INFLUENCE OF LEVEL AND TYPE OF GRAIN SUPPLEMENTATION ON INTAKE AND UTILIZATION OF EARLY-SUMMER, BLUESTEM-RANGE FORAGE BY BEEF STEERS

by

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INTRODUCTION

Grazing ruminants often respond to supplemental energy in a positive manner because pastures are frequently deficient in energy with respect to the animals' requirements for maximum production. Historically, however, responses to energy supplementation have been variable and difficult to predict. There are two main reasons for this variation. Firstly, the term "energy supplement" is a loosely defined term, typically referring to any grain-based supplement. This allows for considerable variation in chemical makeup of "energy" supplements. Secondly, dietary supplements exert effects on many nutritional and physiological aspects that will influence the animal's response. The responses to supplementation are not always additive with respect to the nutrient composition of the basal diet and the supplements. Therefore, in order to design supplementation schemes to increase performance of grazing ruminants, it is necessary to study the ways in which supplements interact with other dietary components and physiological processes.

REVIEW OF LITERATURE

Response of grazing ruminants to energy supplementation

Animal performance

Reported responses in animal performance typify the variability resulting from energy supplementation and clarify the need for a more basic understanding of energy supplement use by the grazing ruminant. Dodsworth and Ball (1962) obtained increases in live weight gains in 6-9 month old steers with grain supplementation while 20 month old steers failed to respond similarly. In a three-year study involving supplementation on fertilized and unfertilized pasture, Karn and Lorenz (1983) found no effects the first year, improvements in gain only on fertilized pastures the second year and improvements only on the unfertilized pastures in the third year. Speth et al. (1962) were able to reduce winter weight losses of cows and to increase percentage of calves weaned and calf weaning weights by supplying cows with .45 kg of barley over the winter whereas Bellows and Thomas (1976), as well as Kartchner (1980), failed to influence cow performance with higher levels of barley-based supplements. Even when performance responses have been positive, grain supplements have often failed to boost performance to anticipated levels (McClymont, 1956; Raleigh, 1970). This has typically been attributed to depressions in forage intake and digestibility as discussed in following sections.

In addition to other sources of variability, at least two separate studies (Lonsdale et al., 1971; Tayler and Wilkinson, 1972) have demonstrated that full body weight gains can give a biased assessment of weight gain responses to supplementation in cattle. Lonsdale et al. (1971) found no effects of high levels of barley supplementation on live weight gains of steers. However, weight of gut contents differed at slaughter so that carcass weight gains were higher with, than without barley.

With production systems in the United States, energy supplementation on pasture perhaps has the largest consequences for stocker cattle systems. Indeed, several studies have analyzed the impact of energy supplementation on stocker performance both on pasture and in the subsequent drylot or feedlot phase. Energy supplementation has shown consistent improvement of gains on pasture with the most efficient gains typically resulting from the lowest levels of supplementation (Lake et al., 1974; Denham, 1977). While some researchers have shown slight depression of subsequent feedlot gains with grain supplementation (Perry et al., 1971, 1972; Denham, 1977), Coleman et al. (1976) demonstrated that when animals are placed in drylot at a common weight instead of after a certain number of days on pasture, the differences in drylot-period gains disappear. Additionally, Coleman et al. (1976) reported higher dressing percentages after the feedlot phase with steers that consumed supplemental grain on pasture as compared to unsupplemented steers. These differences existed even though animal weights were

similar among treatments at the time of slaughter.

The performance response by grazing ruminants to energy supplementation may depend on the factors limiting energy intake. With forage-based diets, intake is generally limited by ruminal fill (Blaxter et al., 1961; Campling and Balch, 1961; Conrad et al., 1964) allowing improvements in gain when grain supplements are provided (Forbes et al., 1966, 1967; Raleigh, 1970). Additionally, when intake is limited by forage availability, energy supplements can be beneficial to weight gain (Musangi et al., 1965). However, with poor quality roughages, low crude protein (CP) concentration can reduce forage intake (Elliot 1967a, Egan, 1970). Energy supplementation under these circumstances can depress weight gains (Clanton and Zimmerman, 1970).

Forage Intake

In general, energy supplementation has been associated with depressed forage intake (Allison, 1985; Horn and McCollum, 1987; Lusby and Wagner, 1987) and many factors have been shown to influence substitution ratios (units change in forage intake per unit change in concentrate intake).

Forage factors. A large amount of literature indicates that substitution ratios are greater with high quality than with low quality roughages (Blaxter et al., 1961; Blaxter and Wilson, 1963; Montgomery and Baumgardt, 1965b; Campling and Murdoch, 1966; Golding et al., 1976; Lamb and Eadie, 1979; Jarrige et al., 1986). In general, low quality roughages are characterized by low crude protein

concentrations and poor dry matter digestibilities (DMD) and many researchers have demonstrated that energy supplementation of such diets has little influence on forage intake when compared with nonsupplemented diets (Blaxter and Wilson, 1963; Cook and Harris, 1968; Lamb and Eadie, 1979; Kartchner, 1980; DelCurto et al., 1989). In these studies, basal forage intake was probably limited by low CP:digestible energy ratio (Egan, 1970). Although intakes would probably respond favorably to CP supplementation under these conditions, the ratio of CP:digestible energy in the grain supplements was apparently high enough to prevent further depressions in forage intake. With high quality forages it is possible that the energy requirements of the animal are met and metabolic control of intake becomes important. Indeed, some workers have demonstrated metabolic control of intake with forage-based diets (Conrad et al., 1964; Bines and Davey, 1970; Dinius and Baumgardt, 1970). However, factors other than the chemical composition of the forage may be important in determining the effects of supplements on intake. Forage processing is one such factor. Montgomery and Baumgardt (1965b) were able to convert a negative substitution ratio by corn on oat straw to a positive effect by grinding the straw. Similarly, Mould et al. (1983a) found a larger depression in forage intake when long hay was supplemented with barley than when the hay was ground and pelleted. Additionally, in the grazing situation, forage availability can influence substitution ratios. Newton and Young (1974) found greater substitution when forage was plentiful than when it was scarce.

Supplement factors. The starch and crude protein concentrations of the supplement can have a major influence on the substitution ratio. Typically, supplements high in crude protein do not depress forage intake (Cook and Harris, 1968; Rittenhouse et al., 1970; Kartchner, 1980; DelCurto et al., 1989) whereas supplements high in starch either have no effect (Lonsdale et al., 1971; DelCurto et al., 1989) or tend to substitute for forage intake (Forbes et al., 1966; Rittenhouse et al., 1970; Jones et al., 1988). Meijs (1986) reduced the substitution effect of supplement for forage from .45 kg forage organic matter (OM) per kg supplement OM to .21 by feeding a high-fiber, beetpulp-based concentrate as opposed to a high-starch, corn-based supplement. In addition to the supplement composition, processing methods can alter the substitution effects of energy supplements. Whole barley depressed grass intake by .35 kg forage dry matter (DM) per kg supplement DM while pelleted barley had a substitution ratio of .53 in a study by Ørskov and Fraser (1975). Also, it has been demonstrated that the substitution ratio of a given concentrate for a given forage increases with increasing level of concentrate supplement (Jarrige et al., 1986).

Animal factors. The threshold level at which metabolic intake regulation dominates over physical intake regulation (eg., ruminoreticular fill) depends on the metabolic requirements of the animal. Animals with high metabolic requirements should accommodate a higher level of energy intake than those with comparatively low requirements. This results in higher substitution ratios in animals with lower

metabolic requirements (Conrad et al., 1964; Dinius and Baumgardt, 1970; Ellis, 1978). Supplementation can also influence intake by altering the behavior of the grazing ruminant. Forbes et al. (1967) implied that forage intake was depressed to a greater extent with supplementation in a grazing situation than in confinement. Adams (1985) was able to minimize disruption of grazing patterns by offering grain supplements in the afternoon as opposed to morning and thereby increase the forage intake of grazing steers. Limited research has also demonstrated the ability of supplements to increase the crude protein and in vitro dry matter disappearance of diet samples collected from esophageal fistulas in sheep (Jung and Koong, 1985). These effects could, in turn, alter forage intake.

Digestibility

For at least 40 years, researchers have realized that energy supplementation of forage-based diets can depress fiber digestibility (Swift et al., 1947). Since this time, many factors have been found that are involved in this depression.

Forage factors. Mould et al. (1983b) determined that in situ forage digestibility influenced the magnitude of the depression in DMD observed with grain supplementation. Specifically, they found greater supplement-induced DMD depressions with lower quality forages. However, Lamb and Eadie (1979) demonstrated that crude protein concentration and basal forage organic matter digestibility (OMD) alone are insufficient to predict the influence of grain on digestibility. In their study, grain supplementation increased acid detergent fiber

(ADF) digestibility of timothy hay (4.7% CP, 47.3% OMD) while other forages of both lower (3.5% CP, 43.8% OMD) and higher (6.2% CP, 52% OMD) quality had depressed ADF digestibilities with grain supplementation. In addition to forage quality, forage processing can influence effects of grain supplements. Montgomery and Baumgardt (1965b) depressed cellulose digestibility of pelleted hay and found no significant effect on long hay with addition of corn at 50% of the diet DM. Similarly, barley supplementation depressed ADF digestibility more when animals were fed pelleted hay compared with long hay (Mould et al., 1983a).

Supplement factors. In general, increasing the level of grain supplementation yields progressively larger depressions in fiber digestibility (Montgomery and Baumgardt, 1965a; Forbes et al., 1966; Lamb and Eadie, 1979). Also, both Ørskov and Fraser (1975) and Mould et al. (1983b) demonstrated that processing methods which increase the rate of solubilization of the supplement can lead to larger depressions in fiber digestibility.

Proposed mechanisms. Various theories have been proposed to explain the mechanisms by which grain supplements depress forage digestibility. The most common theories involve pH depressions. Cellulase isolated from Ruminococcus albus has been shown to be active over a pH range of 6.0 to 6.8 (Smith et al., 1973) and Terry et al. (1969) showed that in vitro cellulose digestion was dependant on pH. Similarly, supplement-induced depressions of in situ cotton thread disappearance associated with a pH depression from 6.5 to 6.0 were alleviated when

pH was restored with sodium bicarbonate (Osbourn et al., 1970). Mould and Ørskov (1983) found that in situ cellulolytic activity was partially inhibited when pH dropped from 6.6 to 6.2 as a result of infusion of a mineral acid mixture. However, pH depressions below 6.0 resulted in rapid inhibition of cellulolysis. These researchers noted that energy supplementation of forage diets causes diurnal patterns in pH depression, unlike the maintained pH depression in these studies. Therefore, the ability of these data to explain in vivo responses with supplementation is limited. In the in vivo situation, small ruminal pH shifts have been used to explain increased fiber digestibility when "high-fiber" energy supplements are fed as opposed to grain supplements (McCullough, 1968; Anderson et al., 1988).

Factors other than depressed pH also may be instrumental in depressing ruminal forage digestion with energy supplementation. Although Mould et al. (1983b) related some in vivo digestibility depressions to decreased ruminal pH, they concluded that at least a portion of the depression was due to other factors. These workers suggested that the presence of soluble carbohydrate could depress forage digestion. Indeed, work by Smith et al. (1973) has shown that the presence of cellobiose and glucose inhibited cellulase activity in Ruminococcus albus. Similarly, Henning et al. (1980) found a decrease in cellulose and hemicellulose digestibility that was unrelated to ruminal pH and suggested that starch or its fermentation products may inhibit cellulase and hemicellulase synthesis and/or activity. In

addition to directly depressing enzyme activity through feedback inhibition or similar mechanisms, soluble carbohydrates can provide alternative energy sources for some cellulolytic bacteria (Bryant, 1973). These effects may help explain increases in the lag time associated with fiber digestion both in vitro (Mertens and Loften, 1980) and in situ (Miller and Muntifering, 1984). However, Miller and Muntifering (1984) concluded that depressions in fiber digestion with grain supplementation are primarily mediated through decreased potential extent of digestion rather than through increased lag times. Another popular theory for grain-induced depression of fiber digestion involves competition between ruminal microorganisms for available nutrients. In particular, low ruminal ammonia concentrations are believed to inhibit forage digestibility in some instances since ammonia is the main source of nitrogen for many cellulolytic bacteria (Bryant, 1973). In vitro studies by el-Shazly et al. (1961) indicated that inhibition by end products of starch fermentation was not a major factor in depressing cellulose digestion but that depressions were most likely due to a lack of available nitrogen. Also, supplementation can alter the efficiency of utilization of digested forage by shifting the site of cellulose digestion post-ruminally (Macrae and Armstrong, 1969).

Ruminal fill and passage rates

In addition to digestion rate, intake is dependant upon ruminal fill and rate of passage of indigestible material from the rumen. Several workers have demonstrated decreasing particulate passage rates with grain supplementation of

forage diets (Eng et al., 1964; Campling, 1966; Chase and Hibberd, 1987; Hart, 1987) which could permit supplementation to depress intake without affecting digestibility. Limited information is available on the effects of grain supplements on ruminal liquid dilution rates. DelCurto et al. (1989) found increased liquid dilution rates with supplementation of a low quality forage while Jones et al. (1988) reported no influence of supplementation on liquid dilution rate with moderate quality forages. Additionally, no relationship was found between liquid dilution rates and particulate passage rates in this study.

The effects of grain supplementation on ruminal fill appear to be modified by various factors. The first of these factors is the forage:concentrate ratio. Bines and Davey (1970) depressed ruminal fill of dry matter and liquid when an 18% CP concentrate was added to a barley straw diet to result in forage:concentrate ratios from 60:40 to 0:100. However, DelCurto et al., (1989) demonstrated the ability of a 12% CP supplement to increase ruminal fill of dry matter, indigestible fiber and liquid when added to a 3% CP forage diet. Forage to concentrate ratio in this case was 67:33. Additionally, forage quality appears to modify the influence of supplementation on ruminal fill. Montgomery and Baumgardt (1965b) reported depressed total gastrointestinal tract fills with corn supplementation of 16-18% CP hays whereas supplementation increased fill when animals were consuming 4% CP straw diets. Finally, restricting forage intake can influence ruminal fill changes seen with supplementation. Supplementation of cattle with restricted hay intakes

increased ruminal dry matter fill and did not affect ruminal liquid fill whereas similar levels of supplements fed to cattle consuming hay ad libitum depressed liquid fill with no effect on dry matter fill in a study by Campling (1966).

Ruminal fermentation characteristics

In addition to depressing ruminal pH as discussed earlier, grain supplementation can alter other ruminal fermentation characteristics. Both Lamb and Eadie (1979) and DelCurto et al. (1989) reported increased total VFA concentrations with grain supplementation to forages containing 9% and 3% CP, respectively. However, Montgomery and Baumgardt (1965a,b) found no effects on total VFA concentrations in the rumen when higher quality forages (>15% CP) were supplemented with corn. In the latter study, total VFA concentrations were increased when corn was added to a 4% CP straw diet. In studies reporting increased VFA concentration with supplementation, the increases in total VFA were associated with unchanged propionate proportions. In contrast, increases in molar percent propionate occurred in the studies in which total VFA concentrations were unaffected. More consistent effects have been noted for responses of the other major VFA to grain supplementation. Molar proportions of acetate generally decrease while butyrate proportions increase with grain supplementation (Montgomery and Baumgardt, 1965a,b; Lamb and Eadie, 1979; DelCurto et al., 1989). Additionally, grain supplementation consistently fails to alter ruminal NH_3 concentrations (Lamb and Eadie, 1979; Guthrie and Wagner, 1988; DelCurto et al., 1989).

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EXPERIMENTAL

Introduction

With the advent of intensive-early stocking in the tallgrass prairie (Smith and Owensby, 1978), livestock producers have realized increased beef production from available land area. Stocker gains from .72 to 1.2 $kg \cdot hd^{-1} \cdot d^{-1}$ have been reported on early-growing-season pasture (Owensby et al., 1988) and potential may exist for increasing gains with low levels of grain supplementation (Launchbaugh et al., 1983). Additionally, grain supplements can serve as carriers for various feed additives. However, in some circumstances, grain supplementation has been reported to diminish forage intake and(or) utilization (Horn and McCollum, 1987). The many interrelated mechanisms for these effects make it difficult to predict the grain levels that would interfere with intake and(or) utilization of early-growing-season, bluestem range. Additionally, differences among grain types could elicit variable effects on forage utilization (Mould et al., 1983). Therefore, the objectives of this study were to determine the influence of supplemental sorghum grain levels and the effect of different grains in supplemental mixes on intake, digestibility, solid and liquid dynamics and fermentation patterns in steers consuming early-growing-season, bluestem range.

Experimental Procedure

Exp. 1. In June 1986, a two-part study was initiated to determine the influence of various levels of sorghum grain supplementation on utilization of early-

growing-season, bluestem range. The study pastures were located in the Flint Hills region of the tallgrass prairie, approximately 5 miles northwest of Manhattan, KS. Principal vegetative species in the pastures were big bluestem (Andropogon gerardii), little bluestem (Andropogon scoparius) and Indiangrass (Sorghastrum nutans). In the first part of this experiment, 12 esophageally cannulated Hereford x Angus yearling steers (avg initial wt 225 kg; SE = 8 kg) were divided into 3 weight blocks and randomly assigned to one of four treatments: 1) non-supplemented control, 2) .45 kg sorghum grain·hd^{-1}·d^{-1}, 3) .91 kg sorghum grain·hd^{-1}·d^{-1} and 4) 1.82 kg sorghum grain·hd^{-1}·d^{-1} (as-fed; 0, .17, .32 and .66% of BW, respectively). Steers were fed supplements at 0800 daily. After a 10 d adaptation period, esophageal samples were collected for two 30-min periods each day (0900 and 2000) for 3 d (July 1 - 3). All animals were maintained on a 2 ha pasture. During each collection period, the animals were gathered, fitted with collection bags and returned to this pasture to graze. The steers were not held off of feed or water prior to collections. Representative esophageal samples from each animal were dried at 50°C in a forced air oven for 48 h. The dry samples then were ground to pass a 1-mm screen with a Cyclotec[1] sample mill, composited for each animal and stored in sealed plastic bags prior to analyses.

In the second part of this experiment, 16 ruminally cannulated Hereford x Angus yearling steers (avg wt 272 kg; SE = 6 kg) were divided into 4 weight blocks

[1]Tecator, Inc. Herndon, VA.

and randomly assigned to each of the four treatments described above. Steers were housed in individual pens (2 m x 6 m) in a partially enclosed barn. Supplements were fed at 1130 daily, and grab samples of the supplement were taken at this time. Early-growing-season, bluestem-range forage was swathed daily from the study pastures with a stubble height of approximately 15 cm. This forage was coarsely chopped (7-10 cm) to minimize waste at the feed bunk. Chopped forage was immediately sampled for DM determination and fed at 1330, within 2 h of harvesting. Forage was fed to each steer at 115% of the steer's previous 7-d average intake. Refused forage was weighed and sampled each day immediately before supplementation. Beginning on June 11, steers were adapted to diets for 14 d. Voluntary DMI measurements were made over the subsequent 7-d period. During the following 7-d period, in addition to measuring intake, steers were fitted with fecal collection bags, and total fecal output was weighed and sampled (5% of each steer's fecal output) daily.

On d 28 of the trial, at 0930, each steer was pulse-dosed intraruminally with 2.5 g of Co:EDTA (Uden et al., 1980) in 250 ml of distilled water to determine liquid dilution rates. The marker was dispersed throughout the rumen to facilitate uniform distribution. Ruminal fluid samples were drawn by suction-strainer (19 mm diameter; 1.5 mm mesh) from three areas in the ventral rumen just before dosing and at 3, 5, 7, 9, 12 and 24 h postdosing. These samples then were frozen until analyses. On day 29, following the 24-h fluid sampling, ruminal contents from each

steer were manually removed, weighed, sampled in triplicate and returned.

Forage, supplement, ort, fecal and ruminal digesta samples were dried at 50°C in a forced-air oven and ground to pass a 1-mm screen with a Cyclotec sample mill. Fecal, ruminal and orts samples were composited for each steer, whereas forage and supplement samples were each composited into a single sample.

Exp. 2. From June 11 to July 9, 1987, 16 two-year-old, ruminally cannulated steers (avg wt 360 kg; SE = 10 kg) were divided into 4 weight blocks and randomly assigned to one of four treatments: 1) non-supplemented control, 2) corn supplement, 3) wheat supplement or 4) sorghum grain supplement. The corn and wheat supplements were coarsely cracked, whereas the sorghum grain was finely rolled. Supplements were fed daily at .37% (as-fed; avg = 1.26 kg) of BW. The corn and sorghum grain contained 16.4 and 13.4% soybean meal (as-fed basis), respectively, to make them isonitrogenous with the wheat supplement. The animals were housed in individual feeding pens (2 m x 6 m) in a partially enclosed barn for the duration of the trial. Bluestem-range forage was harvested and fed daily as described for Exp. 1. Trace-mineralized salt blocks[2] were provided on a free-choice basis for the duration of the trial. Supplemental grain was fed at 1230 daily, and the forage was offered at 1430 daily. Orts were removed and weighed before supplementation each day.

[2]Trace-mineralized salt contained not less than .2% Mn, .1% Fe, .1% Mg, .05% S, .025% Cu, .01% Co, .008% Zn and .007% I.

The steers were adapted to diets for 14 d, followed by a 7-d voluntary intake measurement and a 7-d intake and total fecal collection period. Rumens were evacuated at 1100 on the last day of the trial and sampled as in Exp. 1.

Forage, supplement, ort, fecal and ruminal digesta samples were collected and processed as described for Exp. 1. A zero-hour ruminal fluid sample was collected at 1200 on d 28, followed by administration of a pulse dose of .92 g Cr (prepared as Cr:EDTA according to Binnerts et al., 1968) in 350 ml distilled water. Subsequent samples of ruminal fluid were drawn at 1, 3, 6, 9, 12 and 23 h postdosing. The dosing and sampling techniques for the liquid marker were the same as described for the first experiment. Supplements and forage were fed at .5 and 2.5 h postdosing, respectively.

Laboratory procedures. Forage, supplement, ort, fecal and ruminal digesta samples were dried in a convection oven at 100°C to determine DM concentration. Organic matter concentrations were determined by ashing in a muffle furnace at 500°C for 8 h. Chemical components from esophageal collections were expressed on an OM basis. Crude protein was determined as Kjeldahl N (AOAC, 1980) x 6.25. Neutral detergent fiber (NDF), ADF, and ADL were determined by the procedures of Robertson and Van Soest (1981). The ash insoluble in detergent solution was subtracted from the NDF and ADF values (ash-free NDF and ash-free ADF, respectively) for the esophageal samples. Acid detergent insoluble nitrogen (ADIN) was isolated from the forage with Kjeldahl N analysis of the ADF

residue. Forage, supplement and ruminal digesta samples were analyzed for indigestible ADF (IADF; Cochran et al., 1986) with plastic, 100 ml centrifuge tubes fitted with bunsen valves used in place of glass screw-capped tubes. Starch concentration in forage, supplement, orts and feces was determined by enzymatic cleavage of starch into glucose units (MacRae and Armstrong, 1968). Quantification of the glucose units was accomplished using the automated procedure of Gochman and Schmitz (1972). Gross energy was measured in the forage, supplement, ort and fecal samples from Exp. 1 by oxygen bomb calorimetry (Kleiber, 1975).

Nutrient intakes (DM, GE, NDF and starch) were determined by subtracting the nutrient contained in the orts from that in the forage and supplement offered during the fecal collection period. These values and the values for fecal output of the various nutrients were used to calculate digestibility. Ruminal passage rates of IADF were determined by dividing the daily IADF intake by the quantity of IADF in the rumen (Van Soest, 1982).

All ruminal fluid samples were analyzed immediately for pH at the time of sampling using a portable pH meter[3] and then were divided into three aliquots for subsequent analyses. Four milliliters of each sample were frozen for Co analysis and another 4 ml were added to 1 ml of 25% metaphosphoric acid and frozen prior to VFA analysis. Finally, 1 ml was added to 4 ml .1 N HCl and frozen for NH_3-

[3]Orion Research Inc., Boston, MA.

N analysis. After thawing, ruminal fluid samples were centrifuged at 39,000 x g for 20 min prior to the various analyses. Ammonia N concentrations were determined on an autoanalyzer using the hypochlorite method[4]. Ruminal VFA were measured on a gas chromatograph as described by Jacques et al. (1987). Cobalt and Cr concentrations were determined by atomic absorption spectrophotometry, and these values were used to determine liquid dilution rate (Warner and Stacy, 1968).

Statistical analysis. All dependent variables were analyzed by ANOVA using the GLM program of SAS (1985). Diet quality, intake, digestibility and ruminal fill and passage data were analyzed as randomized complete block designs. The model statement included terms for treatment and block. In Exp. 1, treatment sums of squares were partitioned into linear, quadratic, and cubic effects of sorghum grain level with orthogonal polynomials. In Exp. 2, means were separated by Fisher's Protected Least Significant Difference ($P<.10$). Ruminal pH, molar percentages of VFA, the acetate:propionate ratio and NH_3-N concentrations were analyzed as a split-plot design (Steel and Torrie, 1980). The whole plot sources of variation, treatment and weight block, were tested using the treatment by block interaction as the specified error term. The subplot effects, time and time by treatment interaction, were tested using the residual sum of squares. When no significant time by treatment interaction occurred, data were pooled across time.

[4]Technicon Corp., Tarrytown, NY.

Results

Exp. 1. Supplementation did not affect (P>.10) the concentration of CP in samples collected from esophageally cannulated animals (Table 1). However, the esophageal samples had higher CP values than the harvested forage fed in the digestion trial (6.6% of OM). The concentration of ash-free NDF in the OM exhibited a cubic (P<.05) response and a trend toward a quadratic response was noted for ash-free ADF (P = .16) and ADL (P = .18). However, actual differences in fibrous constituents among treatments were relatively minor.

Chemical composition of the diets fed in confinement is given in Table 2. Acid detergent insoluble nitrogen was equivalent to 21% of the total N in the forage fed in this experiment (not corrected for orts).

Supplementation had no effect (P>.10) on forage DM intake (Table 3). However, total DM intake increased linearly (P<.01) with increasing grain level. Digestible energy intake reached 320 kcal/kg $BW^{.75}$ at the highest level of supplementation. Although total tract apparent DM digestibility showed a cubic response (P<.05) to increasing grain level, the magnitude of the differences in digestibility among treatments was minimal, no greater than 2.6%. Neutral detergent fiber digestion was unaffected (P>.10) by increasing level of sorghum grain. Starch digestibility was depressed in a linear fashion (P<.01) with increasing grain level. Comparisons of starch digestibility between supplemented and nonsupplemented groups are of little value, given the limited quantity of starch in

the forage consumed by the nonsupplemented steers. The total amount of starch digested increased linearly ($P<.01$) with increasing grain level.

No differences ($P>.10$) were noted for ruminal DM fill or IADF fill measured just before feeding (Table 4). Passage of IADF from the rumen was not altered ($P>.10$) with supplementation. Ruminal liquid fill responded to increasing grain supplementation in a quadratic manner ($P<.10$). The values for all supplemented treatments were very similar, but the liquid fill of the control group surpassed all supplemented treatments. The liquid dilution rate tended ($P = .17$) to increase with increasing level of supplementation, whereas liquid flow rate was unaffected ($P>.10$).

Ruminal pH was depressed in a linear fashion ($P<.10$) with increasing level of sorghum grain (Table 5). However, even at the highest level of grain supplementation, pH was maintained at 6.45. Total VFA concentration responded to increasing grain supplementation in a cubic ($P<.10$) manner. Although molar percentage of acetate was slightly depressed ($P<.01$) with increasing grain level, no effect ($P>.10$) was observed for the molar percentage of propionate or for the acetate:propionate ratio. Similarly, ruminal NH_3-N values and molar proportions of isobutyrate were unaffected ($P>.10$) by supplementation. Molar proportions of isovalerate exhibited a quadratic ($P<.01$) response to increasing grain level while molar proportions of butyrate and valerate showed sampling time by treatment interactions ($P<.10$; Table 6). Although patterns within each time period were

variable, the molar percentages of both of these VFA generally increased with increasing level of grain supplementation.

Experiment 2. Results from Exp. 2 were similar to results from Exp. 1. Concentration of ADIN in the forage (without correction for orts) was equivalent to 20% of the total forage N.

Intake of forage DM was not influenced (P>.10) by supplementation (Table 7). Therefore, supplementation tended (P = .16) to increase total DMI. Supplementation had no effect (P>.10) on total tract apparent digestibility of DM or NDF. Comparisons among supplementation treatments showed that steers fed wheat had higher (P<.01) starch digestibility than did those fed either corn or sorghum grain-based supplements. More grams of starch were digested per day with than without supplementation (P<.01).

Ruminoreticular fill of DM (2.34% BW), IADF (.65% BW) and liquid (155 ml/kg BW) measured just before feeding were not affected (P>.10) by supplementation. Similarly, supplementation failed to influence (P>.10) liquid dilution rate (8.38 %/h) or liquid flow rate (4.6 liters/h). Wheat-supplemented steers tended (P=.14) to have higher rates of ruminal IADF passage than did sorghum grain- or non-supplemented steers, while corn-supplemented steers had intermediate rates. Ruminal IADF passage rates were 2.14, 2.39, 2.73 and 2.18 %/h (SE = .25) for the non-supplemented, corn, wheat and sorghum grain groups, respectively.

Ruminal pH, VFA concentrations and acetate:propionate ratios were unaffected (P>.10) by any of the supplements (Table 8). Similarly, molar percentages of propionate and butyrate were not altered (P>.10) by treatment. However, the molar proportion of ruminal acetate was lower (P<.10) in both wheat- and sorghum grain-supplemented steers vs control steers. Molar proportions of isobutyrate responded to sorghum grain supplementation (P<.10) but not to corn or wheat supplementation (P>.10). Ruminal NH_3-N concentration and molar percentages of valerate and isovalerate exhibited sampling time by treatment interactions (P<.10; Table 9). Wheat supplementation resulted in higher (P<.10) ruminal NH_3-N than no supplementation or sorghum grain supplementation at 0, 1 and 3 h sampling times and higher (P<.10) levels than corn supplementation at 1 and 3 h. There were no treatment effects (P>.10) at the 6 and 9 h sampling times, but the corn-supplemented group reached higher values than the non-supplemented or sorghum grain-supplemented groups at 12 h (P<.05). No significant effects were noted for isovalerate proportions at any sampling time. However, for the 0h sampling time, molar proportions of isovalerate tended (P = .13) to be higher for the sorghum grain-supplemented group than for the wheat- or non-supplemented groups. All supplemented groups had higher valerate proportions than the control group at 0, 1 and 6 h post-dosing, whereas the wheat-supplemented group had higher proportions than any of the other treatments at 3 and 6 h post-dosing and higher proportions than the control group at 12 h.

Additionally, the valerate proportions with corn supplementation were higher than without supplementation at 3 h post-dosing.

Discussion

Diet Quality. Increasing levels of sorghum grain failed to produce consistent changes in diet selection in this study. This disagrees with Jung and Koong (1985), who demonstrated the potential of increasing concentrations of CP and decreasing the NDF content in grazed forage when increasing levels of mixed alfalfa hay/corn supplements were fed to sheep. However, the highest supplemental level in their experiments approached .9% BW.

Differences existed in the CP concentrations of esophageally collected and harvested forage, even though the samples were collected from similar pastures during the same time period. This could be attributed to the ability of the animal to select a diet higher in CP than the average of the existing forage (Bath et al., 1956; Jefferies and Rice, 1969) and possibly to N contamination of esophageal samples through the saliva (Blackstone et al., 1965; Langlands, 1966) although Hart (1983) indicated that salivary N contamination may be minimal.

The forages fed in confinement had very similar CP and ADL concentrations between the two experiments. However, the NDF concentration of the forage was somewhat higher in the second experiment than in the first. Differences in the NDF and ADL concentrations of the harvested and refused forage in both experiments indicate that the animals selected forage of lower NDF and ADL

concentrations than the average of the offered forage.

Intake. The supplementation schemes in these experiments did not result in depressed forage intake. Grain supplementation may depress forage intake by decreasing forage digestibility (Horn and McCollum, 1987) or by allowing animals to attain maximal DE intake (Baumgardt, 1970). Neither of these factors appeared to inhibit forage intake in these experiments. Therefore, DE intake increased with increasing grain level, indicating potential to improve animal gains with grain supplementation. Horn and McCollum (1987) concluded that concentrate supplementation up to 30 g/kg metabolic BW would be expected to exert only minimal influence on forage intake. In the present study, steers at the highest level of supplementation received only 25 g concentrate/kg metabolic BW. In addition, several researchers have demonstrated that low-level grain supplementation of poor to moderate quality forages does not depress forage intake when compared to non-supplemented treatments (Blaxter and Wilson, 1963; Cook and Harris, 1968; Lamb and Eadie, 1979; Kartchner, 1980; DelCurto et al., 1989).

Digestibility. Although DMD was depressed to a small degree with increasing supplementation in Exp. 1, NDF digestibility was not affected in either experiment. Ørskov and Fraser (1975) demonstrated that maintenance of high ruminal pH can diminish the negative effects of grain supplements on fiber digestion. In our experiments, ruminal pH was maintained at levels conducive to fiber digestion.

Responses of forage fiber digestibility to grain supplementation are varied. Diets composed of warm-season grasses have been reported to be affected differently by grain supplementation than diets containing cool-season grasses. Jones et al. (1988) demonstrated that supplemental corn grain had different effects on ruminal NDF digestibility for bermuda grass than for orchard grass diets. With warm-season grass diets, some workers have noticed substantial depressions in fiber digestibility (Chase and Hibberd, 1987; DelCurto et al., 1989), when forages with CP concentrations between 2.9 and 4.2% have been supplemented with grain-based supplements. Others have not found evidence of a grain-elicited depression of fiber digestion (Rittenhouse et al., 1970; Guthrie and Wagner, 1988) with forages of marginal quality (4.2 - 5.6% CP). These differences may be explained by higher total crude protein intakes in the latter two studies. However, a study by Kartchner (1980) supports the view that CP intake alone is insufficient for predicting digestibility responses to grain supplementation. In this study, 1.4 kg cracked barley failed to affect forage DMD in the first year, whereas feeding the same quantity of cracked barley significantly depressed forage DMD in the second year. The 6.3% depression in forage DMD occurred in spite of an apparent increase in CP in the range forage from year 1 (6.0%) to year 2 (8.1%). Forage DMD in the nonsupplemented steers in his study was 54.9 and 40.6% for years 1 and 2, respectively. That study indicates that other factors, such as basal forage digestion, also should be considered when attempting to predict the effects of grain

supplements on forage digestibility. The lack of depression of NDF digestibility in the present experiments may have been influenced by the relatively high NDF digestibility of the basal forage.

The mild depression of DMD at the two highest grain levels in Exp. 1 is the result of lower digestibility of the non-starch component of the DM. In spite of the depression in starch digestibility, the increasing addition of starch to the diet had a positive impact on total DMD which helped to buffer depressions in DMD from the non-starch DM. Joanning et al. (1981) showed similar depressions in starch digestion as grain content increased in corn silage-based diets. However, negative associative effects were not evident in their study until the diet reached relatively high grain levels. The elevated starch digestibility observed for the wheat-supplemented treatment in Exp. 2 concurs with findings that wheat exhibits higher ruminal and total tract digestion than sorghum grain in high concentrate diets (Axe et al., 1987).

Ruminal Fill and Passage. Grain supplementation had no effect on exit of IADF from the rumen. Because ruminal evacuations were conducted approximately 23 h after supplementation, a substantial portion of the grain should have disappeared from the rumen. Mertens and Loften (1980) reported that the rate of fiber digestion in vitro was not affected by starch addition. If rate of fiber digestion was not affected by grain supplementation in these experiments, fill values should have been relatively similar just before feeding, given the lack of treatment effect

on forage intake. This is particularly true because fill values were expressed on an IADF basis, and the grain portion would constitute only a minor portion of the IADF. Such observations also are helpful in understanding the lack of influence of treatments on passage rates.

Fermentation Characteristics. In Exp. 2, ruminal NH_3-N concentrations were substantially below the 1.2 to 2.9 mM recommended by Satter and Slyter (1974) to maximize protein synthesis by ruminal microbial cells. However, the ruminal NH_3-N values in this study are similar to those reported (<1 mM) by Guthrie and Wagner (1988) who fed a basal diet of prairie hay that was similar in species and chemical composition to the forage fed in these experiments. These observations suggest that the provision of more typical "protein" supplements might have benefited microbial fermentation of the forage in our experiments. The relatively high ruminal NH_3-N of the wheat treatment at early sampling times may reflect the relative ruminal degradation potentials of the different grains. Oltjen et al. (1966) reported higher ruminal NH_3-N in steers fed all-concentrate wheat diets compared to corn diets.

The total VFA concentrations of the control diets for both experiments are intermediate between those reported by McCollum and Galyean (1985) and Chase and Hibberd (1987) for similar warm-season grass diets. The digestible energy intakes offer a partial explanation for the pattern in total VFA concentrations in Exp. 1, although the depression for the .91 kg supplementation level remains

unexplained. The slight depression in the molar proportion of acetate with wheat supplementation in Exp. 2 is supported by the observations of Oltjen et al. (1967) who reported acetate percentages of 55.5, 50.5 and 56.5% for all-concentrate corn, wheat and milo diets, respectively.

Implications

Supplementation of early-growing-season, bluestem-range forage with up to 1.82 kg rolled sorghum grain had no effect on forage intake and only a mild influence on most forage utilization characteristics studied. Similarly, forage intake and utilization were not appreciably disrupted by supplementation with either corn, wheat or sorghum grain-based supplements fed at .35% BW. In light of these results, a reasonable potential exists for grain supplements at these levels to enhance gain responses in cattle grazing tallgrass prairie pastures in the spring and early summer.

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TABLE 1. INFLUENCE OF INCREASING LEVEL OF SORGHUM GRAIN (SG) SUPPLEMENTATION ON QUALITY OF DIET SELECTED BY GRAZING BEEF STEERS

	SG kg · hd^{-1} · d^{-1}					Contrasts[a]		
Item	0	.45	.91	1.82	SE[b]	L	Q	C
OM, %	91.1	91.2	91.0	91.0	.1	.54	.95	.16
% of OM								
CP	11.9	11.9	11.9	11.8	.7	.87	.96	.93
Ash-free NDF	79.9	82.9	79.4	81.5	1.5	.72	.99	.04
Ash-free ADF	44.7	45.5	46.9	45.9	1.0	.28	.16	.52
ADL	8.2	9.0	8.8	8.5	.5	.80	.18	.39

[a]Probability of observing a greater F value: L=linear response, Q=quadratic response, C=cubic response.

[b]n=3.

TABLE 2. CHEMICAL COMPOSITION OF DIETS CONSUMED BY STEERS

		% of DM				
Experiment 1	DM	OM	CP	NDF	ADL	STARCH
Harvested Forage	37.2	92.9	6.1	62.7	6.5	2.6
Refused Forage	42.9	92.2	6.1	66.7	7.0	3.2
Sorghum grain supplement	92.9	98.3	9.2	9.5	.8	64.8
Experiment 2						
Harvested forage	39.9	92.4	5.8	73.7	5.7	2.1
Refused forage	43.9	91.1	5.6	75.4	6.6	1.5
Corn supplement[a]	92.8	93.8	15.1	12.2	.4	72.8
Wheat	93.9	97.3	14.4	19.9	1.4	73.8
Sorghum grain supplement[a]	93.3	97.4	14.2	10.9	1.4	76.5

[a]Corn and sorghum grain supplements contained 16.4 and 13.4% soybean meal (as-fed), respectively.

TABLE 3. INFLUENCE OF INCREASING LEVEL OF SORGHUM GRAIN (SG) SUPPLEMENTATION ON VOLUNTARY DM INTAKE AND APPARENT DIGESTIBILITY BY BEEF STEERS (EXP. 1)

	SG kg·hd^{-1}·d^{-1}					Contrasts[a]		
Item	0	.45	.91	1.82	SE[b]	L	Q	C
Steer weight, kg	267	271	281	274	6			
Intake:								
Forage DM, % BW	2.12	2.21	2.16	2.23	.14	.49	.93	.56
Total DM, % BW	2.12	2.36	2.47	2.85	.14	.01	.93	.61
Digestible Energy, kcal/kg BW$^{.75}$	240	273	271	320	17	.01	.90	.24
Digestibility:								
DM, %	55.3	55.8	53.2	53.5	.9	.02	.46	.04
NDF, %	48.8	48.6	46.4	47.0	1.7	.26	.48	.40
Starch, %	86.7	86.3	82.4	77.6	2.0	.01	.59	.37
Starch, g/d	119	339	559	923	30	.01	.18	.72

[a]Probability of observing a greater F value: L=linear response, Q=quadratic response, C=cubic response.

[b]n=4.

TABLE 4. INFLUENCE OF INCREASING LEVEL OF SORGHUM GRAIN (SG) SUPPLEMENTATION ON RUMINAL FILL AND PASSAGE RATES IN BEEF STEERS (EXP. 1)

	SG kg · hd^{-1} · d^{-1}					Contrasts[a]		
Item	0	.45	.91	1.82	SE[b]	L	Q	C
Ruminal DM fill, %BW[c]	1.99	1.62	1.92	2.08	.26	.42	.31	.23
Ruminal IADF[d] fill, % BW[c]	.62	.54	.64	.69	.09	.27	.57	.38
Ruminal IADF passage, %/h	2.4	2.6	2.4	2.4	.4	.81	.90	.70
Ruminal liquid fill, ml/kg BW[c]	142	111	116	118	11	.16	.07	.32
Liquid dilution rate, %/h	6.88	7.36	7.75	8.15	.87	.17	.75	.98
Liquid flow rate, liters/h	2.6	2.2	2.5	2.6	.4	.67	.48	.37

[a]Probability of observing a greater F value: L=linear response, Q=quadratic response, C=cubic response.

[b]n=4.

[c]Fill values measured approximately 23 h after supplementation.

[d]IADF = indigestible ADF.

TABLE 5. INFLUENCE OF INCREASING LEVEL OF SORGHUM GRAIN (SG) SUPPLEMENTATION ON RUMINAL FERMENTATION CHARACTERISTICS IN BEEF STEERS (EXP. 1)

	SG kg·hd^{-1}·d^{-1}					Contrasts[a]		
Item	0	.45	.91	1.82	SE[b]	L	Q	C
pH	6.62	6.54	6.46	6.45	.09	.07	.64	.81
VFA concentration, mM	81.52	86.56	80.96	89.24	3.72	.17	.55	.07
Acetate: propionate	6.24	6.09	5.96	6.05	.24	.37	.48	.80
NH_3-N, mM	4.26	2.05	2.06	3.46	2.08	.84	.29	.78
Mol/100 mol								
Acetate	78.13	76.89	75.87	75.57	.54	.01	.25	.77
Propionate	12.61	12.65	12.77	12.56	.40	.98	.67	.75
Isobutyrate	.58	.56	.56	.56	.04	.73	.66	.97
Isovalerate	.55	.51	.48	.57	.02	.70	.01	.24

[a]Probability of observing a greater F value: L=linear response, Q=quadratic response, C=cubic response.

[b]n=24.

TABLE 6. INFLUENCE OF INCREASING LEVEL OF SORGHUM GRAIN (SG) SUPPLEMENTATION AND SAMPLING TIME ON RUMINAL CONCENTRATIONS OF BUTYRATE AND VALERATE (EXP. 1)

Item	SG kg·hd^{-1}·d^{-1}					Contrasts[a]		
	0	.45	.91	1.82	SE[b]	L	Q	C
	----------mol/100 mol----------							
Butyrate								
0 h	7.87	8.82	9.71	10.05	.37	.01	.04	.65
3 h	7.74	9.12	10.47	10.75	.40	.01	.01	.45
5 h	7.49	9.21	9.81	10.12	.40	.01	.01	.43
7 h	7.60	8.85	9.91	10.13	.47	.01	.03	.72
9 h	7.81	9.04	9.97	10.35	.45	.01	.04	.86
12 h	8.04	8.78	9.55	9.90	.36	.01	.10	.64
Valerate:								
0 h	.35	.44	.49	.53	.09	.07	.51	.93
3 h	.40	.47	.42	.73	.08	.01	.15	.27
5 h	.37	.41	.48	.50	.06	.06	.46	.64
7 h	.36	.47	.38	.37	.05	.05	.46	.61
9 h	.45	.34	.27	.44	.09	.98	.04	.78
12 h	.30	.51	.48	.49	.12	.23	.23	.37

[a]Probability of observing a greater F value: L=linear response, Q=quadratic response, C=cubic response.

[b]n=4.

TABLE 7. INFLUENCE OF SUPPLEMENTARY GRAIN TYPE ON VOLUNTARY DM INTAKE AND DIGESTIBILITY IN BEEF STEERS (EXP. 2)

	Supplemental grain type[a]					Treatment Effect
Item	NS	C	W	SG	SE[b]	P=
Steer weight, kg	353	357	372	362	10	
DM Intake:						
Forage, % BW	2.45	2.50	2.40	2.49	.18	.95
Total, % BW	2.45	2.85	2.74	2.84	.18	.16
Digestibility:						
DM, %	51.4	54.8	56.0	52.1	2.7	.34
NDF, %	51.6	52.5	50.7	49.1	3.9	.82
Starch, %	83.4[c]	84.2[c]	95.4[d]	86.1[c]	1.6	.01
Starch, g/d	155[c]	918[d]	1029[d]	988[d]	70	.01

[a]NS=no supplement, C=corn, W=wheat, SG=sorghum grain.

[b]n=4.

[c,d]Row means with different letters in their superscripts differ (P<.10).

TABLE 8. INFLUENCE OF SUPPLEMENTAL GRAIN TYPE ON RUMINAL FERMENTATION CHARACTERISTICS IN BEEF STEERS (EXP. 2)

	Supplemental grain type[a]					Treatment Effect
Item	NS	C	W	SG	SE[b]	P=
pH	6.68	6.60	6.59	6.63	.06	.43
VFA concentration, mM	63.35	66.63	63.10	65.95	4.73	.83
Acetate: propionate	7.06	7.03	6.30	6.72	.43	.32
Mol/100 mol						
Acetate	80.03[c]	79.65[cd]	77.68[e]	78.56[de]	.80	.06
Propionate	11.38	11.37	12.56	11.81	.80	.44
Isobutyrate	.39[c]	.39[c]	.37[e]	.46[d]	.03	.09
Butyrate	7.66	7.92	8.65	8.45	.61	.38

[a]NS=no supplement, C=corn, W=wheat, SG=sorghum grain.

[b]n=24.

[c,d,e]Row means with different letters in their superscripts differ (P<.10).

TABLE 9. INFLUENCE OF SUPPLEMENTAL GRAIN TYPE AND SAMPLING TIME ON RUMINAL CONCENTRATIONS OF AMMONIA, ISOVALERATE AND VALERATE (EXP. 2)

	Supplemental grain type[a]					Treatment Effect
Item	NS	C	W	SG	SE[b]	P=
Ammonia, mM						
0 h	.63[c]	.81[cd]	1.14[d]	.67[c]	.19	.09
1 h	.53[c]	.94[c]	1.66[d]	.81[c]	.31	.03
3 h	.55[c]	.75[c]	1.92[d]	.63[c]	.51	.08
6 h	.54	.47	.60	.41	.27	.91
9 h	.34	.86	.93	1.11	.49	.48
12 h	.40[c]	.94[d]	.69[cd]	.45[c]	.18	.05
	----------mol/100 mol----------					
Isovalerate						
0 h	.42	.46	.41	.56	.06	.13
1 h	.47	.49	.48	.54	.07	.77
3 h	.39	.37	.46	.39	.06	.57
6 h	.26	.29	.28	.30	.06	.91
9 h	.25	.27	.26	.33	.06	.64
12 h	.32	.38	.38	.42	.06	.41
Valerate						
0 h	.13[c]	.30[d]	.30[d]	.34[d]	.06	.02
1 h	.21[c]	.40[d]	.42[d]	.37[d]	.06	.04
3 h	.21[c]	.33[d]	.51[e]	.29[cd]	.05	.01
6 h	.22[c]	.28[d]	.36[e]	.26[d]	.02	.01
9 h	.16	.20	.27	.25	.06	.22
12 h	.21[c]	.27[cd]	.33[d]	.27[cd]	.03	.05

[a]NS=no supplement, C=corn, W=wheat, SG=sorghum grain.

[b]n=4.

[c,d,e]Row means with different letters in their superscripts differ (P<.10).

APPENDIX

TABLE 1. RUMINALLY FISTULATED STEER ID NUMBERS, WEIGHTS, WEIGHT BLOCKS AND TREATMENT ASSIGNMENTS (EXP. 1).

Steer ID	Initial wt for blocks, kg	Initial wt on trial, kg	End of trial wt, kg	Weight block[a]	Treatment (lb SG)
118	289	297	257	HH	0
86	281	285	274	MH	0
132	269	273	248	ML	0
102	209	214	216	LL	0
63	299	302	283	HH	1
53	279	277	276	MH	1
127	260	264	258	ML	1
52	235	240	217	LL	1
529	311	320	286	HH	2
64	281	286	273	MH	2
71	257	266	244	ML	2
128	248	251	244	LL	2
65	291	305	282	HH	4
105	276	281	262	MH	4
112	252	256	247	ML	4
131	248	254	237	LL	4

[a]HH = high, MH = moderate-high, ML = moderate low, LL = low.

TABLE 2. DRY MATTER OFFERED AND REFUSED, FECAL OUTPUT AND RUMINAL FILL DATA (EXP. 1)[a].

	Intake Period		Digestibility period					
Steer ID	Forage DMI, kg	Supp. DMI, kg	Offered forage, kg DM	Refused forage, kg DM	Supp. DMI, kg	Fecal DM, kg	Ruminal DM fill, kg	Ruminal liquid fill, kg
118	43.95	0	51.50	13.01	0	17.06	6.39	35.5
86	45.04	0	55.70	11.12	0	19.49	7.02	42.4
132	37.32	0	48.40	9.33	0	17.57	4.38	34.3
102	32.05	0	39.42	9.82	0	13.66	3.69	36.9
63	42.40	2.96	48.69	12.73	2.96	16.83	5.17	32.1
53	44.72	2.96	48.46	14.25	2.96	16.48	4.40	34.6
127	38.45	2.96	45.22	8.94	2.96	16.14	4.35	29.6
52	41.00	2.96	44.94	13.43	2.96	16.08	3.63	24.6
529	49.26	5.91	58.34	13.66	5.91	24.08	6.02	35.0
64	47.81	5.91	51.08	13.50	5.91	19.68	6.58	34.1
71	35.68	5.91	43.44	10.29	5.91	18.09	5.56	33.9
128	37.59	5.91	46.39	9.46	5.91	20.28	3.65	27.3
65	50.39	11.81	57.93	13.92	11.81	26.70	5.23	33.2
105	40.13	11.81	45.66	10.48	11.81	21.01	5.02	28.7
112	43.27	11.81	51.98	12.31	10.64	23.16	6.98	35.4
131	37.55	11.81	44.24	11.13	11.81	21.14	5.22	31.4

[a]All values during intake and digestibility periods represent totals for the 7-d periods.

TABLE 3. ESOPHAGEALLY FISTULATED STEER ID NUMBERS, WEIGHT BLOCKS, TREATMENT ASSIGNMENTS AND CHEMICAL COMPOSITION OF ESOPHAGEALLY-COLLECTED FORAGE SAMPLES.

Steer ID	Treatment, lb SG	Weight block[a]	Dry Matter, %	Percent of dry matter: Organic matter, %	NDF, %	Ash-free NDF, %	Crude protein, %
51	0	L	93.61	90.93	77.46	72.13	11.40
42	0	M	93.36	91.11	80.00	73.41	10.19
125	0	H	92.77	91.15	80.45	72.63	10.94
73	1	L	93.08	90.98	85.68	78.79	10.54
113	1	M	93.13	91.32	82.43	75.95	10.22
83	1	H	93.34	91.25	79.73	72.11	11.68
70	2	L	92.97	90.85	80.73	73.48	10.50
44	2	M	93.19	90.84	76.98	70.85	11.45
114	2	H	93.31	91.25	79.52	72.28	10.51
129	4	L	93.00	90.86	83.22	75.55	11.35
74	4	M	92.90	91.27	80.73	74.54	10.95
123	4	H	92.69	90.99	79.51	72.42	9.88

[a]H = high, M = moderate, L = low

TABLE 4. CHEMICAL COMPOSITION OF FRESH GRASS, SORGHUM GRAIN (SG) SUPPLEMENT AND ORTS FROM DIGESTION TRIAL (EXP. 1)

Sample type	DM, %	percent of dry matter						
		OM, %	NDF, %	ADF, %	ADL, %	CP, %	IADF, %	Starch, %
Fresh grass	93.42	92.88	62.68	42.04	6.03	6.07	17.60	2.61
SG supp.	91.77	98.32	9.46		0.83	9.22	0.54	64.76
Orts:								
118	93.63	92.04	64.18		7.11	6.16	22.02	2.75
86	91.89	92.22	66.82		6.68	6.16	19.02	3.14
132	93.04	91.44	69.55		6.70	6.15	21.40	2.62
102	92.42	92.22	68.68		7.73	5.95	23.26	3.14
63	92.38	92.10	66.92		6.35	6.01	22.43	3.23
53	93.68	92.56	65.46		5.89	6.17	20.63	3.18
127	92.98	92.32	67.48		6.19	6.34	19.54	3.20
52	93.39	92.30	62.38		6.54	6.23	21.12	3.14
529	93.68	92.34	65.74		6.22	6.35	19.46	3.43
64	93.25	92.20	65.78		6.25	5.89	20.31	2.78
71	92.48	92.30	66.91		6.50	5.95	19.78	3.05
128	92.72	92.29	70.66		6.38	6.12	21.35	3.38
65	92.22	91.94	66.81		6.32	6.21	22.80	2.92
105	92.02	92.22	68.24		6.80	5.96	21.97	3.38
112	92.50	92.51	65.20		5.95	6.14	20.14	5.28
131	93.52	92.48	66.77		5.89	6.14	17.33	3.38

TABLE 5. CHEMICAL COMPOSITION OF FECAL SAMPLES FROM DIGESTION TRIAL (EXP. 1).

		percent of dry matter			
Steer ID	DM, %	OM, %	NDF, %	ADL, %	Starch, %
118	91.30	88.28	70.05	17.43	0.75
86	91.79	88.12	67.78	16.21	0.61
132	91.69	88.99	72.94	17.43	0.66
102	91.35	88.86	69.88	16.04	0.96
63	91.54	88.62	69.40	14.02	1.66
53	91.44	89.02	67.20	14.40	2.65
127	91.84	87.90	65.02	15.13	1.82
52	91.65	89.91	68.36	14.00	3.00
529	91.80	89.58	61.16	12.54	4.01
64	91.27	90.10	65.94	12.84	3.86
71	91.90	90.40	60.90	11.14	3.81
128	91.76	90.40	62.04	11.80	4.66
65	91.28	90.93	57.06	10.28	7.60
105	91.78	90.21	54.85	10.39	7.01
112	92.23	91.00	54.95	10.62	8.11
131	91.50	91.10	57.66	9.63	9.73

TABLE 6. CHEMICAL COMPOSITION OF RUMINAL DIGESTA SAMPLES (EXP. 1).

		percent of dry matter	
Steer ID	DM, %	OM, %	IADF, %
118	92.40	88.96	36.87
86	91.80	89.37	38.33
132	91.45	87.14	39.04
102	90.40	82.52	33.23
63	91.89	88.20	35.77
53	90.72	87.73	36.28
127	91.02	88.47	39.24
52	91.38	88.26	35.68
529	91.92	90.02	37.94
64	92.14	90.06	37.86
71	92.20	90.26	35.26
128	90.68	88.47	37.18
65	91.59	89.42	38.10
105	92.04	89.57	34.98
112	91.45	90.25	38.87
131	92.31	89.39	36.58

TABLE 7. RUMINAL PH AT VARIOUS TIMES (EXP. 1)

	Sampling time					
Steer ID	Oh	3h	5h	7h	9h	12h
118	6.56	6.53	6.48	6.37	6.34	6.35
86	6.80	6.73	6.51	6.38	6.59	6.54
132	6.81	6.90	6.75	6.65	6.82	6.67
102	6.80	6.84	6.58	6.68	6.57	6.59
63	6.70	6.55	6.47	6.47	6.59	6.30
53	6.71	6.88	6.58	6.56	6.46	6.47
127	6.72	6.62	6.38	6.34	6.49	6.44
52	6.71	6.62	6.50	6.43	6.46	6.58
529	6.75	6.61	6.43	6.43	6.46	6.44
64	6.42	6.53	6.31	6.27	6.32	6.21
71	6.37	6.33	6.26	6.24	6.38	6.13
128	6.80	6.73	6.68	6.65	6.79	6.58
65	6.69	6.50	6.32	6.40	6.30	6.13
105	6.65	6.58	6.59	6.64	6.47	6.40
112	6.58	6.43	6.48	6.05	6.07	6.33
131	6.61	6.57	6.51	6.50	6.63	6.37

TABLE 8. RUMINAL NH_3 CONCENTRATION (mM) AT VARIOUS TIMES (EXP. 1)

	Sampling time					
Steer ID	Oh	3h	5h	7h	9h	12h
118	3.208	5.264	2.181	0.6398	2.181	0.639
86	1.129	3.204	0.563	0.045	0.186	0.752
132	22.255	8.486	11.881	4.524	9.995	4.713
102	2.181	1.153	NA	NA	NA	NA
63	2.449	1.506	0.186	0.940	0.752	0.374
53	1.506	3.204	3.581	0.374	0.186	0.374
127	3.958	7.731	3.015	0.374	0.752	0.186
52	0.125	6.292	4.236	1.153	1.667	4.236
529	1.506	12.070	2.072	NA	0.563	0.374
64	1.129	2.072	0.186	0.093	0.093	0.186
71	NA	2.181	NA	NA	NA	NA
128	1.129	6.034	3.204	2.638	0.752	0.752
65	1.695	31.312	1.129	0.186	0.186	0.752
105	1.318	2.638	1.129	0.752	1.318	1.318
112	2.181	4.236	7.319	10.403	NA	NA
131	0.280	4.713	2.638	0.186	0.186	0.186

TABLE 9. RUMINAL ACETATE CONCENTRATION (mM) AT VARIOUS TIMES (EXP. 1)

	Sampling time					
Steer ID	Oh	3h	5h	7h	9h	12h
118	76.129	53.746	67.834	76.267	71.189	66.898
86	61.282	56.196	63.535	71.608	75.697	56.878
132	67.646	47.431	66.264	57.843	60.019	73.200
102	61.733	59.037	51.762	64.772	56.039	66.730
63	66.465	51.273	60.062	92.118	68.693	68.096
53	63.407	49.180	60.997	67.515	73.578	60.626
127	75.811	73.225	66.393	81.744	63.578	59.304
52	67.483	58.919	66.116	65.807	73.313	63.829
529	67.942	59.906	64.880	71.092	60.837	64.067
64	81.040	50.119	67.473	62.598	64.569	66.839
71	70.392	57.520	59.170	62.728	58.602	67.315
128	53.438	42.674	45.957	48.421	59.907	65.960
65	61.995	57.294	71.678	78.539	73.955	87.072
105	79.763	74.876	62.663	59.608	72.122	70.007
112	67.582	68.399	59.809	72.805	84.681	70.473
131	61.613	60.443	47.369	58.542	62.998	53.445

TABLE 10. RUMINAL PROPIONATE CONCENTRATION (mM) AT VARIOUS TIMES (EXP. 1)

	Sampling time					
Steer ID	Oh	3h	5h	7h	9h	12h
118	11.283	09.507	09.800	10.719	10.257	08.049
86	09.817	09.294	09.991	12.202	13.267	10.066
132	10.960	08.525	10.770	09.152	09.629	11.111
102	10.883	10.131	08.772	10.945	09.617	11.078
63	10.431	08.263	09.176	14.611	10.765	10.482
53	10.666	08.101	10.102	11.088	12.070	09.528
127	12.918	12.801	11.616	13.613	11.052	10.318
52	10.860	10.038	11.076	11.292	12.113	09.948
529	11.760	10.932	11.121	11.808	10.390	10.112
64	13.434	08.872	10.950	10.130	10.466	10.984
71	12.626	11.010	10.256	11.645	10.948	11.881
128	08.467	06.816	06.951	07.408	09.440	10.319
65	09.623	08.584	10.863	11.907	11.415	13.541
105	12.197	11.826	09.224	09.817	12.201	11.836
112	12.553	13.330	10.529	13.075	16.076	13.500
131	10.279	10.003	07.757	09.487	10.951	08.786

TABLE 11. RUMINAL ISOBUTYRATE CONCENTRATION (mM) AT VARIOUS TIMES (EXP. 1)

	Sampling time					
Steer ID	Oh	3h	5h	7h	9h	12h
118	.635	.454	.485	.462	.422	.406
86	.467	.447	.387	.406	.492	.378
132	.589	.435	.538	.470	.520	.493
102	.518	.517	.410	.444	.409	.426
63	.501	.410	.362	.614	.410	.379
53	.592	.488	.429	.520	.495	.412
127	.621	.622	.481	.497	.417	.427
52	.501	.506	.505	.438	.503	.391
529	.620	.617	.523	.480	.429	.413
64	.605	.444	.543	.449	.454	.445
71	.566	.466	.350	.475	.435	.398
128	.365	.372	.251	.318	.378	.395
65	.459	.452	.380	.481	.439	.433
105	.539	.564	.457	.516	.589	.555
112	.574	.582	.399	.438	.530	.446
131	.487	.527	.505	.415	.740	.348

TABLE 12. RUMINAL BUTYRATE CONCENTRATION (mM) AT VARIOUS TIMES (EXP. 1)

	Sampling time					
Steer ID	Oh	3h	5h	7h	9h	12h
118	07.770	05.315	06.589	07.132	07.129	06.840
86	06.615	05.906	06.142	07.686	08.200	06.537
132	06.303	04.942	06.218	05.419	05.736	06.555
102	06.207	05.502	04.857	06.016	05.429	06.840
63	06.983	05.648	06.189	09.614	07.100	07.109
53	07.223	05.594	07.383	07.329	08.308	06.814
127	08.922	08.820	08.297	09.559	07.855	07.079
52	08.245	07.896	08.720	08.562	09.544	07.525
529	09.247	08.200	08.383	08.959	08.318	08.021
64	10.511	07.315	08.973	08.288	08.365	08.603
71	09.057	08.603	07.896	08.805	08.182	08.408
128	06.309	05.540	05.501	05.926	07.163	07.954
65	08.588	08.327	09.983	11.182	10.513	11.568
105	10.100	10.872	08.404	08.266	10.143	09.368
112	09.447	10.446	07.953	09.403	11.856	09.594
131	07.766	07.962	05.932	07.246	08.041	06.458

TABLE 13. RUMINAL ISOVALERATE CONCENTRATION (mM) AT VARIOUS TIMES (EXP. 1)

	Sampling time					
Steer ID	Oh	3h	5h	7h	9h	12h
118	.508	.496	.505	.475	.407	.385
86	.497	.541	.493	.424	.480	.367
132	.505	.404	.522	.410	.489	.360
102	.456	.445	.383	.411	.363	.346
63	.463	.381	.378	.457	.338	.305
53	.538	.483	.437	.544	.408	.389
127	.735	.592	.468	.415	.334	.365
52	.410	.437	.425	.364	.413	.333
529	.573	.563	.407	.360	.304	.403
64	.566	.451	.514	.374	.340	.334
71	.473	.468	.358	.404	.371	.374
128	.314	.301	.219	.203	.354	.347
65	.511	.517	.497	.574	.453	.431
105	.517	.556	.437	.419	.514	.903
112	.594	.649	.480	.402	.520	.448
131	.501	.512	.368	.494	.456	.332

TABLE 14. RUMINAL VALERATE CONCENTRATION (mM) AT VARIOUS TIMES (EXP. 1)

	Sampling time					
Steer ID	Oh	3h	5h	7h	9h	12h
118	.334	.280	.289	.334	.549	.317
86	.266	.313	.310	.256	.240	.115
132	.362	.227	.350	.286	.310	.270
102	.246	.289	.240	.339	.404	.319
63	.286	.277	.308	.416	.359	.623
53	.455	.357	.329	.366	.276	.500
127	.452	.424	.378	.410	.241	.268
52	.360	.353	.355	.309	.357	.289
529	.357	.359	.227	.325	.053	.399
64	.523	.257	.386	.280	.236	.234
71	.434	.361	.529	.251	.289	.417
128	.414	.231	.331	.310	.272	.601
65	.636	.777	.463	.565	.465	.567
105	.430	.571	.428	.387	.465	.481
112	.451	.530	.372	.418	.529	.586
131	.356	.617	.314	.299	.276	.235

TABLE 15. RUMINAL COBALT CONCENTRATIONS AND SAMPLING TIMES (EXP. 1).

Steer 118		Steer 86		Steer 132		Steer 102	
Time[a]	[Co][b]	Time	[Co]	Time	[Co]	Time	[Co]
0	0	0	0	0	0	0	0
2.92	19.806	2.92	17.304	3.00	26.859	2.92	28.418
4.83	17.450	4.92	14.079	4.92	21.771	4.83	18.455
6.75	13.681	6.92	11.545	6.83	17.304	6.75	17.073
8.75	10.853	8.92	9.702	8.83	16.834	8.83	14.770
11.75	10.382	11.92	6.477	11.83	12.367	11.75	11.545
23.75	4.816	23.92	2.918	23.83	6.433	23.75	7.341

Steer 63		Steer 53		Steer 127		Steer 52	
Time	[Co]	Time	[Co]	Time	[Co]	Time	[Co]
0	0	0	.257	0	0	0	0
2.92	27.188	2.92	23.754	2.92	31.027	2.92	31.320
4.83	18.950	4.92	19.607	4.83	20.984	4.83	19.377
6.75	15.423	6.92	16.843	6.75	17.215	6.67	17.534
8.75	14.483	8.92	12.927	8.75	15.565	8.75	16.382
11.75	10.251	11.92	9.702	11.75	10.618	11.75	9.932
23.75	5.727	23.92	5.406	23.75	5.099	23.67	5.959

Steer 529		Steer 64		Steer 71		Steer 128	
Time	[Co]	Time	[Co]	Time	[Co]	Time	[Co]
0	.612	0	0	0	0	0	1.194
2.92	20.276	2.92	17.304	2.92	24.884	2.92	33.996
4.83	16.128	4.83	15.921	4.83	17.304	5.17	18.393
6.75	12.367	6.83	12.927	6.83	16.599	6.75	19.571
8.75	10.016	8.83	12.236	8.83	14.483	8.83	17.215
11.75	6.960	11.83	9.471	11.83	10.956	11.75	12.974
23.75	2.690	23.83	4.992	23.83	5.699	23.75	4.533

Steer 65		Steer 105		Steer 112		Steer 131	
Time	[Co]	Time	[Co]	Time	[Co]	Time	[Co]
0	.257	0	0	0	0	0	0
2.83	21.220	2.83	29.378	2.92	18.875	2.92	24.884
4.75	16.613	4.83	21.927	5.17	13.778	4.83	17.304
6.67	15.691	6.67	18.157	6.75	10.956	6.83	16.834
8.67	11.775	8.75	15.330	8.83	9.781	8.83	14.483
11.67	8.780	11.67	10.853	11.83	5.784	11.83	9.781
23.67	3.886	23.67	4.674	23.83	3.348	23.83	4.458

[a]Time from dosing in hours [b]Cobalt concentration in ppm

TABLE 16. RUMINALLY FISTULATED STEER ID NUMBERS, WEIGHTS, WEIGHT BLOCKS AND TREATMENT ASSIGNMENTS (EXP. 2).

Steer ID	Wt	Wt block[a]	Treatment[b]
86	405	HH	NS
64	360	MH	NS
112	343	ML	NS
128	303	LL	NS
118	395	HH	CR
105	363	MH	CR
529	348	ML	CR
52	321	LL	CR
X83	463	HH	WH
53	380	MH	WH
71	346	ML	WH
127	302	LL	WH
65	439	HH	SG
63	391	MH	SG
102	328	ML	SG
131	291	LL	SG

[a]HH = high, MH = moderate-high, ML = moderate-low, LL = low
[b]NS = no supplement, CR = corn, WH = wheat, SG = sorghum grain

TABLE 17. DRY MATTER OFFERED AND REFUSED AND FECAL OUTPUT (EXP.2)[a]

	Intake period		Digestibility period			
Steer ID	Forage DMI, kg	Supp. DMI, kg	Offered forage, kg DM	Refused forage, kg DM	Supp. DMI, kg	Fecal DM, kg
86	64.06	0	68.01	9.08	0	29.56
64	69.55	0	NA	NA	NA	NA
112	59.79	0	59.70	9.85	0	22.46
128	48.67	0	51.12	8.08	0	21.95
118	60.56	9.85	64.42	6.90	9.73	29.82
105	61.02	8.90	66.33	9.94	8.85	28.69
529	67.60	8.58	72.28	7.81	8.26	33.61
52	59.07	7.63	65.06	9.67	7.67	29.12
X83	57.57	11.12	56.98	9.90	11.04	24.00
53	66.83	8.90	66.51	9.49	8.95	28.79
71	61.93	8.26	65.47	10.90	8.35	32.26
127	58.52	6.99	60.93	8.31	7.16	23.85
65	78.86	10.81	82.04	12.26	10.67	34.89
63	68.55	9.53	73.91	9.17	9.49	35.94
102	53.48	7.95	57.11	9.26	8.00	28.51
131	52.26	6.99	55.57	6.58	7.11	27.31

[a]Values represent totals for 7-d periods

TABLE 18. RUMINAL DRY MATTER AND LIQUID FILL (EXP. 2)

	Evacuation 1 (1100 h)		Evacuation 2 (1700 h)	
Steer ID	DM fill, kg	Liquid fill, kg	DM fill, kg	Liquid fill, kg
86	10.78	67.31	12.07	76.01
64	8.93	59.74	8.94	57.80
112	7.85	54.46	9.18	62.55
128	6.28	43.55	6.74	45.13
118	8.80	57.37	10.14	63.86
105	8.38	53.25	9.32	58.67
529	8.67	61.81	11.46	68.67
52	7.97	49.35	8.51	46.76
X83	6.86	51.82	9.02	65.55
53	6.54	48.40	8.67	47.63
71	8.47	59.29	9.59	57.03
127	7.06	47.65	8.30	51.85
65	9.98	65.61	10.23	60.82
63	9.67	57.52	11.89	65.29
102	7.31	54.66	9.13	57.04
131	9.71	54.99	10.73	68.72

TABLE 19. CHEMICAL COMPOSITION OF FRESH GRASS AND SUPPLEMENTS FROM DIGESTION TRIAL (EXP. 2)

		percent of dry matter						
Sample type	DM, %	OM, %	NDF, %	ADF, %	ADL, %	CP, %	IADF, %	Starch, %
Fresh grass	94.06	92.41	73.67	43.17	5.71	5.8	16.90	2.08
Corn supplement	91.91	96.79	12.22	4.71	0.35	15.1	0.07	72.75
Wheat supplement	91.52	97.34	19.92	4.00	1.42	14.4	1.99	73.80
Sorghum grain supplement	91.74	97.40	10.89	5.91	1.43	14.2	0.55	76.51

TABLE 20. CHEMICAL COMPOSITION OF ORTS FROM DIGESTION TRIAL (EXP. 2)

Steer ID	DM, %	percent of dry matter						
		OM, %	NDF, %	ADF, %	ADL, %	CP, %	IADF, %	Starch, %
86	87.33	90.00	77.30	47.62	8.08	6.33	23.03	0.94
64	NA	NA	NA	NA	NA	NA	NA	NA
112	93.41	91.06	75.11	46.25	6.26	5.49	19.87	1.60
128	94.03	91.10	77.26	47.38	7.48	5.51	22.27	1.19
118	93.79	91.07	74.85	44.73	6.18	5.75	20.59	1.48
105	93.21	90.35	76.27	46.45	7.76	5.65	20.49	1.45
529	94.31	92.30	76.18	46.49	6.24	5.35	22.52	1.50
52	94.24	91.00	73.57	44.97	5.60	5.32	20.46	1.54
X83	93.32	91.28	75.04	44.68	5.66	5.96	19.36	2.35
53	93.31	91.88	76.60	44.89	6.22	5.57	19.44	1.61
71	93.56	91.12	75.09	46.01	6.78	5.54	20.61	1.63
127	93.40	91.68	75.58	45.08	6.78	5.42	23.58	1.49
65	92.61	90.93	74.75	45.80	6.02	5.47	19.10	1.47
63	94.30	90.46	74.94	44.47	6.82	5.30	21.51	1.52
102	94.67	91.43	74.89	45.70	6.38	5.39	20.86	1.50
131	94.61	91.35	74.01	44.77	6.68	5.56	21.46	1.47

TABLE 21. CHEMICAL COMPOSITION OF FECAL SAMPLES FROM DIGESTION TRIAL (EXP. 2)

		percent of dry matter				
Steer ID	DM, %	OM, %	NDF, %	ADF, %	ADL, %	Starch, %
86	94.58	88.04	72.36	51.31	13.80	0.81
64	NA	NA	NA	NA	NA	NA
112	93.93	86.85	70.25	50.62	13.86	0.78
128	94.41	88.79	74.41	50.78	11.95	0.78
118	93.98	88.03	66.37	45.08	13.14	4.94
105	94.61	88.21	71.42	49.05	13.89	2.75
529	94.15	88.86	68.24	46.71	12.47	3.93
52	94.17	88.78	69.92	47.72	12.95	4.17
X83	94.35	87.69	70.69	48.80	13.00	1.60
53	94.99	87.76	74.48	51.52	16.50	1.27
71	94.33	89.44	76.86	50.46	11.48	1.13
127	94.60	86.94	71.18	50.04	14.24	1.21
65	94.98	87.70	67.87	47.12	13.73	3.28
63	94.57	88.78	69.75	48.20	11.90	3.14
102	94.55	89.02	69.73	49.40	13.66	3.50
131	94.09	89.60	69.67	46.45	10.43	3.94

TABLE 22. CHEMICAL COMPOSITION OF RUMINAL DIGESTA SAMPLES (EXP. 2)

	Evacuation 1		Evacuation 2	
Steer ID	DM, %	IADF, %	DM, %	IADF, %
86	94.74	30.50	94.47	27.15
64	93.57	25.91	94.30	25.36
112	93.84	29.90	94.88	27.44
128	93.32	26.39	93.64	25.08
118	94.05	28.73	93.84	27.28
105	93.84	29.00	94.17	25.50
529	94.50	28.17	94.88	24.27
52	94.34	26.33	94.70	26.50
X83	93.88	25.62	94.07	22.87
53	93.96	26.29	93.76	26.96
71	94.34	27.05	93.26	24.16
127	93.67	27.86	94.00	26.42
65	93.84	29.68	93.32	26.52
63	94.04	28.51	94.00	24.14
102	94.57	28.10	93.68	22.42
131	94.62	26.28	94.90	20.61

TABLE 23. RUMINAL PH AT VARIOUS TIMES (EXP. 2)

Steer ID	Sampling time					
	Oh	1h	3h	6h	9h	12h
86	6.77	6.80	6.72	6.66	6.54	6.62
64	6.86	6.80	6.69	6.64	6.57	6.67
112	6.76	6.77	6.68	6.38	6.40	6.43
128	6.79	6.87	6.80	6.64	6.72	6.87
118	6.61	6.65	6.59	6.63	6.51	6.55
105	6.67	6.67	6.67	6.39	6.41	6.50
529	6.82	6.73	6.67	6.55	6.63	6.55
52	6.62	6.64	6.66	6.55	6.56	6.63
X83	6.83	6.85	6.68	6.60	6.60	6.68
53	6.78	6.81	6.67	6.58	6.50	6.56
71	6.69	6.67	6.52	6.27	6.37	6.33
127	6.69	6.62	6.58	6.46	6.37	6.36
65	6.66	6.60	6.66	6.53	6.50	6.33
63	6.76	6.77	6.67	6.50	6.64	6.49
102	6.73	6.78	6.69	6.64	6.55	6.57
131	6.74	6.68	6.70	6.61	6.55	6.68

TABLE 24. RUMINAL NH_3 CONCENTRATION (mM) AT VARIOUS TIMES (EXP. 2)

	Sampling time					
Steer ID	Oh	1h	3h	6h	9h	12h
86	0.475	0.343	0.219	1.312	0.284	0.448
64	0.639	0.420	0.436	0.306	0.414	0.275
112	0.792	0.650	0.782	0.263	0.349	0.523
128	0.606	0.693	0.749	0.263	0.317	0.340
118	0.803	1.065	0.511	0.587	0.468	1.019
105	0.901	0.693	0.306	0.555	0.274	1.450
529	0.726	1.010	0.566	0.414	0.706	0.426
52	0.792	1.010	1.636	0.317	1.972	0.847
X83	1.699	2.355	1.820	0.295	1.063	0.717
53	1.305	1.830	2.458	0.847	1.658	0.793
71	0.617	0.420	0.176	0.165	0.360	0.793
127	0.945	2.049	3.224	1.074	0.652	0.448
65	0.879	1.032	1.182	0.630	1.074	0.793
63	0.988	0.726	0.630	0.284	2.426	0.588
102	0.486	0.650	0.349	0.555	0.674	0.211
131	0.333	0.846	0.349	0.165	0.274	0.221

TABLE 25. RUMINAL ACETATE CONCENTRATION (mM) AT VARIOUS TIMES (EXP. 2)

	Sampling time					
Steer ID	0h	1h	3h	6h	9h	12h
86	52.207	45.961	44.302	60.037	46.724	52.673
64	30.308	40.648	38.183	58.020	57.601	53.057
112	44.876	47.912	62.459	63.104	66.032	62.671
128	34.262	47.726	43.686	53.524	52.204	57.439
118	45.039	57.247	48.922	53.538	48.794	65.319
105	53.492	40.424	56.374	63.040	57.534	66.234
529	40.252	34.188	45.110	66.583	62.800	65.059
52	45.710	52.856	46.241	59.826	59.540	38.418
X83	46.894	40.135	42.593	57.110	55.508	45.106
53	47.772	43.137	38.498	55.170	64.834	67.202
71	39.442	29.837	30.105	57.621	53.522	43.180
127	46.286	52.010	41.377	56.614	53.602	68.879
65	54.397	52.243	38.560	65.971	52.209	75.975
63	40.803	51.483	52.133	64.189	73.897	70.883
102	44.785	28.503	42.862	54.174	49.469	63.255
131	33.874	36.294	46.558	46.968	55.464	49.131

TABLE 26. RUMINAL PROPIONATE CONCENTRATION (mM) AT VARIOUS TIMES (EXP. 2)

Steer ID	Sampling time					
	Oh	1h	3h	6h	9h	12h
86	07.961	07.064	06.292	08.080	06.408	06.963
64	04.198	06.176	04.916	08.041	07.904	07.928
112	07.042	07.461	08.926	08.148	08.995	09.021
128	04.725	07.611	05.998	07.209	07.384	08.132
118	06.435	09.010	06.700	07.050	05.880	08.982
105	08.195	05.974	08.007	08.805	08.390	10.068
529	05.672	05.022	05.891	09.145	08.640	09.364
52	06.962	08.783	06.265	08.390	08.975	05.348
X83	07.338	06.314	06.727	08.203	08.323	06.295
53	07.492	07.070	05.184	08.186	10.251	10.910
71	07.495	05.440	05.901	11.560	11.688	09.674
127	06.470	08.149	05.688	07.593	07.355	10.123
65	08.083	07.781	04.800	08.541	06.946	10.794
63	05.696	07.842	06.497	08.640	10.133	10.502
102	06.758	04.343	05.965	07.957	07.795	09.817
131	05.783	06.738	08.101	07.804	09.827	08.650

TABLE 27. RUMINAL ISOBUTYRATE CONCENTRATION (mM) AT VARIOUS TIMES (EXP. 2)

	Sampling time					
Steer ID	Oh	1h	3h	6h	9h	12h
86	.300	.266	.218	.271	.185	.215
64	.163	.236	.150	.263	.230	.252
112	.274	.283	.341	.248	.278	.283
128	.145	.295	.209	.225	.233	.287
118	.241	.381	.235	.227	.181	.325
105	.365	.244	.319	.313	.269	.407
529	.225	.190	.182	.302	.273	.354
52	.208	.299	.168	.216	.233	.154
X83	.314	.231	.254	.320	.299	.224
53	.248	.263	.145	.184	.197	.290
71	.186	.134	.135	.226	.241	.248
127	.207	.291	.199	.183	.155	.294
65	.383	.320	.150	.272	.244	.404
63	.271	.383	.215	.293	.346	.419
102	.316	.219	.221	.304	.309	.426
131	.222	.264	.281	.232	.317	.292

TABLE 28. RUMINAL BUTYRATE CONCENTRATION (mM) AT VARIOUS TIMES (EXP. 2)

	Sampling time					
Steer ID	0h	1h	3h	6h	9h	12h
86	4.526	4.337	4.516	5.854	4.429	5.227
64	2.461	3.559	3.496	6.070	5.876	5.317
112	4.740	5.115	6.478	6.808	7.554	7.130
128	2.390	3.685	3.865	4.999	4.689	5.053
118	4.105	5.750	5.167	5.666	4.252	6.355
105	5.412	4.605	6.083	7.184	7.148	7.323
529	3.220	3.218	4.149	7.122	6.699	7.098
52	3.560	4.593	4.207	5.588	5.607	3.697
X83	4.073	3.781	4.678	5.944	6.270	5.099
53	4.074	4.217	3.977	6.068	7.202	6.767
71	3.721	2.992	3.313	6.442	6.128	5.694
127	4.941	6.356	6.170	7.936	7.097	9.210
65	5.825	6.032	4.346	8.063	6.289	9.149
63	3.613	5.023	5.038	6.886	7.374	7.685
102	4.050	3.015	4.183	5.862	6.007	7.374
131	3.245	3.848	4.856	5.394	6.480	5.342

TABLE 29. RUMINAL ISOVALERATE CONCENTRATION (mM) AT VARIOUS TIMES (EXP. 2)

	Sampling time					
Steer ID	0h	1h	3h	6h	9h	12h
86	.266	.278	.222	.193	.135	.206
64	.156	.227	.158	.197	.190	.223
112	.280	.327	.316	.194	.215	.252
128	.150	.260	.229	.168	.167	.234
118	.252	.357	.254	.221	.140	.290
105	.369	.290	.291	.268	.256	.374
529	.235	.210	.185	.233	.210	.322
52	.212	.272	.187	.171	.176	.164
X83	.352	.338	.372	.358	.316	.300
53	.192	.225	.148	.092	.134	.218
71	.171	.157	.154	.211	.219	.279
127	.218	.300	.243	.156	.099	.239
65	.331	.278	.171	.204	.204	.370
63	.301	.331	.203	.203	.220	.340
102	.334	.249	.252	.262	.269	.417
131	.250	.265	.248	.196	.254	.271

TABLE 30. RUMINAL VALERATE CONCENTRATION (mM) AT VARIOUS TIMES (EXP. 2)

Steer ID	Sampling time					
	0h	1h	3h	6h	9h	12h
86	.158	.184	.171	.164	.000	.159
64	.000	.000	.000	.157	.153	.133
112	.156	.192	.186	.161	.174	.163
128	.000	.136	.167	.148	.133	.137
118	.169	.251	.236	.202	.000	.182
105	.205	.244	.218	.234	.202	.217
529	.136	.174	.160	.220	.171	.221
52	.185	.254	.188	.201	.217	.157
X83	.190	.246	.351	.328	.222	.223
53	.160	.192	.198	.229	.206	.202
71	.157	.175	.176	.248	.200	.233
127	.189	.256	.297	.258	.175	.254
65	.225	.198	.145	.214	.155	.236
63	.176	.200	.176	.188	.185	.226
102	.194	.176	.177	.194	.203	.256
131	.156	.186	.159	.158	.190	.164

TABLE 31. RUMINAL CHROMIUM CONCENTRATIONS AND SAMPLING TIMES (EXP. 2).

Steer 86		Steer 64		Steer 112		Steer 128	
Time[a]	[Cr][b]	Time	[Cr]	Time	[Cr]	Time	[Cr]
0	0	0	0	0	0	0	0
1.62	7.683	1.30	9.419	1.11	11.115	1.75	7.522
3.70	6.345	3.37	7.992	3.20	10.130	3.80	5.963
6.68	4.810	6.38	7.035	6.18	7.305	6.80	3.663
9.70	3.956	9.42	3.128	9.22	5.733	9.82	3.220
12.63	2.932	12.32	3.822	12.15	4.447	12.73	2.695
22.48	1.824	22.13	2.187	21.92	1.969	22.58	1.480

Steer 118		Steer 105		Steer 529		Steer 52	
Time	[Cr]	Time	[Cr]	Time	[Cr]	Time	[Cr]
0	0	0	0	0	0	0	0
1.67	4.748	1.53	12.872	1.22	9.380	1.35	22.243
3.72	3.658	3.62	11.405	3.28	9.013	3.43	16.951
6.72	2.937	6.60	7.838	6.28	6.880	6.42	14.018
9.75	2.498	9.63	4.567	9.32	4.233	9.45	7.477
12.67	1.988	12.53	4.250	12.23	3.644	12.35	8.182
22.52	0.983	22.38	1.548	22.05	1.453	22.18	3.554

Steer X83		Steer 53		Steer 71		Steer 127	
Time	[Cr]	Time	[Cr]	Time	[Cr]	Time	[Cr]
0	0	0	0	0	0	0	0
1.82	5.512	1.42	16.912	1.70	3.678	1.25	11.979
3.88	4.208	3.50	15.709	3.78	3.138	3.33	9.173
6.85	2.569	6.48	9.328	6.73	2.320	6.32	8.182
9.88	2.135	9.52	5.810	9.78	2.230	9.35	4.682
12.82	1.854	12.43	6.322	12.72	1.428	12.27	4.147
22.63	0.956	22.27	3.505	22.55	0.582	22.08	1.671

Steer 65		Steer 63		Steer 102		Steer 131	
Time	[Cr]	Time	[Cr]	Time	[Cr]	Time	[Cr]
0	0	0	0	0	0	0	0
1.72	15.384	1.17	13.469	1.48	13.763	1.58	7.035
3.47	11.162	3.25	9.058	3.55	13.483	3.67	8.396
6.48	9.001	6.27	5.531	6.53	10.342	6.63	4.976
9.52	4.924	9.30	3.936	9.57	6.245	9.67	3.472
12.42	5.402	12.18	3.625	12.48	5.249	12.58	2.842
22.25	2.064	22.02	1.791	22.33	3.606	22.43	1.396

[a]Time from dosing in hours [b]Chromium concentration in ppm

INFLUENCE OF LEVEL AND TYPE OF GRAIN SUPPLEMENTATION ON INTAKE AND UTILIZATION OF EARLY-SUMMER, BLUESTEM-RANGE FORAGE BY BEEF STEERS

by

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ABSTRACT

Two experiments using 16 ruminally cannulated steers evaluated the effects of grain supplementation on forage utilization by beef steers consuming early-summer, bluestem- range forage. In Exp. 1, treatments were no supplement, .45, .91 and 1.82 $kg \cdot hd^{-1} \cdot d^{-1}$ of sorghum grain. In Exp. 2, treatments were no supplement, corn, wheat and sorghum grain supplemented at .35% of body weight daily. In each experiment, forage was harvested daily and fed at 115% of the average intake over the previous 7 d. Each experiment included 14-d adaptation, 7-d voluntary intake measurement, 7-d total fecal collection and 1-d ruminal evacuation periods. Additionally, 12 esophageally cannulated steers were used in Exp. 1 to determine effects of supplemental grain on quality of forage selected. Forage dry matter intake, NDF digestibility, ruminal indigestible ADF fill, liquid dilution rate and acetate/propionate were unaffected ($P>.10$) by treatment in both experiments. Similarly, CP concentration in grazed forage was not affected ($P>.10$) by treatment in Exp. 1, although NDF concentration in grazed forage was slightly altered ($P<.05$) by supplementation. Minor depressions in total tract DMD ($P<.05$), starch digestibility ($P<.01$) and pH ($P<.10$) were observed at the two highest levels of supplementation in Exp. 1. In contrast, starch digestibility was slightly elevated ($P<.01$) in Exp. 2 when wheat was supplemented. In conclusion, altering the level or type of grain supplemented to steers consuming early-summer, bluestem-range forage exerted minimal impact on forage utilization.

(Key Words: Beef Cattle, Forage, Supplements, Voluntary Intake, Digestibility, Rumen Fermentation)