:2967–2977.

Bowman, J. G., B. F. Sowell, and J. A. Paterson. 1995. Liquid supplementation for ruminants fed low-quality forage diets: a review. Anim. Feed Sci. and Tech. 55:105-138.

Campling, R. C. 1970. Physical regulation of voluntary intake. In: A. T. Phillipson (ed.) Physiology of Digestion and Metabolism in the Ruminant. Oriel Press, Ltd., Newcastle, U.K. p. 226-234.

Cappellozza, B. I., R. F. Cooke, M. M. Reis, R. S. Marques, T. A. Guarnieri Filho, G. A. Perry, D. B. Jump, K. A. Lytle and D. W. Bohnert. 2015. Effects of protein supplementation frequency on physiological responses associated with reproduction in beef cows. J. Anim. Sci. 93:386-394.

Cochran, R. C. 1995. Developing optimal supplementation programs for range livestock. In: 50 years of range research revisited, KSU Range Field Day. Manhattan, KS.

Coleman, S. W. and K. M. Barth. 1973. Quality of diets selected by grazing animals and its relation to quality of available forage and species composition of pastures. J. Anim. Sci. 36:754-761.

Cooke, R. F., J. D. Arthington, C. R. Staples, W. W. Thatcher, and G. C. Lamb. 2007. Effects of supplement type on performance, reproductive, and physiological responses of Brahman-crossbred females. J. Anim. Sci. 85:2564–2574.

DelCurto, T., R. C. Cochran, D. L. Harmon, A. A. Beharka, K. A. Jacques, G. Towne, and E. S. Vanzant. 1990. Supplementation of dormant tallgrass-prairie forage: I. Influence of varying supplemental protein and (or) energy levels on forage utilization characteristics of beef steers in confinement. J. Anim. Sci. 68:515-531.

Elrod, C. C., and W. R. Butler. 1993. Reduction of fertility and alteration of uterine pH in heifers fed excess ruminally degradable protein. J. Anim. Sci. 71:694–701.

Forcherio, J. C., G. E. Catlett, J. A. Paterson, M. S. Kerley, and M. R. Ellersieck. 1995. Supplemental protein and energy for beef cows consuming endophyte-infected tall fescue. J. Anim. Sci. 73:3427-3436.

Funk, M. A., M. L. Galyean, M. E. Branine and L. I. Krysl. 1987. Steers grazing blue grama rangeland throughout the growing season. I. Dietary composition, intake, digesta kinetics and ruminal fermentation. J. Anim. Sci. 65:1342.

Guthrie, M. J. and D. G. Wagner. 1988. Influence of protein or grain supplementation and increasing levels of soybean meal on intake, utilization and passage rate of prairie hay in beef steers and heifers. J. Anim. Sci. 66:1529.

Hammon, D. S., G. R. Holyoak, and T. R. Dhiman. 2005. Association between blood plasma urea nitrogen levels and reproductive fluid urea nitrogen and ammonia concentrations in early lactation dairy cows. Anim. Reprod. Sci. 86:195–204.

Hannah, S. M., R. C. Cochran, E. S. Vanzant, and D. L. Harmon. 1991. Influence of protein supplementation on site and extent of digestion, forage intake, and nutrient flow characteristics in steers consuming dormant bluestem-range forage. J. Anim. Sci. 69:2624.

Klevesahl, E. A., R. C. Cochran, E. C. Titgemeyer, T. A. Wickersham, C. G. Farmer, J. I. Arroquy, and D. E. Johnson. 2003. Effect of a wide range in the ratio of supplemental rumen degradable protein to starch on utilization of low-quality, grass hay by beef steers. Anim. Feed Sci. Tech. 105:5-20.

Köster, H. H., R. C. Cochran, E. C. Titgemeyer, E. S. Vanzant, I. Abdelgadir, and G. St-Jean. 1996. Effect of increasing degradable intake protein on intake and digestion of low-quality, tallgrass-prairie forage by beef cows. J. Anim. Sci. 74:2473-2481.

Kropp, J. R., R. R. Johnson, J. R. Males, and F. N. Owens. 1977. Microbial protein synthesis with low-quality roughage rations: Isonitrogenous substitution of urea for soybean meal. J. Anim. Sci. 46:837–843.

Lalman, D., and D. Gill. 1999. Oklahoma Gold Q&A Late-season Supplementation Program for Stocker Cattle. Oklahoma Coop. Ext. Serv., Stillwater, OK.

Lardy, G. P., D. D. Adams, T. J. Klopfenstein, and R. T. Clark. 1999. First limiting nutrient for summer calving cows grazing autumn-winter range. J. Range Manage. 52:317–326.

Llewellyn, D. A., R. C. Cochran, T. T. Marston, D. M. Grieger, C. G. Farmer, and T. A. Wickersham. 2006. Influence of limited fall protein supplementation on performance and forage utilization by beef cattle grazing low-quality native grass pastures. Anim. Feed Sci. Technol. 127:234–250.

Marston, T. T., and K. S. Lusby. 1995. Effects of energy or protein supplements and stage of production on intake and digestibility of hay by beef cows. J. Anim. Sci. 73:651–656.

Mathis, C. P., R. C. Cochran, J. S. Heldt, B. C. Woods, I. E. O. Abdelgadir, K. C. Olson, E. C. Titgemeyer, and E. S. Vanzant. 2000. Effects of supplemental degradable intake protein on utilization of medium- to low-quality forages. J. Anim. Sci. 78:224-232.

McCollum, F. T., and M. L. Galyean. 1985. Influence of cottonseed meal supplementation on voluntary intake, rumen fermentation and rate of passage of prairie hay in beef steers. J. Anim. Sci. 60:570-577.

McCollum, F. T., M. L. Galyean, L. J. Krysl and J. D. Wallace. 1985. Cattle grazing blue grama rangeland. I. Seasonal diets and rumen fermentation. J. Range Manage. 38:539.

Moore, J. E., M. H. Brant, W. E. Kunkle, and D. I. Hopkins. 1999. Effects of supplementation on voluntary forage intake, diet digestibility, and animal performance. J. Anim. Sci. 77:122-135.

Nelson, C. J., and L. E. Moser. 1994. Plant Factors Affecting Forage Quality. In: G. C. Fahey Jr., editor, Forage quality, evaluation, and utilization. Am. Soc. Agronomy, Crop Sci. Soc. Am., and Soil Sci. Soc. Am., Madison, WI. p. 115–154.

NRC. 1984. Nutrient Requirements of Beef Cattle. National Academy Press, Washington, DC.

NRC. 1996. Nutrient Requirements of Beef Cattle, 7th rev. ed. National Academy Press, Washington, DC.

Olson, K. C., R. C. Cochran, T. J. Jones, E. S. Vanzant, E. C. Titgemeyer, and D. E. Johnson. 1999. Effects of ruminal administration of supplemental degradable intake protein and starch on utilization of low-quality warm season grass hay by beef steers. J. Anim. Sci. 77:1016-1025.

Orskov, E. R. 1982. Protein Nutrition in Ruminants. Academic Press, New York.

Pitts, J. S., F. T. McCollum, and C. M. Britton. 1992. Protein supplementation of steers grazing tobosagrass in spring and summer. J. Range Manage. 45:226-231.

Rutledge, J. J., O. W. Robison, W. T. Ahlschwede, and J. E. Legates. 1971. Milk yield and its influence on 205-day weight of beef calves. J. Anim. Sci. 33:563-567.

Satter, L. D., and L. L. Slyter. 1974. Effect of ammonia concentration on rumen microbial protein production in vitro. Br. J. Nutr. 32:199-208.

Schauer, C. S., D. W. Bohnert, D. C. Ganskopp, C. J. Richards, and S. J. Falck. 2005. Influence of protein supplementation frequency on cows consuming low-quality forage: Performance, grazing behavior, and variation in supplement intake. J. Anim. Sci. 83:1715–1725.

Spencer, T. E., and F. W. Bazer. 2002. Biology of progesterone action during pregnancy recognition and maintenance of pregnancy. Front. Biosci. 7:1879–1898.

Stafford, S. D., R. C. Cochran, E. S. Vanzant, and J. O. Fritz. 1996. Evaluation of the potential of supplements to substitute for low-quality, tallgrass-prairie forage. J. Anim. Sci. 74:639–647.

Vasconcelos, J. L. M., S. Sangsritavong, S. J. Tsai, and M. C. Wiltbank. 2003. Acute reduction in serum progesterone concentrations after feed intake in dairy cows. Theriogenology 60:795–807.

Van Soest, P. J. 1994. Nutritional Ecology of the Ruminant. 2nd Ed. Comstock Publ. Assoc., Ithaca, NY p. 281-289.

Wickersham, T. A., E. C. Titgemeyer, R. C. Cochran, E. E. Wickersham, and D. P. Gnad. 2008. Effect of rumen-degradable intake protein supplementation on urea kinetics and microbial use of recycled urea in steers consuming low-quality forage. J. Anim. Sci. 86:3079-3088.

CHAPTER II

Effect of Crude Protein Supplementation on Performance of Cow-Calf Pairs and Replacement Heifers Grazing Late Growing Season Forage

Effect of crude protein supplementation on performance of cow-calf pairs and replacement heifers grazing late growing season forage

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Abstract

Concurrent experiments were conducted to evaluate the effect of protein supplementation to beef cattle grazing warm-season shortgrass forage during the late growing season. Cattle in all experiments grazed adjacent shortgrass pastures dominated by Buffalograss (Buchloe dactyloides) and Blue Grama (Bouteloua gracilis). Precipitation in the area for the period between May 1 and October 1 was 176% of normal. For all Exp., treatments consisted of a supplemented group (1.32 kg of a 39% CP fed 3 times a week) and a non-supplemented control group. Treatment groups were fed a daily average of 0.22 kg of CP. In Exp. 1, 45 multiparous cows (initial BW 646 ± 61 kg) were observed for BW, BCS, and Calf BW every 14 d. Forage clippings were taken simultaneously with cow measurements. Cow measurements and forage clippings began July 6 and concluded September 28. Cow final BW (*P* = 0.24) and ADG (P = 0.38) were not affected by treatment. There was no difference (*P* = 0.97) in cow final BCS regardless of treatment. Calf ADG (*P* = 0.54) and weaning weight (*P* = 0.45) were not affected by treatment. In Exp. 2, 26 primiparous cows (initial BW 546 ± 41 kg) were supplemented and measurements obtained in the same manner as Exp.1. Cow final BW (*P* = 0.39) and final BCS (*P* = 0.81) did not differ between treatments. Cow ADG (*P* = 0.07) tended to be greater when supplemented with 0.22 kg CP per day. Calf ADG

(*P* = 0.50) and weaning weight (*P* = 0.11) did not differ between treatments. In Exp. 3, 25 replacement heifers (initial BW 412 ± 31 kg) were observed for BW and forage clippings were obtained every 14d. Heifer final BW (*P* = 0.17) was not different between treatments. Heifer ADG (*P* = 0.02) was greater for supplemented heifers. Supplementing protein to cattle grazing late season medium quality forage is advantageous for increasing ADG in replacement heifers and potentially beneficial to improve condition in lactating primiparous cows. Repeating this experiment under varied precipitation patterns, as is normal for short-grass regions, would be beneficial to further examine the impact of late growing season protein supplementation on cow-calf pair/replacement heifer performance.

KEYWORDS: Crude protein, forage, supplementation, cow-calf pairs

Introduction

Providing a CP supplement to ruminants grazing low quality (CP < 7%) forage generally increases forage intake (McCollum and Galyean, 1985). Pitts et al. (1992) reported that steers grazing warm season shortgrass prairie exhibited greater weight gain during the summer (April – July) when provided a CP (0.14 or 0.28 kg / d) supplement. Crude protein content is greatest in young growing forages; however, as the plant matures CP becomes diluted as fiber begins to increase (Van Soest, 1994). This shift occurs as the maturing plants draw carbohydrates from below-ground stores to use for energy, diluting CP. Low quality forages, lacking in CP, do not provide sufficient N to rumen microbes in cattle which is necessary to breakdown forage (Satter and Slyter, 1974). Several studies (McCollum and Galyean, 1985; Pitts et al., 1992) have demonstrated supplementing protein to yearling cattle grazing low quality forage improves intake and performance.

Supplementing protein to cattle grazing late growing season forage can be cost-prohibitive, one many producers are unwilling to provide. However, greater milk yields have been reported from cattle given supplemental protein while grazing low-quality forage (Forcherio et al., 1995). According to Rutledge et al. (1971) the single most important determinant of weaning weight is the lactation performance of the dam. Increased calf weaning weight may offset the cost of supplementation and provide additional income for the producer. In the current experiment, it was expected that if nutrient availability to dams is increased under low quality forage conditions, calf performance will increase. The objective of these experiments was to determine the effect of protein supplementation to cattle grazing during late growing season on pre-weaning performance of calves, condition of dams, and replacement heifer performance.

Materials and Methods

All procedures were approved by the West Texas A&M University/CREET Institutional Animal Care and Use Committee (Proposal #72715). The experiments began July 6th and continued for 12 weeks until calf weaning, September 28. All experiments were conducted at West Texas A&M University Nance Ranch near Canyon Texas. Precipitation from May 1 through October 1 was 176% of normal (Western Regional Climate Center; Mean precipitation calculated using values observed from 1948-2013).

Experiment 1. British cross multiparous cows (n = 45; initial BW 646 ± 13 kg; age 5.5 ± 1.8 years) were stratified by initial body weight and randomly assigned to a supplemented treatment (TRT, 1.32 kg of a 39% CP range cube fed 3 times a week), or a non-supplemented control. Calves nursed cows for the entirety of the experiment. Calves were 85 ± 23 days old and had an initial BW of 137 ± 8 kg at onset of the experiment.

Cattle receiving the crude protein supplement received 0.22 kg of CP per day. Supplement level was based on Oklahoma State University's Oklahoma Gold supplement program (Lalman and Gill, 1999). Oklahoma Gold reports increased performance of stocker cattle grazing late-season forage from feeding 0.45 kg of a 38-41% CP supplement daily (Lalman and Gill, 1999).

All cattle grazed a single shortgrass prairie pasture (164.7 ha), and were managed as a single group for the duration of the experiment. Cattle in Exp. 1 were stocked at a rate of 3.66 ha / cow-calf pair. The shortgrass pasture was dominated by Buffalograss (*Buchloe dactyloides*) and Blue Grama (*Bouteloua gracilis*).

Supplements were fed during the 12-week period preceding calf weaning (September 28). Feeding commenced on July 6 and concluded when calves were weaned. Supplements were fed to cattle at 0700 three mornings per week. On mornings that cattle were supplemented all cattle were brought in to a sorting facility and sorted by TRT or CON. Cattle receiving no supplement were immediately returned to pasture along with all calves. Cattle receiving supplement were penned individually and fed 1.32 kg (DMB) of a 39% crude protein range cube (Hi-Pro Feeds, Friona, TX). The cattle were allotted 1 hour to consume the supplement. No ORTS were collected due to all cattle consuming the entirety of supplement at each feeding. Upon completion of consuming the cubes the treatment cattle were let back out to pasture.

At onset of the experiment, and again at weaning, cows and calves were weighed and cows were also evaluated for body condition (1-9 scale; Herd et al., 1986) for two consecutive days to obtain an average initial and final body weight. Body condition scores were taken by the same two trained technicians each time. Cattle (cows and calves) were weighed every 14 d during the experiment. On the evening prior to weigh days, cattle were gathered and held at a sorting facility. Cows and calves had ad-libitum access to prairie hay and water before being weighed at 0600 the next morning. Upon conclusion of weight and BCS collection cattle were moved back to their pasture, sorted, and treatment cattle were fed supplement.

Forage clippings were taken from the pasture every 14 d, corresponding with weigh days. A clipping square that measured 0.23 m^2 was used to take 10 clippings. Forage was hand clipped to ground level and bagged. Forage availability was calculated: dried forage, g (average weight of 10 clippings) * 44.85 = kg of dried forage / ha (USDA, 2006). Dried forage weights used in this calculation were ascertained by drying samples at 55°C in a forced-air oven for 48 hours

Experiment 2. British cross primiparous beef cows (n = 26; initial BW 546 ± 12 kg; 2 years old) were stratified by initial body weight and randomly assigned to supplemented treatment (TRT, 1.32 kg of a 39% CP range cube fed 3 times a week), or a non-supplemented control. Calves nursed cows for the entirety of the experiment. Calves were 103 ± 17 days old and had an initial BW of 137 ± 5.4 kg at onset of the experiment. All cattle grazed a single mixed shortgrass prairie pasture (192.2-ha) and were managed as a single group for the duration of the experiment. The shortgrass pasture was dominated by Buffalograss (*Buchloe dactyloides*) and Blue Grama (*Bouteloua gracilis*). Cattle in Exp. 2 were stocked at a rate of 7.39 ha / cow-calf pair. No ORTS were collected due to all cattle consuming the entirety of supplement at each feeding. Primiparous cows were supplemented and measurements obtained in the same manner as Exp.1.

Experiment 3. British cross yearling heifers (n = 25, initial BW 412 ± 9 kg) were stratified by initial body weight and randomly assigned to supplemented treatment (TRT, 1.32 kg of a 39% CP fed 3 times a week), or a non-supplemented control. All heifers grazed a single mixed shortgrass prairie pasture (57.5-ha) for the duration of the experiment. Heifers in Exp. 3 were stocked at a rate of 2.3 ha / animal. The shortgrass pasture was dominated by Buffalo Grass (*Buchloe dactyloides*) and Blue Gramma (*Bouteloua gracilis*). No ORTS were collected due to all cattle consuming the entirety of supplement at each feeding. Replacement heifers were supplemented and measurements obtained in the same manner as Exp.1 and 2.

Dry matter of forage clippings were analyzed by drying samples at 55°C in a forced-air oven for 48 hours. Samples were then composited within period and pasture and submitted to Servi-Tech (Amarillo, TX, USA) for analysis of CP, NDF, ADF, and calculation of TDN.

Body weight and ADG were analyzed as a linear mixed model with one-way treatment structure in a completely randomized design (PROC MIXED; SAS Institute Inc., Cary, NC), with animal serving as the experimental unit. The class statement included treatment and the model statement included treatment.

Calf and replacement heifer ADG by period was analyzed as repeated measures in a completely randomized design (PROC MIXED; SAS Institute Inc., Cary, NC), with animal serving as the experimental unit. The class statement included treatment and period and the model statement included treatment, period, & TRT x Pd interaction.

Means separation and P-values were determined using LSMEANS with PDIFF option. Treatment differences are discussed when $P \leq 0.05$; tendencies are discussed when $P > 0.05$ and < 0.10.

Results and Discussion

Experiment 1 (Mature Cows)

Forage analysis and available forage are summarized in Table 1.2. Beef cattle forage intake is maximized when approximately 2250 kg of dried forage mass / ha is available. (Rayburn, 1986). At the beginning of period 4, available forage was less than 2250 kg/ha, however, in period 5 it increased to above 2250 kg/ha. The decrease during period 4 below the recommended level followed by an increase is due to the inherent variation found in shortgrass prairie pastures. The variability in forage mass across periods is not thought to have reduced to forage intake.

Cow final BW, ADG, and final BCS ($P \geq 0.24$; Table 1.3) were not affected by treatment. Moore et al. (1999) reported that under conditions where TDN:CP ratio > 7:1 protein supplementation increased voluntary feed intake. The TDN:CP ratio in this experiment ranged from 6.5:1 to 8.1:1 (Table 1.2). A TDN:CP > 7:1 is not uncommon during the late growing season. While Moore et al. (1999) reported increased performance when TDN:CP > 7, inconsistency of forage quality in the current experiment made differences associated with the TDN:CP ratio negligible.

No difference ($P = 0.45$; Table 1.3) was observed in weaning weights of calves between treatment. Beaty et al. (1994) reported a linear increase in calf weaning weight when dams were supplemented four levels of crude protein while grazing tallgrass prairie during the winter prior to calving. Calf ADG ($P = 0.54$) was not affected by treatment.

Forcherio et al. (1995) fed lactating beef cows grazing tall fescue two different levels (100 g/d or 200 g/d) of CP from late May until late July. Calves from dams receiving CP, regardless of level, tended to have increased milk intake when compared to calves whose dams received no supplement. They were unable to conclude that calves from supplemented dams had a greater ADG than their non-supplemented counterparts.

Variation in animal and forage characteristics has a great impact as to the efficacy of supplemental protein (Mathis et al., 2000). Cattle grazing native range pastures will have different responses to supplemental protein than cattle grazing monocultures as seen in the current experiment and other studies (Beaty et al., 1994; Forcherio et al., 1995). Cattle in the current experiment were stocked at an average stocking rate and had abundant opportunity to select a diet more nutritious (Coleman et al., 1973) than that of the reported forage average.

Experiment 2 (First-calf Heifers)

Forage analysis and available forage are summarized in Table 1.4. As in Exp. 1, available forage less than the recommended level (2250 kg of dried forage / ha) was observed in period 5; however, it was followed by an increase in forage mass in the following period. Differences can be explained through pasture variation and forage intake is not thought to have been depressed.

Differences were not observed (P = 0.39; Table 1.6) in cow final BW between treatments. Also, no differences (P = 0.81) in cow BCS. Cow ADG tended (P = 0.07) to be greater in the TRT-group.

Tendencies for TRT ADG to be greater would plausibly be attributed to the age of the primiparious cows used, as they were just two years old. Cows at this stage of production have many nutritional challenges, first lactation, second gestation, and continued growth (Johnson and Funston, 2013). Primiparous cows only reach ~80% of mature size at 24 months of age. If parturition is planned to take place at this age the animal must have adequate nutrition for lactation and growth (Freetly et al., 2006). Influences in growth indicate that supplemental protein improved the nutritional status of the animal.

There were no differences (P = 0.11) in calf weaning weight between treatments. Rutledge et al. (1971) reported that 60% of the variance in 205 d weaning weights could be attributed to differences in milk yield. Age of the dam was most closely related to milk production, as it has a quadratic relationship with age. Milk yield peaked when cows were approximately 8.4 years of age. We hypothesized that supplement may increase milk production in primparous cows, and the difference would manifest as increased calf weight. However, this was not observed.

A TRT x Pd interaction (P = 0.02; Figure 1.2) was seen in calf ADG. In periods 1-5 inconsistency of calf performance in relation to treatment is speculated to be due to forage quality. Using the TDN:CP ratio (Moore et al., 1999) described previously, forage quality in periods 1-5 varied from a high of 8.2:1 to 6.8:1. In the 6th period however the TDN:CP ratio was 9.7:1. Hypothetically, this could suggest that in earlier periods, forage quality was not limiting milk production as the animals were choosing a diet more nutritious than reported (Coleman et al., 1973). However, in the 6th period, forage quality declined to a point where primiparous cows would have potentially been challenged to choose a nutritionally adequate diet. Supplemental protein may have increased TRT cow intake, which in turn may increase milk yield, subsequently increasing TRT calf performance in the sixth period.

Experiment 3 (Replacement Heifers)

Forage analysis and available forage is shown in Table 1.6. Available forage maintained close to the recommended level (2250 kg of dried forage / ha) during most periods. A pronounced increase was reported at the beginning of period six which is attributed to pasture variation.

No differences (P = 0.17) were found in final BW of heifers between treatments. Heifers receiving CP supplement did (P = 0.02; Table 1.7) have a greater ADG than CON heifers. Improving condition of gestating heifers shortened rebreed time (Bagley, 1993). Spitzer et al. (1995) noted that 96% of heifers with a BCS of 6 were pregnant at 60 days post parturition, while only 56% of heifers with a BCS of 4 were pregnant at 60 days. Hypothetically, maintaining heifers in better condition to calving will increase the herd's conception rate and shorten their rebreed time.

Implications

Under the conditions of this experiment, calf performance from primiparous and multiparous cows grazing native rangeland was not affected by crude protein supplementation during the late growing season. This may be attributable to the quality of forage grazed. In subsequent studies it would be advantageous to quantify milk yield from primiparous and multiparous cows being supplemented protein while grazing forage of varying quality. Differences in ADG of young beef females grazing medium quality forage prove the ability of supplemental protein to improve weight gain in young beef females entering winter. Abnormal temperatures and precipitation patterns may have caused the abnormal forage growth patterns. Due to the inherent variability of precipitation patterns in shortgrass prairie, we intend to repeat this experiment to evaluate the effect of supplemental protein during the late growing season on cow, calf, and replacement heifer weight gain under varying climatic conditions.

Literature Cited

Bagley, C.P. 1993. Nutritional management of replacement beef heifers: a review. J. Anim. Sci. 71:3155-3163.

Beaty, J. L., R. C. Cochran, B. A. Lintzenich, E. S. Vanzant, J. L. Morrill, R. T. Brandt, and D. E. Johnson. 1994. Effect of frequency of supplementation and protein concentration in supplements on performance and digestion characteristics of beef cattle consuming low-quality forages. J. Anim. Sci. 72:2475-2486.

Coleman, S.W. and K. M. Barth. 1973. Quality of diets selected by grazing animals and its relation to quality of available forage and species composition of pastures. J. Anim. Sci. 36:754-761.

Forcherio, J. C., G. E. Catlett, J. A. Paterson, M. S. Kerley, and M. R. Ellersieck. 1995. Supplemental protein and energy for beef cows consuming endophyte-infected tall fescue. J. Anim. Sci. 73:3427-3436.

Freetly, H. C., J. A. Nienaber, and T. Brown-Brandl. 2006. Partitioning of energy during lactation of primiparous beef cows. J. Anim. Sci. 84:2157-2162.

Herd, D.B. and L.R. Sprott. 1986. Body condition, nutrition and reproduction of beef cows. Ext. Bull. No. 1526. Texas Agric. Ext. Serv., College Station, TX.

Johnson, D. K., and R.N. Funston. 2013. Postbreeding heifer management. Vet. Clin. North Am. Food Anim. Pract. 29: 627-641.

Lalman, D. and D. Gill. 1999. Oklahoma Gold Q&A Late-season Supplementation Program for Stocker Cattle. Oklahoma Coop. Ext. Serv., Stillwater, OK. ANSI 3033.

Mathis, C. P., R. C. Cochran, J. S. Heldt, B. C. Woods, I. E. O. Abdelgadir, K. C. Olson, E. C. Titgemeyer, and E. S. Vanzant. 2000. Effects of supplemental degradable intake protein on utilization of medium- to low-quality forages. J. Anim. Sci. 78:224-232.

McCollum, F. T. and M. L. Galyean. 1985. Influence of cottonseed meal supplementation on voluntary intake, rumen fermentation and rate of passage of prairie hay in beef steers. J. Anim. Sci. 60:570-577.

Moore, J. E., M. H. Brant, W. E. Kunkle, and D. I. Hopkins. 1999. Effects of supplementation on voluntary forage intake, diet digestibility, and animal performance. J. Anim. Sci. 77:122-135.

NRC. 1996. Nutrient Requirements of Beef Cattle, 7th rev. ed. Natl. Acad. Press. Washington, DC.

Pitts, J. S., F. T. McCollum, and C. M. Britton. 1992. Protein supplementation of steers grazing tobosagrass in spring and summer. J. Range Manage. 45:226-231.

Rayburn, E. B. 1986. Quantitative aspects of pasture management. Seneca Trail RC&D Technical Manual. Franklinville, N.Y.: Seneca Trail RC&D.

Rutledge, J. J., O.W. Robison, W.T. Ahlschwede, and J.E. Legates. 1971. Milk yield and its influence on 205-day weight of beef calves. J. Anim. Sci. 33:563-567.

Satter, L. D., and L. L. Slyter. 1974. Effect of ammonia concentration on rumen microbial protein production in vitro. Br. J. Nutr. 32:199–208.

Spitzer, J. C., D. G. Morrison, R. P. Wettemann, and L. C. Faulkner. 1995. Reproductive responses and calf birth and weaning weights as affected by body condition at parturition and postpartum weight gain in primiparous beef cows. J. Anim. Sci. 73:1251-1257.

USDA\NRCS. 2006. National range and pasture handbook. Natural Resources Conservation Service, United States Department of Agriculture, Washington, DC.

Van Soest, P. J. 1994. Nutritional Ecology of the Ruminant. 2nd Ed. Comstock Publ. Assoc., Ithaca, NY p. 281-289.

Table 1.1. Analysis of range cubes

Nutrient	%, DM basis
CP[1]	39.0
Crude fat[2]	2.3
Crude fiber[2]	14.0

[1]Nutrient analysis conducted by commercial laboratory (Servi-Tech Laboratories, Amarillo, TX)
[2]Analysis provided by range cube manufacturer

Table 1.2. Chemical composition and availability of forage grazed in Exp. 1

Nutrient analysis[1]	Period					
	1	2	3	4	5	6
CP, %	8.0	6.9	8.1	7.3	6.3	6.2
ADF, %	43.8	43.5	45.1	49.2	47.7	46.7
TDN, %[2]	53.4	54.3	52.5	47.1	48.9	50.7
Forage available[3]	2662	2585	2635	2195	2382	2596

[1]Nutrient analysis conducted by commercial laboratory (Servi-Tech Laboratories, Amarillo, TX).
[2]NRAES-63. Penn State Univ. Dairy Reference Manual. 1995. Table 5.25, p 108
[3]Forage available = kg of dried forage / ha

Table 1.3. Effect of protein supplementation on mature cow and calf performance (Exp. 1)

	Control	Treatment[1]	SEM	P-value
Cow				
Initial BW, kg	654	639	13.0	0.41
Final BW, kg	678	658	11.8	0.24
ADG, kg	0.28	0.23	0.04	0.38
Initial BCS[2]	6.07	5.89	0.14	0.37
Final BCS[2]	6.16	6.15	0.13	0.97
Calf[3]				
Initial BW, kg	144	130	8.0	0.24
Weaning weight, kg	243	233	9.3	0.45
ADG, kg	1.19	1.22	0.03	0.54

[1]Treatment group received 1.32 kg of a 39% CP range cube 3 times a week.
[2] 1-9 scale; Herd et al., 1986
[3]1 Calf died during experiment, not related to treatments.

Figure 1.1. The effect of supplemental protein on calf ADG by period from cows grazing shortgrass prairie during the late growing season; Exp. 1; TRT x Pd (*P* = 0.37); SEM = 0.06.

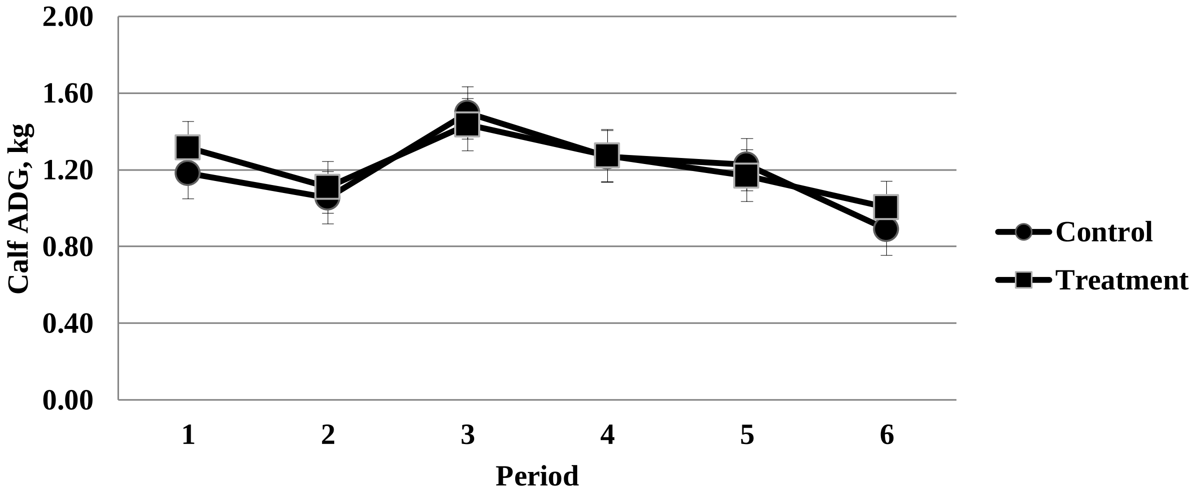


Table 1.4. Chemical composition and availability of forage grazed in Exp. 2

Nutrient Analysis[1]	Period					
	1	2	3	4	5	6
CP, %	6.5	7.4	6.6	7.0	6.0	5.3
ADF, %	44.1	44.6	47.0	48.9	51.7	45.8
TDN, %[2]	53.4	52.5	49.8	48.0	45.3	51.6
Forage available[3]	2801	3034	2751	2852	1856	2349

[1]Nutrient analysis conducted by commercial laboratory (Servi-Tech Laboratories, Amarillo, TX).
[2]NRAES-63. Penn State Univ. Dairy Reference Manual. 1995. Table 5.25, p 108
[3]Forage available = kg of dried forage / ha

Table 1.5. Effect of protein supplementation on primiparous cow and calf performance (Exp. 2)

	Control	Treatment[1]	SEM	P-value
Cow				
Initial BW, kg	543	548	11.6	0.76
Final BW, kg	547	561	11.8	0.39
ADG, kg	0.04	0.15	0.04	0.07
Initial BCS[2]	5.88	5.88	0.12	1.00
Final BCS[2]	5.81	5.85	0.11	0.81
Calf				
Initial BW, kg	143	132	5.4	0.16
Weaning weight, kg	230	217	5.7	0.11
ADG, kg	1.04	1.01	0.031	0.50

[1]Treatment group received 1.32 kg of a 39% CP range cube 3 times a week.

[2]1-9 scale; Herd et al., 1986

Figure 1.2. The effect of supplemental protein on calf ADG by period from primiparous cows grazing shortgrass prairie during the late growing season; Exp. 2; TRT x Pd (*P* = 0.02); SEM = 0.06.

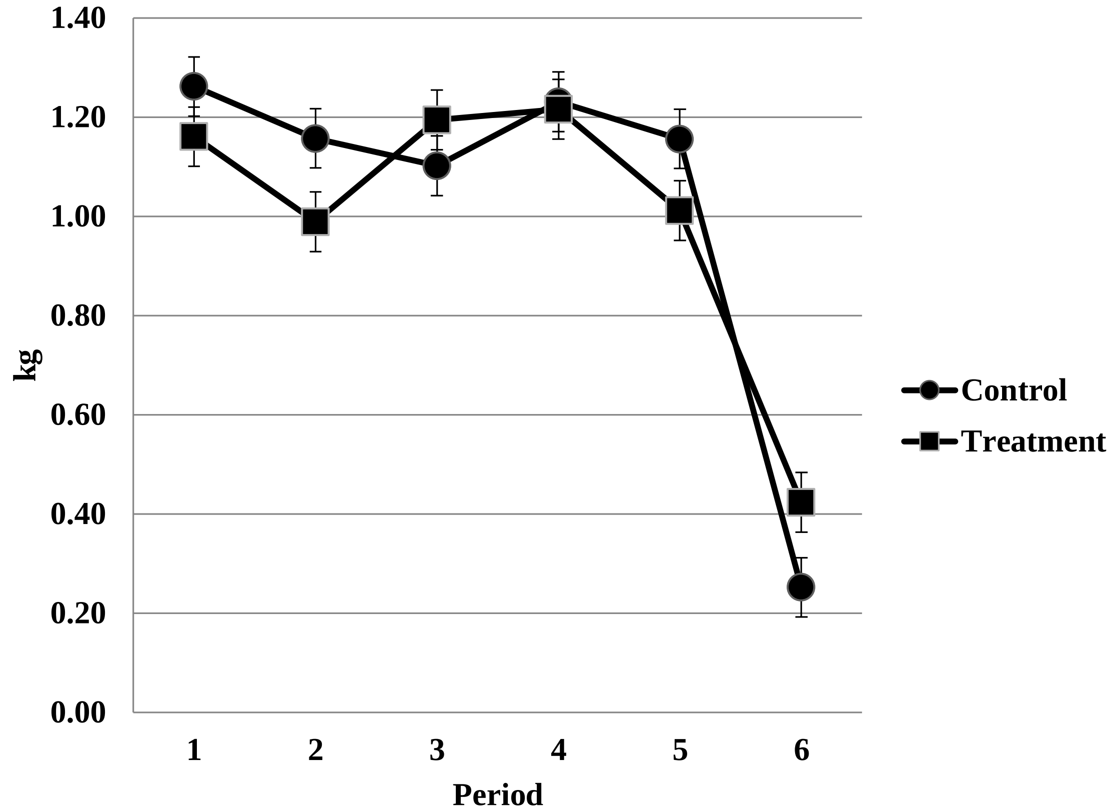


Table 1.6. Chemical composition and availability of forage grazed in Exp. 3

Nutrient Analysis[1], DM basis	Period					
	1	2	3	4	5	6
CP, %	6.4	7.5	6.8	6.9	5.8	5.2
ADF, %	44.2	44.1	44.6	46.2	46.1	44.9
TDN, %[2]	53.4	53.4	52.5	50.7	50.7	52.5
Forage available[3]	3494	2294	2036	2201	2131	2899

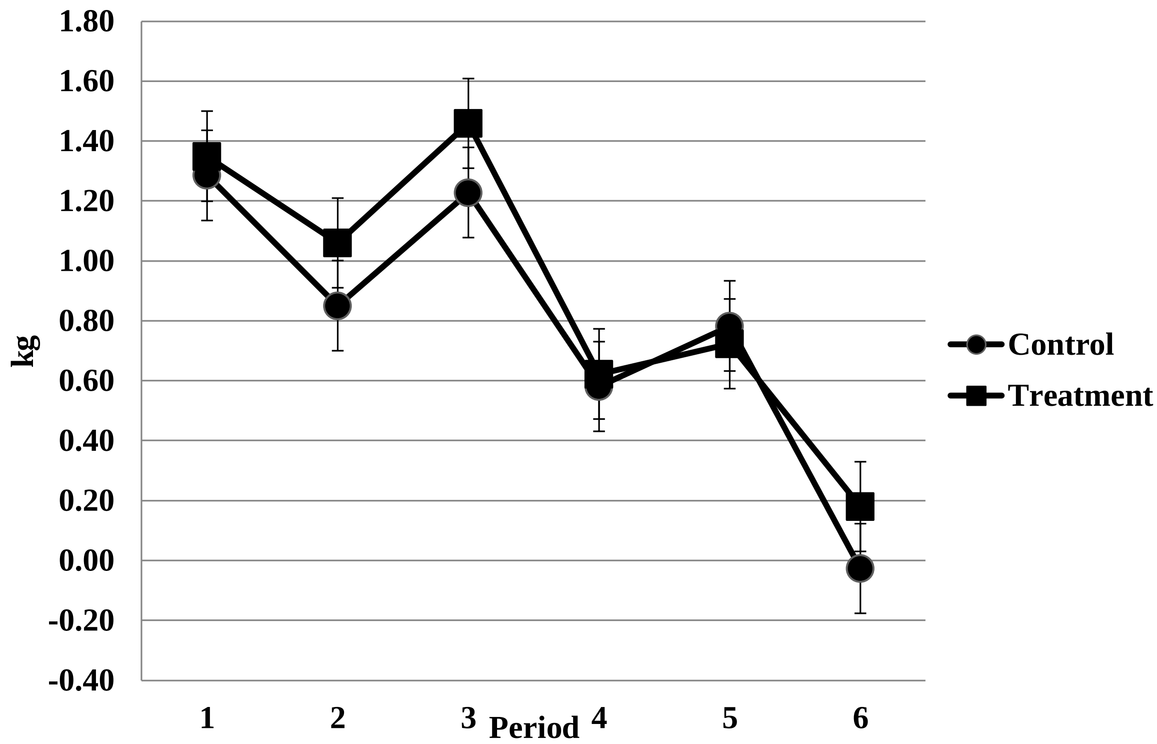
[1]Nutrient analysis conducted by commercial laboratory (Servi-Tech Laboratories, Amarillo, TX).
[2]NRAES-63. Penn State Univ. Dairy Reference Manual. 1995. Table 5.25, p 108
[3]Forage available = kg of dried forage / ha

Table 1.7. Effect of protein supplementation on yearling heifer performance (Exp. 3)

	Control	Treatment[1]	SEM	P-value
Initial BW, kg	407	416	8.9	0.52
Final BW, kg	475	492	9.0	0.17
ADG, kg	0.80	0.91	0.03	0.02

[1]Treatment group received 1.32 kg of a 39% CP range cube 3 times a week.

Figure 1.3. The effect of supplemental protein on ADG by period in yearling heifers grazing shortgrass prairie during late growing season; Exp. 3; TRT x Pd (*P* = 0.91); SEM = 0.15.



CHAPTER III

Effects of Condensed Tannin Extract Supplementation on Digestibility and Nitrogen Balance in Growing Beef Cattle

Effects of condensed tannin extract supplementation on digestibility and nitrogen balance in growing beef cattle

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Abstract

To evaluate the effect of condensed tannins (CT) on N excretion, a commercially available CT extract (ByPro; Silva Team, Ontario, CA) was included in a cereal grain-based diet at 3 levels (0, 1, or 2% of diet, DM basis). British-cross steers (n = 18; BW = 374 ± 34 kg) were individually offered ad libitum access to diets (15.6% CP). Steers were randomly assigned to 3 groups, then randomly assigned to treatments within group. Each group was fed CT for 14 d, 10 d for treatment adaptation and 4 d for total fecal and urine collection. No group by treatment interactions was detected ($P \geq 0.18$) among the response variables. Provision of CT did not affect ($P \geq 0.64$) DM intake or apparent total-tract DM digestion. Nitrogen intake was not affected ($P = 0.58$) by inclusion of CT in the diet, but fecal N output increased ($P = 0.04$) at 2% CT inclusion compared with control. However, there was no difference ($P = 0.36$) in urine N output among treatments. Nitrogen retention was less ($P = 0.03$) with 2% CT than 0 or 1% CT. Proportion of total N excreted in urine decreased ($P = 0.03$) with CT supplementation at 1 or 2% in the diet. Similarly the proportion of total N excreted in feces increased ($P = 0.03$) with 1 or 2% CT inclusion. Site of N excretion was shifted away from urine and toward feces when CT was included in a complete diet fed to beef cattle.

KEYWORDS: condensed tannin, digestibility, nitrogen balance, beef cattle

Introduction

Nitrogen (N) lost to the environment from livestock production is a concern because of its role in the formation of fine particulate matter ($PM_{2.5}$) that negatively affects human health (US EPA, 2004). Also, manure N may be lost to surface water through runoff (Morse, 1996). Excess dietary nitrogen is predominantly excreted in urine (Erickson and Klopfenstein, 2010) from ruminants as urea, which is rapidly hydrolyzed to ammonia (Mobley et al., 1995), by the urease enzyme. Nitrogen in feces is considered to be less volatile due to organic N slow mineralization rate (Webb, 2001). Shifting the site of N excretion from urine to feces may decrease fugitive N loss from ruminants.

Condensed tannins (CT) are a polyphenolic secondary compound of various forages, compounds which are not inherently needed by the organism for survival or growth but serve a purpose such as defense of the plant against herbivory (Waghorn, 2008). Condensed tannins bind with dietary protein in the rumen (Reed, 1995), creating tannin-protein complexes which decrease the rate of protein degradation in the rumen. Decreased protein degradation yields minimal ammonia levels in the rumen and may decrease urinary nitrogen excretion (Tiemann et al., 2008). Powell et al. (2009) reported CT inclusion in high CP silage-based diets decreased urinary N and increased fecal N in lactating dairy cows. Significant inclusion (> 20% of diet DM) of ethanol byproducts in ruminant diets increases dietary CP above accepted animal requirements (13.5% CP; Gleghorn et al., 2004) under ad libitum feeding management. Our hypothesis is that feeding CT to beef steers consuming a corn-based growing diet will alter the site of predominant N excretion from the urine to the feces without detriment to nutrient digestion.

Materials and Methods

All procedures were approved by the West Texas A&M University/CREET Institutional Animal Care and Use Committee (Proposal #31113).

Eighteen Angus cross steers (BW = 374 ± 34kg) were used to determine the effects of CT supplementation during the growing period on N balance and diet digestibility. Steers were randomly assigned to 1 of 3 groups, as only 6 metabolism crates were available. Following group assignment, steers were then randomly assigned to 1 of 3 treatments; CT added at 0% of diet DM (**CON**), 1% of diet DM (**1% CT**), or 2% of the diet (**2% CT**).

For the duration of the experiment steers had *ad libitum* access to feed fed at 110% of average voluntary intake over the previous four days. Steers were individually fed a corn-based growing diet (Table 2.1). The corresponding amount of CT Extract (ByPro; Silva Team, Ontario, CA) was mixed daily by hand into each individual calf's feed. Feed refusals were collected daily and composited by animal within group to evaluate diet and digestibility factors. Within each group steers were adapted to their respective diets in individual tie stalls for 7 d, then housed in metabolism crates for 7 d; 3 d for crate adaptation and 4 d for total fecal and urine collections. At 0600 on d 11 through 14, a clean bucket containing 900 ml of 10% (wt/wt) H_2SO_4 (added to urine containers to prevent NH_3 volatilization) was placed under each metabolism crate. Feces were collected in a metal bin lined with plastic. The plastic liner was replaced every 24 h during collection. Each morning, urine collections were weighed and urine thoroughly mixed. Urine from each animal were sub-sampled (60 ml), and immediately frozen. This procedure was followed each of the 4 collection days, with 60 mL sub-samples added to the frozen composite. Fecal samples were weighed and thoroughly mixed. For fecal samples, a 5% sample by weight was sub-sampled and immediately frozen. This procedure was followed each of the four collection days, with the 5% by weight sample being added to the frozen composite.

Laboratory Analyses

Dry matter of feces, feed, and ORTS were analyzed by drying samples to a constant weight at 55° C in a forced-air oven for 48 hours. Samples were ground through a 1mm screen using a Wiley Mill (Model 4, Thomas-Wiley, Philadelphia, PA). Lab corrected DM on fecal, ORTS, and diet samples were conducted with a forced-air oven at 105° C for 24 hours. Ash content was determined for ORTS, feed, and fecal samples using a muffle-furnace at 450^{o} C for 8 hours. The NDF content of ORTS, feed, and fecal samples was determined using an ANKOM 200 (ANKOM-Technology, Fairport, NY, USA). Fecal and urine samples were analyzed by Servi-Tech Laboratories (Amarillo, TX, USA) for N analysis using the methods of AOAC (2012; Method 2001.11). Ammonium N was calculated using the ammonium N method (AOAC, 941.04) and urea plus ammonium N method (AOAC, 941.04). Urea was calculated as the difference between urea plus ammonium (-) ammonium. Total tract digestibility of DM, NDF, and N was calculated by dividing fecal output (DM) of each by DMI, subtracted from 100 (Merchen, 1988).

Statistical Analysis

Digestion and N balance were analyzed as a linear mixed model with a one-way treatment structure in a completely randomized design (PROC MIXED; SAS Institute Inc., Cary, NC), with animal serving as the experimental unit. The class statement included steer and treatment. The model statement included treatment, group, and treatment x group. No interactions between treatment and group were detected ($P >$ 0.10); therefore only the main effect of treatments are reported.

Means separation and *P*-values were determined using LSMEANS with the PDIFF option. Orthogonal contrasts were used to separate linear and quadratic effects of CT inclusion in the diet. Treatment differences are discussed when $P \leq 0.05$; tendencies are discussed when $P > 0.05$ and < 0.10.

Results and Discussion

Intake

Dry matter, OM, or NDF intake did not differ ($P \geq 0.55$; Table 2.2) among treatments. When CT inclusion is < 5% DM it is generally accepted that DMI will not be affected. Diets containing CT > 5% decreased voluntary intake in grazing sheep (Barry and McNabb, 1999; Barry and Manley, 1984; Waghorn et al., 1994). Condensed tannin levels of < 2% DM did not decrease DMI in steers consuming concentrate diets (Krueger et al., 2010; Mezzomo et al., 2011). Additionally, modest inclusion of CT (0.3% of daily DM) fed to steers consuming a high-concentrate diet tended to increase DMI (Rivera-Méndez et al., 2016).

Digestibility

Fecal OM and NDF output were not affected ($P \geq 0.77$) by the incorporation of CT into the diet. Similarly, no difference ($P = 0.60$) was observed in apparent total tract DM digestion among treatments. No differences were reported in total tract digestibility or NDF digestion when CT was included in a forage-based diet fed to growing beef cattle at rates up to 2% (Beauchemin et al., 2007). Likewise, when CT (0.4% of daily DM) was fed to cattle consuming a high-concentrate diet, no differences were observed in digestibility of fiber or DM (Mezzomo et al., 2011). Barry and Manley (1984) reported a decrease in fiber digestion in sheep when CT was fed at a high inclusion rate of 10% of daily DM. Condensed tannin extracts obtained from various sources have varying effects on their nutrient binding properties (Beauchemin et al., 2007) which would allow for some variation seen in the literature. Differences in digestibility in various experiments could also be tied to the amount of CT fed. In the Barry and Manley (1984) manuscript, sheep were fed CT at 4 and 10% of DM, which decreased the digestibility of fiber. In contrast, experiments (Beauchemin et al., 2007; Mezzomo et al., 2011) where CT was included at less than or equal to 2% DM, diet digestibility was not affected. In the current experiment CT inclusion did not surpass 2% of DMI and digestion was not affected.

Nitrogen Balance

Nitrogen intake did not differ ($P = 0.58$; Table 2.3) among treatments. Fecal N was greater ($P = 0.04$) in the 2% CT treatment compared to CON. Provision of additional CT provided greater opportunity to create tannin-protein complexes, reducing protein degradability in the rumen, therefore reducing the amount of N excreted in the urine (Tiemann et al., 2008). Tannin-protein complexes may dissociate at a pH < 3.5, which is approximately the pH of the abomasum (Frutos et al., 2004; Patra and Saxena, 2010). However McNabb et al. (1998) indicates that the pH at the beginning of the intestine is roughly 5.0, which could allow for reformation of any tannin-protein complexes (Waghorn, 2008). The hypothetical reformation of tannin-protein complexes in the intestine could impede the digestion of dietary protein, leading to increased fecal N.

Urine N was not different (P = 0.36) between treatments. Urinary N, as a proportion of total N excreted was lower (P = 0.03) when CT was included in the diet. Conversely fecal N was greater (P = 0.03) when CT was included in the diet. This is due to an increase in fecal N and not a decrease of urine N, as less retained N was observed in the 2% CT treatment. Powell et al. (2009) reported similar results to the current experiment, as CT inclusion in the diet increased, the proportion of total N excretion shifted from the urine to the feces. However, this was due to decreased urinary N in the high CT (1.66% of daily DM) treatment and not an increase in fecal N as seen in the current experiment. In the current experiment it was hypothesized that by feeding CT, it would decrease the amount of N excreted in the urine similar to Powell et al. (2009), this was not observed. While not significantly different (P = 0.36), urine N numerically decreased approximately 10 g/d as CT inclusion increased from CON to 2% CT. Fecal N increased nearly 3 times as much (~ 30 g/d increase) in relation to the minimal decrease in urine N excretion. The inability to detect a reduction in urine N excretion leads the authors to reject the hypothesis that CT inclusion in a diet fed to beef steers would reduce urine N excretion.

Retained N was lower (P = 0.03) in the 2% CT treatment when compared to CON and 1% CT, suggesting that tannin-protein complexes may have reformed in the intestine.

Decreases in N-use efficiency would decrease animal performance over time. Koenig et al. (2013) reported that cattle with less retained N during an 84-d backgrounding period had less ADG than counterparts that retained greater N. Decreased ADG would result in a greater number of days on feed to reach a target market endpoint. Cattle that live longer before harvest, theoretically, would have greater N emissions than counterparts finished in fewer days (Cole et al., 2005). Reduced animal performance associated with a decrease in N retention would be attributable to less protein being utilized by the animal for growth. Less retained N of the 2% CT group in the current experiment could result in reduced ADG if treatments were applied for a longer period of time.

Implications

Under the conditions of this experiment proportional N excretion was shifted in to the feces, while not affecting feed intake or digestibility of feed. Levels of CT appear to be below thresholds where CT decreases voluntary dry matter intake. However, CT inclusion did not reduce urine N excretion to the same magnitude that fecal N excretion increased. A reduction in retained N at 2% CT inclusion could negatively affect animal performance. Further research is warranted to assess the effect of CT on intake, performance, and carcass attributes under varying feeding management conditions.

Literature Cited

Barry T. N., and T. R. Manley. 1984. The role of condensed tannins in the nutritional value of *Lotus pedunculatus* for sheep 2. Quantitative digestion of carbohydrates and proteins. Brit. J. Nutr. 51:493-504.

Barry T. N., and W. C. McNabb. 1999. The implications of condensed tannins on the nutritive value of temperate forages fed to ruminants. Brit. J. Nutr. 81: 263-272.

Beauchemin, K. A., S. M. McGinn, T. F. Martinez, and T. A. McAllister. 2007. Use of condensed tannin extract from quebracho trees to reduce methane emissions from cattle. J. Anim. Sci. 85:1990–1996.

Cole, N. A., R. N. Clark, R. W. Todd, C. R. Richardson, A. Gueye, L. W. Greene, and K. McBride. 2005. Influence of dietary crude protein concentration and source on potential ammonia emissions from beef cattle manure. J. Anim. Sci. 83:722-731.

Erickson, G., and T. Klopfenstein. 2010. Nutritional and management methods to decrease nitrogen losses from beef feedlots. J. Anim. Sci. 88:172-180.

Frutos, P., G. Hervás, F. J. Giráldez, and A. R. Mantecón. 2004. Review. Tannins and ruminant nutrition. Span. J. Agric. Res. 2:191–202.

Gleghorn, J. F., N. A. Elam, M. L. Galyean, G. C. Duff, N. A. Cole, and J. D. Rivera. 2004. Effects of crude protein concentration and degradability on performance, carcass characteristics, and serum urea nitrogen concentrations in finishing beef steers. J. Anim. Sci. 82:2705-2717.

Koenig, K. M., S. M. McGinn, and K. A. Beauchemin. 2013. Ammonia emissions and performance of backgrounding and finishing beef feedlot cattle fed barley-based diets varying in dietary crude protein concentration and rumen degradability. J. Anim. Sci. 91:2278-2294.

Krueger, W. K., H. Gutierrez-Banuelos, G. E. Carstens, B. R. Min, W. E. Pinchak, R. R. Gomez, R. C. Anderson, N. A. Krueger, and T. D. A. Forbes. 2010. Effects of dietary tannin source on performance, feed efficiency, ruminal fermentation, and carcass and non-carcass traits in steers fed a high-grain diet. Anim. Feed Sci. Technol. 159:1-9.

Latimer, G. W. Jr. (ed). 2012. AOAC Official Method 941.04. Urea and Ammoniacal Nitrogen in Animal Feed. Official Methods of Analysis of AOAC International. 19th ed. AOAC International, Gaithersburg, Maryland.

McNabb W. C., J. S. Peters, L. Y. Foo, G. C. Waghorn, S. J. Jackson. 1998. Effect of condensed tannins prepared from several forages on the in vitro precipitation of ribulose-1, 5-bisphospathe carboxylase (rubisco) protein and its digestion by trypsin (EC 2.4.21.4) and chymotrypsin (EC 2.4.21.1). J. Sci. Food Agric. 77:201-212.

Merchen, N. R. 1988. Digestion, absorption and excretion in ruminants. In: D. C. Church, editor, The Ruminant Animal: Digestive Physiology and Nutrition. Prentice Hall, Englewood Cliffs, NJ. p. 172–185.

Mezzomo, R., P. V. R. Paulino, E. Detmann, S. C. Valadares Filho, M. F. Paulino, J. P. I. S. Monnerat, M. S. Duarte, L. H. P. Silva, and L. S. Moura. 2011. Influence of condensed tannin on intake, digestibility, and efficiency of protein utilization in beef steers fed high concentrate diet. Livest. Sci. 141:1-11.

Mobley, H. L., M. D. Island, and R. P. Hausinger. 1995. Molecular biology of microbial ureases. Microbiol. Rev. 59:451-480.

Morse, D. 1996. Impact of environmental regulations on cattle production. J. Anim. Sci. 74:3103-3111

Patra, A. K., and J. Saxena. 2011. Review: Exploitation of dietary tannins to improve rumen metabolism and ruminant nutrition. J. Sci. Food Agric. 91:24–37.

Powell, J. M., G. A. Broderick, J. H. Grabber, and U. C. Hymes-Fecht. 2009. Technical note: Effects of forage protein-binding polyphenols on chemistry of dairy excreta. J. Dairy Sci. 92:1765-1769.

Reed, J. D. 1995. Nutritional toxicology of tannins and related polyphenols in forage legumes. J. Anim. Sci. 73:1516–1528.

Rivera-Méndez, C., A. Plascencia, N. Torrentera, and R. A. Zinn. 2016. Effect of level and source of supplemental tannin on growth performance of steers during the late finishing phase. J. Appl. Anim. Res. DOI. 10.1080/09712119.2016.1141776.

Tiemann, T. T., C. E. Lascano, H. R. Wettstein, A. C. Mayer, M. Kreuzer, and H. D. Hess. 2008. Effect of the tropical tannin-rich shrub legumes Calliandra calothyrsus and Flemingia macrophylla on methane emission and nitrogen and energy balance in growing lambs. Animal. 2:790–799.

US EPA. 2004. Air Quality Criteria for Particulate Matter (Final Report, Oct 2004). U.S. Environmental Protection Agency, Washington, DC.

Waghorn, G. C. 2008. Beneficial and detrimental effects of dietary condensed tannins for sustainable sheep and goat production – progress and challenges. Anim. Feed Sci. Technol. 147:116–139.

Waghorn, G. C., I. D. Shelton, W. C. McNabb. 1994. Effects of condensed tannins in Lotus pedunculatus on its nutritive value for sheep. 1. Non-nitrogenous aspects. J. Agric. Sci. 123:99–107.

Webb, J. 2001. Estimating the potential for ammonia emissions from livestock excreta and manures. Environ. Pollution. 111:395-1406.

Table 2.1. Diet composition

Ingredient	% of DM
Grass hay	24.67
Steam-flaked corn	49.90
Molasses	9.13
Cottonseed meal	4.96
Wet distillers grains	8.51
Supplement[1]	2.84
Nutrient composition, % of DM	
Crude protein	15.6
Total digestible nutrients	71.5
Acid detergent fiber	21.4

[1] Supplement contained (DM basis): 53.52% limestone, 16.67% urea, 13.33% potassium chloride, 8.33% sodium chloride, 1.19% magnesium oxide, 1.00% mineral oil (for dust control), 0.003% cobalt carbonate, 0.26% copper sulfate, 0.004% ethylenediaminedihydroiodine, 0.43% manganese oxide, 1.48% zinc sulfate, 0.40% vitamin A (30,000 IU/g), 2.72% vitamin E (44 IU/g), 0.25% selenium premix (0.4% Se), and 0.417% Rumensin 90 (Elanco Animal Health, Indianapolis, IN).

Table 2.2. Effect of Quebracho extract supplementation on intake and digestion of beef steers

	Quebracho extract inclusion, % of DM				
Item	0	1	2	SEM	*P*-value
No. of observations	6	6	5		
DM intake, kg/d	7.99	8.13	7.25	0.865	0.64
Apparent total tract DM digestion, %	67.8	67.0	66.6	1.31	0.60
Digestible DM intake, kg/d	5.40	5.51	4.92	0.567	0.58
OM, kg/d					
Intake	7.40	7.49	6.66	0.52	0.55
Fecal	2.24	2.36	2.16	0.28	0.77
NDF, kg/d					
Intake	5.88	5.94	5.29	0.64	0.58
Fecal	1.41	1.39	1.30	0.18	0.82

[a,b] Means within a row without a common superscript differ ($P < 0.05$)

Table 2.3. Effect of Quebracho extract supplementation on nitrogen balance of beef steers

	Quebracho extract inclusion, % of DM				
Item	0	1	2	SEM	*P*-value
No. of observations	6	6	5		
Nitrogen, g/d					
Intake	199.3	203.1	181.0	21.45	0.58
Fecal	41.0[a]	56.0[ab]	69.4[b]	9.21	0.04
Urinary	69.3	54.4	59.0	10.82	0.36
Urea	58.2	42.3	49.0	9.16	0.23
Ammonium	0.94	0.70	0.55	0.303	0.46
Retained	89.0[a]	92.7[a]	52.6[b]	12.75	0.03
Fractional Nitrogen excretion					
Urine/Total[1]	0.64[a]	0.49[b]	0.46[b]	0.057	0.03
Fecal/Total[1]	0.36[a]	0.51[b]	0.54[b]	0.057	0.03

[a,b] Means within a row without a common superscript differ ($P < 0.05$)
[1]Sum of urine and fecal N excretion