EFFECT OF CORN SUPPLEMENTATION ON THE UTILIZATION OF LOW-QUALITY GRASS HAY BY BEEF COWS

By

CHADWICK CHARLES CHASE, JR.

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HAY BY BEEF COWS

Thesis Approved:

Charles A. Hibberd
Thesis Adviser

Robert P. Wettemann

Don Wagner

Norman N. Durham
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

Cow-calf producers typically must supplement cows on native range during the winter months. Since protein is usually the first limiting nutrient, 40% CP cubes are commonly fed. Under certain circumstances, however, increased nutrient requirements for energy may necessitate both energy and protein feeding. High energy, 20% CP cubes formulated with high starch cereal grains, such as corn, are frequently being utilized.

In some cases, feeding small amounts of high energy supplements have increased forage digestibility. Feeding larger quantities, however, has resulted in both a decrease in intake and digestibility of low-quality forage. The depressions in forage digestibility observed when grain supplements are fed has been attributed to their high (60-70%) starch content. The amount of starch which can be fed without severely depressing low-quality forage utilization has not been determined. If increased amounts of starch-containing grain supplements were fed, prediction equations could be developed to determine at which point grain supplements would no longer be beneficial.

The reason for the depression in forage digestibility when grain supplements are fed is unclear, although many suggest that a change in rumen fermentation patterns (i.e. pH) may inhibit celluloytic bacterial growth. Infrequent feeding of grain supplements might allow the ruminal environment to recover on nonfeeding days to enhance overall fiber digestibility. Bicarbonate additions may buffer ruminal pH and could increase fiber digestibility. In some instances, the addition of nitrogen has overcome the adverse effects of starch on fiber digestibility. Thus, isonitrogenous supplements may need to be fed in order to accurately estimate responses to grain feeding.

Attempts to evaluate the effect of supplementation on particulate and liquid passage rates are lacking for beef cows fed low-quality forage supplemented with grain. The combination of rumen measurements and digesta flow rates may help explain intake and digestibility responses.

The objectives of this research were: 1. to evaluate the effect of grain supplementation on intake, rate and extent of digestion and rate of passage of low-quality native grass hay, 2. to compare daily vs alternate day feeding of corn supplements on intake, rate and extent of digestion and rate of passage of low-quality native grass hay and 3. to evaluate potential alleviation of detrimental starch effects on low-quality grass hay intake, and digestibility via intraruminal administration of ammonia and/or buffer compounds.

CHAPTER II

REVIEW OF LITERATURE

Beef Cow Supplementation

Beef cows wintered on native range generally require protein and possibly energy supplementation. In a 15 year study, Waller et al. (1972) reported that dormant native grass in central Oklahoma averaged 2-3% crude protein (CP). A 450 kg dry pregnant cow (middle third of pregnancy) requires a daily intake of 570 g of protein (N.R.C., 1984). A beef cow grazing dormant native range would need to consume 19 kg of forage (4.2% of body weight) to meet her protein requirement from forage alone. Consequently, protein is typically the first limiting nutrient for cattle maintained on low-quality forages. Adequate energy intake is essential for optimum rebreeding performance and calf production (Wiltbank et al., 1962; Furr and Nelson, 1964; Davis et al., 1977). Clanton et al. (1966) reported a number of performance trials with both energy and protein, and stressed that a supplementation program must be matched to the quality of consumed forage. Since dormant winter range is low-quality, general recommendations are to supplement pregnant, nonlactating beef cows with .5-1.0 kg.

$hd^{-1} \cdot d^{-1}$ of a high-quality plant protein meal such as 40% CP cottonseed cake. Under some circumstances, however, larger quantities of a low protein, high energy supplement such as 20% CP cubes may be justified. During periods of drought or overgrazing, the unavailability of forage may necessitate energy feeding. Other conditions which may increase energy demands include environment, milk production and reproductive status (N.R.C., 1985). Regardless of the reason for increased energy demands, the same amount of protein must still be fed. Thus, twice as much of a 20% CP cube should be fed in place of the 40% CP cube.

Supplementing beef cows with high protein supplements tends to increase both intake and utilization of low-quality forage (Cook and Harris, 1968; Kartchner, 1981). When energy becomes limiting, however, 20% CP supplements containing large amounts of corn or other high energy "starchy" carbohydrates are frequently utilized. Supplementing with low protein, high energy, starchy supplements appears to decrease intake and utilization of low-quality forage (Cook and Harris, 1968; Kartchner, 1981).

Intake

Theories regarding the regulation of food intake can be divided into two major categories: physiological and physical. Physiological mechanisms include chemostatic, thermostatic and lipostatic regulation. Physical regulation of feed intake encompasses size of the reticulorumen, digestibility and rate of disappearance of food from the gastrointestinal tract (McDonald et al., 1981). Physical factors probably regulate forage intake when digestibility of the diet is less than 68% (Conrad et al., 1964). Although there is some skepticism as to the actual digestibility value where physiological mechanisms begin to have more pronounced effects, particularly with respect to highly digestible forages, it is generally suggested that intake of low-quality roughages is primarily regulated by physical factors. It is even debatable whether digestibility is the best predictor of forage intake. The rate of passage of undigested feed residues may be more accurate (Ellis, 1978; Van Soest, 1982). Forage intake is limited by an interaction of rumen volume, passage rate and digestion rate (Ellis, 1978). Additional factors that affect food intake include nutrient deficiencies, physiological state and environmental stress. In reality, feed intake is probably not regulated by any one factor but rather through a complex interaction of many physical and physiological effects.

Forage Intake

A vast number of intake estimates for grazing cattle and sheep in the westen United States were reviewed by Cordova et al. (1978). Intakes ranged from 40 to 90 g DM/kg $BW^{.75}$ or from 1.0 to 2.8% body weight for cattle and sheep. Additionally, the decline in intakes were generally due to advancing plant maturity. Lusby et al. (1976) reported intakes for Hereford cows grazing native range during the summer in Oklahoma. Cows supplemented the previous winter with 1.11 or 2.41 kg/d of a 30% CP pellet (44% soybean meal, 30% milo) had daily intakes during the summer of 99 and 84 g DM/kg $BW^{.75}$ (2.2 and 1.8% BW), respectively.

Forage Intake as Influenced by Supplementation

Intake of dormant winter range is enhanced when sheep or cattle are supplemented with high protein feeds (Cook and Harris, 1968; Forero et al., 1980; Kartchner, 1981). Increased intake of low-quality hay with protein supplementation has been reported (Gallup and Briggs, 1948; Elliot, 1967; Hennessy et al., 1983; McCollum and Galyean, 1985). Cereal grain straw intake by sheep or cattle is increased by supplementation with high protein feeds containing natural protein or urea (Fick et al., 1973; Church and Santos, 1981). There are cases, however, where protein supplementation has had little or no effect on forage intake (Weston and Hogan, 1968; Rittenhouse et al., 1970). Rittenhouse et al. (1970) further proposed that the inconsistent intake response was due to the high lignin content of the forage which decreased rate of organic matter removal from the rumen and subsequently limited intake. In most instances, however, protein supplements appear to stimulate forage intake when dietary crude protein is 6-8% or less.

Low protein, high energy supplements formulated with high starch feeds appear to decrease the intake of low quality roughages. Kartchner (1981) supplemented beef cows on winter range (blue grama, western wheatgrass, needle and thread grass and buffalograss) with isocaloric amounts of barley (.60 kg/d) or soybean meal (.61 kg/d). Cows supplemented with barley tended to have less forage intake (6305 g/d) than unsupplemented cows (6813 g/d) while cows supplemented with soybean meal consumed the most forage (8009 g/d). Forero et al. (1980) observed a 2.3 kg/d decrease in forage intake when cows were supplemented with 1.22 kg/d of a 15% CP corn-based (54% corn) supplement when compared to cows fed 1.22 kg/d of a 40% CP supplement. Similar results were obtained by Hennessy et al. (1983) for steers maintained on carpet grass hay (4% CP) supplemented with 0, 600 or 1200 g protein pellets (40% CP) or 0, 560, 1120 g sorghum grain (9% CP). By 48 days, steers fed sorghum grain consumed 29.5% (560 g) and 23% (1120 g) less hay than unsupplemented steers while steers supplemented with protein meal ate 29.5% (600 g) and 43.5% (1200 g) more hay than unsupplemented steers. Similar responses have been noted when high protein supplements were compared to low protein, high energy supplements on an equal weight or energy basis (Cook and Harris, 1968; Rittenhouse et al., 1970).

The effect of feeding grain on forage intake is difficult to generalize because of the wide variation in forage quality. Some evidence suggests that greater depressions in forage intake are observed when better quality hays are supplemented with grain (Blaxter and Wilson, 1963; Murdoch, 1964; Kartchner, 1981; Leibholz, 1984). Additional data suggest that grain feeding results in the greatest depression in forage intake at low dietary crude protein levels (Elliot, 1967; Andrews et al., 1972). Lyons et al. (1970) fed long barley straw (2.8% CP) to Freisian type steers supplemented with 1.37 kg of a grain mix containing 8.9, 13.6, 19.1 or 29.2% CP. A 25% increase in straw consumption was observed when the 13.6% CP supplement was fed but no differences in straw intake occurred when the 13.6, 19.1 or 29.2% CP supplements were fed. Crabtree and Williams (1971) fed ewe lambs either hay (6.7% CP) or oat straw (3.9% CP) supplemented with 0, 100, 200, or 400 g/d of a 19.1% CP supplement. Regression analysis showed that hay intake decreased 3 g/d for each percentage unit increase in grain content (as a percent of total intake). Conversely, straw intake increased until the grain composed 25% of the total dry matter intake and then declined. A direct (kg for kg) substitution of supplement for high quality forage may occur (Taylor and Wilkenson, 1972; Lake et al., 1974). If grain feeding decreases forage intake on an equal basis (i.e. kg for kg), the energy status of supplemented animals should be improved since a kg of grain is higher in energy than a kg of low-quality forage. In order to make reasonable estimates of energy intake and to understand why intake varies depending on how animals are supplemented, forage utilization must be considered.

Forage Digestibility as Influenced by Supplementation

The negative effects on forage digestibility associated with supplementing high starch feeds such as corn have been documented. Cook and Harris (1968) observed decreased cellulose digestibility when corn or barley supplements were fed to sheep wintered on native range in Utah. In almost all cases, an equal amount of protein supplement (by weight) appeared to increase cellulose digestibility. Kartchner (1981) obtained similar results with beef cows wintered on native range supplemented with isocaloric amounts of barley or soybean meal. When forage dry matter digestibility for the supplemented groups was compared to the unsupplemented group (40.6% DMD), a decrease was observed with barley (34.3%) while soybean meal tended to increase forage dry matter digestibility (43.6%). Other investigators have reported similar decreases in low-quality forage digestibility as a result of feeding low protein, high starch supplements (Andrews et al., 1972; Fick et al., 1973; Forero et al., 1980). Rittenhouse et al. (1970) reported a small increase in forage dry matter digestibility when cattle were fed a high protein supplement on winter range, but observed no deleterious effects when supplements composed of corn and corn starch were fed.

Rumen Environment

The rumen environment is a dynamic ecosystem populated by a variety of microorganisms including bacteria, fungi and protozoa. Much research has been centered on the bacteria which comprise the largest group in number. Bacteroides succinogenes, Ruminococcus albus and Ruminococcus flavefacians represent the major cellulose digestors (Hungate, 1966). Of these, B. succinogenes are associated with the digestion of highly ordered cellulose, such as cotton string (Van Gylswyk and Schwartz, 1984). Although some of the cellulolytic bacteria are also starch digestors, many amylolytic species are also present. Bacteria are associated with the liquid and solid phases and epithelium of the rumen (Cheng and Costerton, 1980). Their contribution to the host animal is associated with the fermentation of carbohydrate substrates and the production of microbial cells. Volatile fatty acids, byproducts of the fermentation process, are used as an energy source by the host animal and the microbial cells produced in the process provide a source of high-quality protein for absorption in the small intestine.

The major volatile fatty acids produced during ruminal fermentation are acetate, propionate and butyrate. Acetate and butyrate are considered energy sources for oxidation, while propionate can be used for gluconeogenesis (Van Soest, 1982). Propionate production has been positively related to animal performance. Highly fermentable feeds, such as corn, result in increased VFA production favored towards propionate (Baldwin and Allison, 1983). Typical ruminal acetate/propionate ratios, for cattle fed grain diets are 2:1 while values on a roughage diet are closer to 3:1. An increase in energy efficiency occurs when the proportion of acetate:propionate is decreased (Van Soest, 1982). Hennessy et al. (1983) reported little difference in molar proportions of volatile fatty acids when steers fed hay (4% CP) were supplemented with a high protein supplement (40% CP) or sorghum grain (9% CP). Total volatile fatty acid concentrations, however, were depressed with grain supplementation suggesting decreased ruminal fermentation.

Bacterial Growth

Hespell (1979) partitioned the factors that affect bacterial growth into two categories: physical-chemical and nutritional. Physical-chemical factors include temperature, pH, oxidation-reduction potential and osmotic and hydrostatic pressures. Cellulolytic bacteria are quite sensitive to ruminal pH. Ruminal pH less than 6.2 may inhibit cellulolytic bacterial growth, whereas amylolytic species can thrive at a pH of 5.6 or less (Orskov, 1982). Highly fermentable feeds such as corn can produce acid conditions in the rumen. Absorption of volatile fatty acids combined with salivary buffers are mechanisms that attempt to maintain the pH at equilibrium (6.7-7.0). On a hay diet, maximal volatile fatty acid concentrations correspond with a decrease in pH which normally occurs four hours postfeeding (Van Soest, 1982). When concentrates are fed, maximum VFA and hydronium ion concentrations may occur 2-3 hours postfeeding.

Bacteria require many cofactors such as nitrogen, branched-chain volatile fatty acids, minerals, vitamins and energy (Hungate, 1966). The amino form of nitrogen utilized by cellulolytic bacteria is ammonia. Some bacteria, however, require amino acids and/or peptides (Hungate, 1966). Bacterial requirements for nitrogen can be satisfied by exogenous feed sources and endogenous recycling of urea through saliva (Nolan et al., 1973). Since rumen ammonia is an intermediate in both the degradation and assimiliation of dietary nitrogen, rumen ammonia levels can be used as an index for predicting the nitrogen status of rumen bacteria (Kropp et al., 1977). Although estimates concerning the optimal concentration of rumen ammonia for maximum bacterial growth are variable and subject to considerable discussion, Satter and Slyter (1974) reported 2 mg NH_3-N/dl as the limiting amount while 5 mg NH_3 -N/dl is required for maximum bacterial growth. Subsequent in vivo studies verified their initial data (Slyter et al., 1979). Low (< 1 mg/dl) rumen ammonia levels have been observed when low protein, high starch supplements were fed (Hennessy et al., 1983). A nitrogen deficiency for microbial growth and/or metabolic requirements of the host, even with adequate energy supply, may limit intake of low-quality forage. Furthermore, a nitrogen deficiency may explain the greater intake of low-quality forages when high protein supplements are used.

Starch Effects on Rumen Function

Cellulose digestibility in vitro was enhanced when small amounts of available carbohydrates were added to the medium (Arias et al., 1951). Adding larger quantities, however, depressed in vitro cellulose digestibility. The addition of 2 g of starch to 2 g of cellulose totally inhibited cellulose digestion (el-Shazly et al., 1961). In vivo digestibility trials have substantiated the differences obtained in vitro. Burroughs et al. (1949) fed steers a mixed diet of corn cobs (1.8 kg) and alfalfa (.4 kg) supplemented with 1.8 kg starch and observed a 50% reduction in dry matter digestibility. When alfalfa (1.8 kg) alone was fed and supplemented with 1.8 kg starch, a 4% reduction in dry matter digestibility was observed, while consumption of corn cobs (1.8 kg) and dried skim milk (.7 kg) in combination with 1.8 kg starch decreased dry matter digestibility 39%. Glenn and Ely (1981) observed slight differences in acid detergent fiber digestibility when lambs fed 700 g/d fescue (71.1%) were compared to those receiving an additional 63 g starch (70.4%). Supplementing lambs fed Coastal bermudagrass hay (12.1% CP) with 200 g glucose reduced both cellulose (50.5 vs 36.8%) and hemicellulose (63.6 vs 54.8%) digestibility (Amos and Evans, 1980). A number of possible explanations have been proposed to account for the depressed cellulose digestibility associated with supplemental starch feeding: (1) starch microbes produce an inhibitor, (2) decreased pH, (3) competition for essential nutrients or (4) change in the microbial population (el-Shazly et al., 1961). An inhibitor produced by starch-digesting microbes has not been found. Rather, an increase in fermentation products, which occurs with starch feeding, has been associated with a decrease in ruminal pH. The decrease in ruminal pH, if severe enough, adversely affects cellulolytic bacteria which may result in decreased cellulose digestibility. When pH has been controlled in in vitro systems, the deleterious effects of starch on fiber digestibility are still evident (el-Shazly et al., 1961). Burroughs et al. (1950) observed a decrease in pH when casein was added to cellulose substrates in vitro. Cellulose digestibility was increased, a likely result of increased VFA production due to enhanced cellulose fermentation. Concentrate feeding results in reduced pH and could contribute to decreased rumen pH and cellulose fermentation (Church, 1976).

Microbial type and numbers were reduced when starch was added to low protein diets, suggesting that a change in the microbial population might be associated with decreased cellulose digestibility (Williams et al., 1953). Van

Gylswyk and Schwartz (1984), however, suggested that the depression in microbial numbers is probably not of sufficient magnitude to account for the decrease in cellulose digestibility associated with starch feeding. Competition between the starch and cellulose-fermenting bacteria for essential nutrients is certainly a possible explanation for the decreased cellulose digestibility observed when forage diets are supplemented with starch. Preferential digestion of starch before cellulose has been suggested for species of bacteria capable of digesting both (Mertens and Loften, 1980). During rapid fermentation, amylolytic bacteria may dominate the available nitrogen supply. At a later time, when cellulolysis begins, cellulolytic bacteria may be starved for nitrogen. Previous reports suggest decreased protein digestibility when ruminants fed high-forage diets are supplemented with readily available carbohydrates (Amos and Evans, 1980; Glenn and Ely, 1981). Increased ruminal escape of undigested fiber could increase both lower gut fermentation and microbial N excretion resulting in misleading apparent crude protein digestibility estimates. Although there is evidence suggesting that the addition of protein may alleviate much of the decrease in fiber digestibility associated with starch feeding (Burroughs et al., 1950; Elliot, 1967; Stern et al., 1978), others have obtained conflicting results (Arias et al., 1951; Glenn and Ely, 1981). A positive response, however, would not be expected if dietary protein was not limiting (>6-8% CP). Stern et al., (1978) postulated that fiber diets with the correct nitrogen to energy ratio should maximize microbial protein production and cellulolysis.

Ruminal Digestion

Digestion rate, the amount of feed digested per unit of time, is related to the composition and quality of the nutrients in the diet (Van Soest, 1982). Other factors related to digestion rate include lag time and potential extent of digestion (Mertens, 1977). Lag time is essentially the time from which a particle enters the rumen until digestion begins. A delay in digestion can be attributed to the microbial population as well as any physical or chemical processes, such as microbial attachment, which must be carried out in order for digestion to begin (Van Soest, 1982). Increased lag times are rather common when highly purified cellulose substrates are offered such as cotton string (Van Soest, 1982). The potential extent of digestion depends on the amount and interaction of undigestible feed constituents such as lignin with fermentable substrates such as cellulose (Mertens, 1977).

Passage Rate

Collectively, digestion rate and passage rate influence ruminal digestion. At the rumen, however, passage rate competes with digestion rate for fiber particles. Passage rate varies depending upon the fraction of digesta considered; the liquid or solid phase. The determinants of fluid dilution rate include the influx of fluids and rumen volume while particulate passage rate determinants are particle size, density and wettability (Owens and Isaacson 1977). Furthermore, they conclude that an increase in turnover rate of the liquid and solid phases will result in: (1) increased microbial protein production, (2) increased ruminal escape of feed protein, starch and fiber, (3) decreased microbial stored carbohydrate escape, (4) decreased propionate, and increased acetate, butyrate and methane production. An increase in microbial protein production is probably attributable to an increase in microbial efficiency due to decreased generation interval (Van Soest, 1982). Hespell (1979) postulates that as long as the maintenance requirements of the bacteria do not change, an increase in microbial growth rate, due to an increased dilution rate, would be advantageous with low-quality forage diets due to a net increase in microbial protein synthesis. Advantages with increased ruminal escape of protein and starch would also be observed since both can be more efficiently utilized if absorbed directly from the small intestine. On high fiber diets, however, the quantity of starch entering the rumen is low. Consequently, it is highly unlikely that large amounts of dietary starch would escape ruminal fermentation. A ruminal nitrogen deficiency could occur when slowly degradable proteins, such as corn protein, comprise a major portion of the supplemental protein (Owens and Isaacson, 1977). An increase in fiber passage, from a forage utilization viewpoint, would be disadvantageous because forage digestion is dependent on residence in the rumen. Additionally, if the ruminal acetate: propionate ratio is increased, a decrease in efficiency may result. Altering passage rates, therefore, involves many interactions and would logically affect forage intake.

Passage Rate Estimates

As previously discussed, passage rate seems to be associated with intake of low-quality roughages. Varga and Prigge (1982) estimated both liquid and particulate passage rates utilizing sheep fed two levels of either orchardgrass or alfalfa hay. At the higher level of intake, solid turnover rate tended to be increased (5.3 vs 6.6%/h) and a two-fold increase in liquid turnover rate occurred (3.3 vs 7.2%/h) when averaged over forage species. They further suggested that an increase in intake affects liquid turnover rate more dramatically than particulate turnover rate. Mudgal et al. (1982) reported similar results when two levels of alfalfa pellets were fed to sheep. At the higher level of intake, liquid dilution rate was increased by 54% and solid turnover rate by 25%.

Intake and flow rates were measured on ewes fed Coastal bermudagrass pellets and a 14% CP corn-soybean meal supplement before and after lambing (Pond et al., 1984). A 59% increase in intake was accompanied by an increased liquid turnover rate (8 to 10%/h) and increased solid turnover rate (4 to 5%/h) after ewes lambed.

A relationship between forage intake and passage rates appears to exist (Ellis, 1978). Furthermore, there may be a more pronounced effect upon the liquid fraction. Since rumen volume has also been implicated as an important determinant of passage rate, it should also be considered. Alfalfa hay fed at 1.40, 1.65, 1.90, 2.15 and 2.40% of body weight to mature Hereford steers resulted in a linear increase in liquid dilution rate, 4.3 to 7.2%/h, and a linear decrease in rumen liquid volume, 149.3 to 135.1 l (Adams and Kartchner, 1984). Galyean et al. (1979) observed a decrease in rumen volume as concentrate intake increased, and suggested that the liquid fraction may be forced from the rumen by an increase in dry matter content.

Increased forage intake observed with protein supplementation has been suggested to be associated with increased passage rate (Ellis, 1978). McCollum and Galyean (1985) observed a 27% increase in hay intake (6.1% CP) when steers were supplemented with 800 g of cottonseed meal. Although rumen volume (24.8 vs 26.4 l) did not differ, both liquid dilution rate (8.8 vs 10.5%/h) and rate of particulate passage (2.9 vs 4.5%/h) were increased by cottonseed meal supplementation. Furthermore, rate of potentially digested dry matter tended to increase when inoculum was used from protein supplemented steers (3.9 vs 4.5%/h). This suggests that nitrogen may have been limiting in unsupplemented cattle and with protein supplementation, rumen microbial nitrogen requirements were satisfied resulting in increased forage digestion rate, passage rate and feed intake.

An increase in dry matter intake and an increase in the roughage level of a diet should result in an increase in fluid dilution rate (Owens and Isaacson, 1977). In a review of seven trials, Estell and Galyean (1985) showed a range of fluid dilution rates from 4.6 to 11.1%/h with the lower dilution rates generally occuring at higher concentrate levels. Furthermore, metabolizable energy content of the diet was positively related to rumen fluid volume, an observation that is in direct conflict to previous suggestions by Galyean et al. (1979).

Energy Intake

Cook and Harris (1968) supplemented sheep grazing winter native range with corn or barley supplements and found that the resultant decrease in forage intake and digestibility could result in greater metabolizable energy (ME) deficiencies in supplemented animals than those consuming forage alone. Since high-protein supplements generally stimulate both forage intake and digestibility, protein supplemented sheep had the greatest total ME intake. When Kartchner (1981) supplemented beef cows on native range with isocaloric amounts of soybean meal or barley, estimated total digestible energy (DE) intakes were 11.74 (controls), 11.52 (barley) and 16.87 Mcal/day (cottonseed meal). Changes in weight and condition scores paralleled estimated DE intakes.

Elliot (1967) fed 18-month old heifers grass hay (3.4 % CP, 52% TDN) supplemented with four different amounts of corn-based feeds each providing three different levels of protein (1.3, 2.6 and 3.9 g DCP·kg $BW^{-.73}\cdot d^{-1}$). Although hay intake was reduced, TDN and DE intakes increased with increasing amount of supplement. Greater responses were noted at higher protein levels; when equivalent amounts of supplement were fed, TDN and DE intakes increased as dietary protein increased. Increased DE intake was reported by Crabtree and Williams (1977) when ewe lambs fed oat straw (3.9% CP) or hay (6.7% CP) were supplemented with increasing amounts (0 to 400 g/d) of a 19% CP supplement (wheat 25%, corn 20%, corn gluten feed 15%, wheat feed 4%, molasses 5% and soybean meal 18%) despite decreases in both straw (242 to 163 g/d) and hay (451 to 296 g/d) intake. These results suggest that the effect of grain feeding on total energy intake is difficult to assess. The response seems to be dependent on the quality of the forage. The interaction with dietary crude protein suggests that isonitrogenous supplements should be compared.

Feeding Frequency

Feeding high protein supplements on an infrequent basis, i.e., every third day, may be as effective as daily feeding (Church, 1972). Cows wintered on bluestem pastures supplemented with cottonseed meal at 2, 4 or 6 day intervals had similar winter weight losses (Pope et al., 1963). No differences in dry matter intake or fiber digestibilities were observed when steers fed a basal diet of native tall-grass hay (7.9% CP) were supplemented with cottonseed meal every 1, 2 or 4 days (Coleman and Wyatt, 1982). Little information, however, is available on the effect of feeding high-starch supplements on an infrequent basis (Raleigh and Lesperance, 1972). Infrequent feeding of high starch supplements might be advantageous, not only from an economic standpoint, but also from a forage utilization standpoint. By feeding on alternate days, the inhibition of cellulose digestibility due to starch feeding may occur only for one day allowing the ruminal environment to recover for the second day. Total cellulose digestibility and intake could be enhanced.

In summary, forage intake and digestibility has been enhanced and depressed when grain supplements were fed. Responses seem to be dependent upon the quality of the forage, protein content of the supplement and how much of the supplement was fed. The reason for the decreased forage intake and digestibility responses has been attributed to low ruminal pH and/or competition between cellulolytic and amylolytic bacteria for available nutrients. The following study was conducted to examine the effects of corn supplementation on native grass hay intake and digestibility with special consideration given to supplemental protein.

CHAPTER III

UTILIZATION OF LOW-QUALITY NATIVE GRASS HAY BY BEEF COWS FED INCREMENTAL QUANTITIES OF CORN GRAIN

Summary

The effect of corn supplementation on intake, digestibility and passage rate of low-quality native grass hay was determined by feeding four isonitrogenous supplements providing 0, 1, 2 or 3 kg of ground corn/d to twelve Hereford cows and four ruminally cannulated mature Hereford x Angus heifers in four simultaneous 4 x 4 Latin squares. Native grass hay harvested in November (4.2% CP, 52.5% ADF and 5.0% AIA) was individually offered free choice. Digestibility of hemicellulose and cellulose decreased linearly ($P<.0001$) as the amount of supplemental corn increased. A cubic response ($P<.05$) was observed for estimated hay digestibility (33.6, 33.5, 24.6 and 23.2% for 0 through 3 kg corn, respectively). Hay intake decreased linearly with increased corn supplementation (8.7 to 5.1 kg/d, $P<.0001$). A cubic response ($P<.005$) was observed for digestible dry matter intake (3.5, 3.9, 3.3 and 3.4 kg/d) suggesting that the energy balance of cattle fed 2 or 3 kg corn/d was little, if any, different than the Control. Particulate passage rate decreased linearly ($P<.05$) from

3.90 to 3.68%/h as increasing quantities of corn were fed. Mean ruminal NH_3-N concentrations decreased linearly (P<.05) with corn feeding and remained <1 mg/dl throughout the day when 3 kg corn/d was fed. Feeding more than 1 kg corn/d results in such severe depressions in forage intake and utilization that cow performance may be less than expected.

Introduction

Small amounts (50-100 g) of readily available carbohydrates appear to stimulate cellulose digestibility in vivo (Fick et al., 1973) and in vitro (Arias et al., 1951). Feeding larger quantities (200-1800 g), however, can depress both forage intake and digestibility (Burroughs et al., 1949; Amos and Evans, 1980). Adding large quantities of starch to cellulose substrates in vitro severely depresses cellulose digestibility (el-Shazly et al., 1961; Stern et al., 1978).

Although previous studies have evaluated isocaloric high protein versus low protein, high starch supplements such as corn or barley, few studies have considered isonitrogenous supplements providing different quantities of starch (Cook and Harris, 1968; Rittenhouse et al., 1970; Kartchner, 1981; Forero et al., 1980). Additional protein may alleviate some detrimental starch effects although previous studies have yielded conflicting results (Burroughs et al., 1949; Campbell et al., 1969; Hennessy et al., 1983). Although a number of explanations for the depression in cellulose digestibility occurring in vitro were summarized by el-Shazly et al. (1961), few experiments in vivo have tried to elucidate the problem studying ruminal and digestive parameters such as passage rate applicable to range cattle. Furthermore, few attempts have been made to deduce a prediction curve designed to estimate responses in forage intake and utilization when various amounts of grain supplements containing starch are fed to cattle consuming low-quality forage.

The objectives of this experiment were to evaluate the effect of feeding four isonitrogenous amounts of corn on: (1) intake and digestibility of low-quality native grass hay and (2) ruminal and digestive parameters, in order that prediction equations could be developed to estimate overall cow productivity over a range of starch intakes.

Materials and Methods

Twelve mature, nonpregnant Hereford cows (average weight, 395 kg) were blocked by weight into three groups. A fourth group consisted of four ruminally cannulated mature Angus x Hereford heifers (average weight, 328 kg). Animals were arranged in four simultaneous 4 x 4 Latin squares. Cattle were individually penned and allowed free access to coarsely chopped (5 cm screen) low quality native grass hay harvested in November. Four isonitrogenous supplements (treatments) were formulated to provide approximately 0, 1, 2 or 3 kg of ground corn hd/d (Table I). Supplements were

TABLE I

INGREDIENT COMPOSITION OF SUPPLEMENTS (DM BASIS)

Item	Corn, kg/d			
	0	1	2	3
Ingredient (IFN), g/d[a]				
Corn, ground (4-02-931)	0	879	1747	2624
Cottonseed meal (5-01-621)	602	404	198	0
Dicalcium phosphate (6-01-080)	76	76	76	76
Trace mineralized salt[b]	25	25	25	25
Potassium chloride (6-03-755)	18	18	18	18
Vitamin A (7-05-243)	20,000 IU	20,000 IU	20,000 IU	20,000 IU
Total	722	1,403	2,065	2,744
Total, $g \cdot kg\ BW^{-.75} \cdot d^{-1}$	8.4	16.3	24.0	31.9

[a] Estimated.
[b] Trace mineralized salt contained 16% zinc, 12% iron, 6% manganese, 3% magnesium, 1% copper, 1% potassium, .6% iodine, .3% cobalt and 1% mineral oil.

TABLE II

NUTRIENT COMPOSITION OF HAY AND SUPPLEMENTS (DM BASIS)

Item	Hay	Corn, kg/d 0	1	2	3
Nutrient, %					
Crude protein	4.2	35.8	19.2	13.3	8.8
Neutral detergent fiber	72.1	25.2	19.9	18.1	14.2
Hemicellulose	19.5	8.6	11.6	13.1	11.2
Acid detergent fiber	52.6	16.6	8.3	5.0	3.0
Cellulose	36.6	11.7	5.1	1.9	ND
Lignin	11.6	4.3	3.0	1.5	ND
Starch	1.2	4.3	42.2	57.3	69.0
Ash	7.7	21.8	11.0	6.7	5.8
Acid insoluble ash	5.02	.31	.15	.11	.10
Nutrient consumption, g/d					
Crude protein		259	269	274	241
Starch		31	663	1340	2151
TDN[a]		458	1098	1723	2362

[a]Estimated.

fed once daily (0800 h). Fourteen day experimental periods consisted of 10 days of adaptation and four days of sampling. On d 10-13 of each period, supplements, hay and ort hay (from d 10) were weighed and sampled to determine nutrient intake. Fecal grab samples were obtained twice daily (0800 and 2000 h) on d 11-14. Feed and hay samples were composited by period while both ort hay and fecal samples were composited by animal within each period. Fecal samples were dried at 80 C for 72 h in a forced air oven. All samples were ground using a Wiley Mill equipped with a 1 mm screen and stored at -15 C. Sample analyses included crude protein (CP) by Kjeldahl (A.O.A.C., 1975), acid detergent fiber (ADF), permanganate lignin (PL), neutral detergent fiber (NDF) (Goering and Van Soest, 1970), and acid insoluble ash (AIA) using the 2 N HCl method (Van Keulen and Young, 1977). All samples, excluding the ort hay, were analyzed for starch content (MacRae and Armstrong, 1968). Hemicellulose was determined by difference of NDF and ADF. Nutrient digestion coefficients were calculated by the marker ratio technique using AIA as the reference marker (Schneider and Flatt, 1975).

All cattle were dosed on d 9 (0800 h) with 250 g of 1.2% Ytterbium (Yb) labelled native grass hay prepared by the immersion technique (Teeter et al., 1984). Fecal grab samples were obtained at 0, 36, 48, 72 and 96 h post dosing. Samples were dried at 80 C for 72 h and ground through a Wiley Mill equipped with a 2 mm screen. Zero h samples were composited by period to be used as standards. Two g fecal samples were dried at 100 C overnight, ashed at 500 C for 8 h, digested in 20 ml of 3.1 N HCl for 24 h and diluted to either 100 ml (0, 36 and 48 h) or 25 ml (72 and 96 h) using a dilution mix (10% HCl, 1 mg KCl/l). Diluted samples were then analyzed for Yb concentration by atomic-absorption spectrophotometry using a nitrous oxide-acetylene flame. Particulate passage rate was estimated from the slope of the regression of the natural logarithm of Yb concentration over time. Since the 36 h values appeared to be on the upslope of the fecal Yb excretion curve, they were deleted from the regression equations.

Rumen sampling of cannulated heifers was performed on d 14 of each period at 0, 3, 6, 9, 12, 18 and 24 h postfeeding. Rumen fluid (500 ml) was obtained from the same location (ventral sac anterior to the ventral coronary groove) and pH was immediately measured using a combination electrode. A 250 ml aliquot was strained through four layers of cheesecloth and acidified using 20% sulfuric acid (1 ml 20% H_2SO_4/50 ml rumen fluid) and frozen at -15 C. Inconsistent pH meter performance in periods 1 and 2 resulted in inaccurate pH data. Consequently, pH data is reported from periods 3 and 4 only. Ruminal ammonia concentrations were determined using 60 ml of rumen fluid in the MgO distillation procedure (A.O.A.C., 1975). The remaining rumen fluid was centrifuged at 1000 g for 10 min and composited across time for each animal (16 composites:1

for each animal for 4 periods). Composite samples were subsampled (5 ml) and combined with 1 ml of 20% meta-phosphoric-2-ethylbutyric acid and centrifuged at 25,000 g for 20 min. Supernatant (2 ul) was then analyzed by standard gas chromotography techniques for volatile fatty acid concentrations.

Dacron bags (6 x 10 cm; pore size 25-75 um) containing 1 g of native grass hay ground through a 2 mm screen were tied to a weighted string (50 cm; 2-2 cm nuts attached; 2 bags/string). One string was placed in each animal beginning on d 10 at 0800 h (96 h) and at times corresponding to 6, 12, 18, 24 and 48 h of incubation. All bags were removed at 0800 h on d 15. Bags were immediately washed with lukewarm water until bag effluent was clean. Bags containing hay not subjected to the rumen were washed in a similar manner to estimate washout. Each bag was then dried at 80 C for 72 h and hay disappearance determined for each time. The contents from each bag were frozen (-15 C) and later analyzed for NDF (Goering and Van Soest, 1970). Percent digestible hay and NDF remaining were calculated by correcting percent residual hay remaining at 6, 12, 18, 24 and 48 h by the percent remaining at 96 h. Rate of digestible hay and NDF disappearance were estimated from the slope of the regression of the natural logarithm of the percent digestible variable (hay or NDF) remaining over time (6-48 h).

During the last period, a cow on the Control (no corn) treatment suffered diarrhea and fecal samples could not be obtained. Treatment means for the missing subcell were estimated using a procedure described by De Lury (1946).

Digestibility and intake data were described by the model:

$Y_{ijkl} = u + S_i + P_j + A(S)_k + T_l + S*P + S*T + E_{ijkl}$,

where Y_{ijkl} is the variable of interest, S is square, P is period, A(S) is animal within square, T is treatment, S*P is the square X period interaction and S*T is the square X treatment interaction. All other interactions were assumed to be zero. Rumen data were analyzed by time for period, animal and treatment effects. Responses to grain supplementation were evaluated using orthogonal contrasts for linear, quadratic and cubic effects (Steel and Torrie, 1980).

Results and Discussion

The native grass hay fed in this study was specifically harvested in mid-November from a field which had not been cut for three consecutive years, to achieve similar quality characteristics as dormant winter range. Waller et al. (1972) in a 15 year study (1957-1972) conducted in central Oklahoma described average composition of big bluestem, little bluestem, indiangrass and switchgrass as having an average CP content of 3.6% in the fall (Sept. to Nov.) to 2.5% in the winter (Dec. to Mar.) and an average crude fiber content of 36% to 39% for fall and winter, respectively. Although the CP content of the hay in this study was slightly higher (4.2%), acid detergent fiber (52.6%) and lignin (11.6%) reflect the hay's low quality characteristics.

Digestibility of major cell wall fiber constituents decreased linearly ($P<.0001$) as the amount of supplemental corn increased (Table III). Hemicellulose digestibility appeared to be most affected, with values ranging from 56.3% when no corn was fed to 24.5% for cattle fed 3 kg corn, a 56% reduction. A smaller reduction (38%) occurred for cellulose digestibility (46.2 to 28.6%). A cubic response ($P<.05$) was observed for estimated hay digestibility (assuming a supplement digestibility of 80%), a trend most closely associated with acid detergent fiber digestibility.

With each added increment of corn, cattle consumed an increased quantity of starch. Severe depression and even total inhibition of cellulose digestibility have been reported when large quantities of starch have been added to cellulose substrates in vitro (el-Shazly et al., 1961; Stern et al., 1978). Burroughs et al. (1949) fed 1.8 kg starch to steers consuming corncobs (1.8 kg) and alfalfa (.4 kg) and reported a 50% reduction in dry matter digestibility. Supplementing lambs maintained on Coastal bermudagrass hay (12.1% CP) with 200 g glucose reduced both cellulose (50.5 vs 36.8%) and hemicellulose (63.6 vs 54.8%) digestibility (Amos and Evans, 1980). The depression in hay and fiber

TABLE III

DIGESTIBILITY COEFFICIENTS AS INFLUENCED BY THE AMOUNT OF CORN SUPPLEMENTED TO CATTLE FED NATIVE GRASS HAY

	Corn, kg/d				
Digestibility, %	0	1	2	3	SE
Neutral detergent fiber[a]	39.6	38.5	29.9	25.6	1.42
Acid detergent fiber[b]	33.5	33.2	27.2	25.9	1.16
Hemicellulose[c]	56.3	51.6	35.9	24.5	2.47
Cellulose[c]	46.2	42.9	34.0	28.6	1.67
Lignin	13.7	21.8	18.7	21.3	3.41
Hay[b]	33.6	33.5	24.6	23.2	1.38
Apparent dry matter[b]	37.2	40.8	39.3	44.2	1.06
Apparent organic matter[b]	39.5	43.1	41.4	46.0	1.05
Apparent crude protein[d]	35.9	35.7	31.1	30.1	1.75
Starch[a]	58.0	85.0	86.3	88.4	3.20

[a]Cubic ($P<.10$).
[b]Cubic ($P<.05$).
[c]Linear ($P<.0001$).
[d]Linear ($P<.05$).

constituent digestibilities observed in this study occurred as the amount of supplemental corn increased, a reflection of the high starch content of corn. Cubic responses ($P<.10$) to supplemental grain for NDF, ADF and hay digestibilities suggest that small quantities of grain (< 1 kg/d) minimally affect hay utilization while larger quantities (2 or 3 kg/d) may seriously depress hay digestibility. The greater reduction in hemicellulose digestibility compared to cellulose digestibility may be related to the more variable, highly lignified structure of hemicellulose (Van Soest, 1982). Starch may affect the hemicellulose digesting bacteria to a greater extent than cellulose bacteria possibly depressing their ability to cleave ligno-hemicellulosic bonds.

A positive cubic response ($P<.10$) was observed for digestibility of dry matter, organic matter and starch as cattle were fed increasing amounts of corn (Table III). Since supplements are highly digestible, increased dry matter and organic matter digestibility would be expected as the amount of supplemental corn increased. The cubic response in apparent dry matter digestibility was a result of a decrease at the 2 kg corn suggesting a depression in some other dietary constituent if supplement digestibility does not change. Indeed, the largest depression in digestibility of all fiber components was observed between 1 and 2 kg of supplemental corn suggesting a possible threshold for starch toleration by ruminal microorganisms.

The response observed for starch digestibility seems to be related to the amount of readily available starch in the diet since starch digestibility was low when no corn was fed (55.6%) but high when the starch containing corn supplements were fed (>85%).

Hay and total dry matter intakes decreased linearly ($P<.0001$) as cattle were supplemented with increasing amounts of corn (Table IV). A cubic response ($P<.005$) was observed for digestible dry matter intake. Intake and digestibility of hay followed similar trends suggesting that intake may have been primarily limited by bulk fill or the amount of undigested hay in the gastrointestinal tract. Feeding 1 kg corn appeared to have the least dramatic effect, decreasing hay intake 585 g when compared to control (no corn) and would be expected since hay digestibilities were similar (33.6 and 33.5% for 0 and 1 kg corn, respectively). Because cattle fed 1 kg corn received an additional 681 g of supplement over the control (no corn) total dry matter intakes were 9.5 kg for the control (no corn) and 9.6 kg for cattle fed 1 kg corn. When more than 1 kg of corn was fed, supplements were unequally substituted for hay (by weight) which resulted in lower total dry matter intake. The unequal replacement of hay for supplement was so extreme that although cattle fed 2 and 3 kg of corn were consuming a diet of greater digestibility than those fed no corn (DMD: 39.3, 44.2 vs 37.2), digestible dry matter intake (DDMI = (hay + supplement) * DMD) did not appear to be

TABLE IV

INTAKE AND PARTICULATE PASSAGE RATE ESTIMATES FOR CATTLE FED NATIVE GRASS HAY SUPPLEMENTED WITH INCREASING QUANTITIES OF CORN

Item	Corn, kg/d				
	0	1	2	3	SE
Intake					
Hay, g/d[a]	8762	8177	6402	5065	276.4
Hay, $g \cdot kg\ BW^{-.75} \cdot d^{-1}$[a]	101.6	94.7	73.7	58.4	3.18
Hay, % BW/d[a]	2.30	2.14	1.66	1.32	.072
Total dry matter, g/d[a]	9484	9580	8467	7809	276.4
Digestible dry matter, g/d[b]	3531	3910	3308	3393	114.1
Particulate passage rate, %/h[c]	3.90	4.04	3.72	3.68	.100

[a]Linear ($P<.0001$).
[b]Cubic ($P<.005$).
[c]Linear ($P<.05$).

enhanced (3308, 3393 and 3519 g for cattle fed 2, 3 and 0 kg corn, respectively). Feeding 1 kg corn, however, appeared to improve digestible dry matter intake (3910 vs 3519 g) when compared to the control (no corn).

Other investigators have reported depressions in both forage intake and digestibility when ruminants grazing low-quality dormant ranges have been supplemented with corn or barley supplements (Cook and Harris, 1968; Kartchner, 1981). Rittenhouse et al. (1970) supplemented cattle grazing dormant winter range with corn-based supplements or an isocaloric amount of a high-protein supplement and observed small depressions in forage intake with no deleterious effects on forage digestibility when the corn supplements were fed.

Particulate passage rate decreased linearly ($P<.05$) as the amount of supplemental corn increased (Table IV). Ruminal rate of digestible hay and NDF disappearance also decreased linearly ($P<.05$) as the heifers were supplemented with increasing increments of corn (Table V). Ellis (1978) suggested that forage intake is regulated by rumen fill, particulate passage and ruminal digestion rate. Recent evidence suggests that the increase in forage intake observed with protein supplementation is associated with an increase in particulate passage rate (McCollum and Galyean, 1985). In the present study, particulate passage rate decreased linearly ($P<.05$) as supplemental corn increased, a similar trend to the response in forage intake. The slight

TABLE V

RUMINAL PARAMETERS FOR HEIFERS FED INCREASING QUANTITIES OF CORN

Ruminal parameter	Corn, kg/d 0	1	2	3	SE
Ammonia-N, mg/dl[a]	2.20	1.12	.88	.61	.330
Total VFA, mM	51.1	51.1	53.5	53.2	2.00
Acetate, mol/100 mol[a]	73.9	72.8	67.8	66.8	1.87
Propionate, mol/100 mol	20.0	20.1	23.0	22.9	1.44
Butyrate, mol/100 mol[a]	5.7	6.8	7.2	7.6	.48
Acetate/propionate ratio[b]	3.8	3.6	3.0	3.0	.31
Rate of digestible hay disappearance, %/h[a]	3.8	3.3	2.0	1.5	.54
Rate of digestible NDF disappearance, %/h[a]	3.9	3.3	2.1	1.4	.54

[a]Linear ($P<.05$).
[b]Linear ($P<.10$).

depression in hay intake (.5 kg) that occurred when 1 kg corn was fed was not reflected in particulate passage rate. Rate of digestible hay and NDF disappearance mimicked each other, with depressions occurring when additional increments of corn were fed. The depression in particulate passage rate and rate of DM and NDF disappearance apparently complement each other and help explain the depression in both hay intake and digestibility previously noted.

A wider range in ruminal pH was observed in a given 24 h period when heifers were fed corn (Figure 1). Although feeding 3 kg corn depressed ruminal pH below 6.3 for a short time (at 6 h post-feeding), there was no evidence that ruminal pH dropped below 6.2, a pH suggested as the critical point for cellulolytic bacteria (Orskov, 1982). Heifers fed 2 or 3 kg corn, however, had ruminal pH values below the Control (no corn) heifers for at least 9 h (between 3 and 12 h post-feeding). Mean ruminal ammonia-N (NH_3-N) concentrations decreased linearly ($P<.05$) as the amount of corn fed increased (Table V). Furthermore, when corn was fed, mean ruminal NH_3-N concentrations were below the recommended minimum for maximum microbial growth (2-5 mg/dl) as suggested by Satter and Slyter, (1974). In fact, feeding 3 kg corn resulted in ruminal NH_3-N concentrations < 1 mg/dl at all sampling times (Figure 2). Since many of the cellulolytic bacteria require NH_3 for microbial growth (Hungate, 1966), the low ruminal NH_3-N values observed when corn was fed may help explain the decreased cellulose

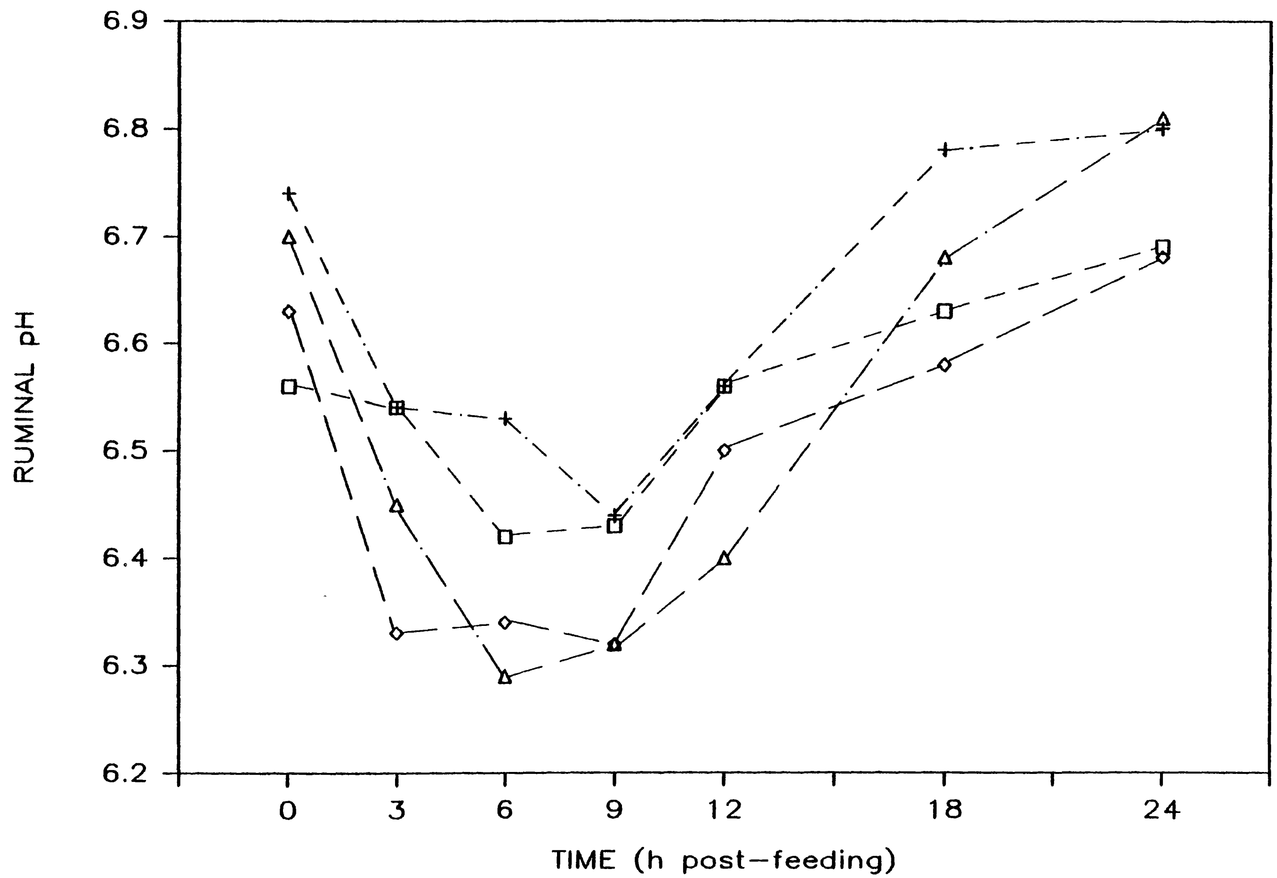

Figure 1. Diurnal Variation in Ruminal pH For Heifers Fed Increasing Quantities of Corn (□—□ 0 kg; +—·+ 1 kg; ◇—◇ 2 kg; △—·△ 3 kg corn)

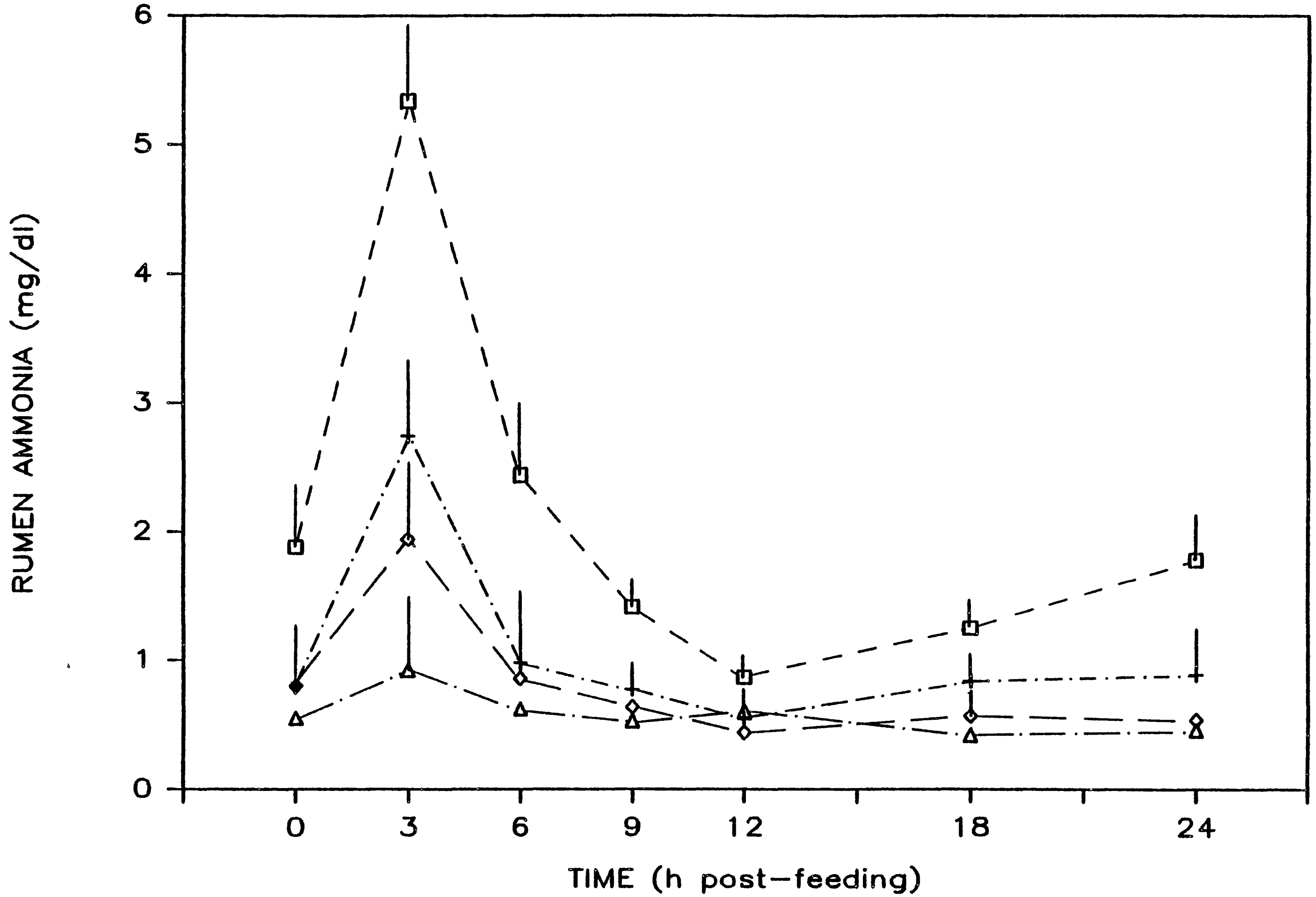

Figure 2. Diurnal Variation Rumen Ammonia Concentrations mg/dl) For Heifers Fed Increasing Quantities of Corn (□-□ 0 kg; +—·+ 1 kg; ◇—◇ 2 kg; △—·△4 kg corn)

digestibility observed in this study. Perhaps nitrogen supplied from the corn was not as available as that from cottonseed meal. Alternatively, direct competition for nitrogen between the amylolytic and cellulolytic bacteria may be responsible. Hennessy et al. (1983) observed similar ruminal NH_3-N concentrations (< 1 mg/dl) when cattle fed low-quality grass hay were supplemented with sorghum grain (9% CP).

Treatment did not influence total VFA or propionate concentrations in the rumen (Table V). As heifers were supplemented with more corn, acetate linearly decreased ($P<.05$) while butyrate linearly increased ($P<.05$). Furthermore, the acetate/propionate ratio tended to decrease linearly ($P<.10$) with corn supplementation, a reflection of decreased acetate. The depression in acetate concentration was apparently offset by an increase in butyrate with no effect on propionate. Although quite presumptuous, the VFA concentrations suggest that cattle fed large quantities of corn were in little, if any, better energy balance than those fed no corn (Orskov et al., 1968). This observation supports the digestible dry matter intake data previously discussed which also suggests that the energy status of cattle fed more than 1 kg of corn was little, if any, better than cattle fed no corn.

A prediction equation relating the effect of corn supplementation (assuming adequate protein supplementation) on daily hay intake was developed using least squares analysis. A linear equation adequately described the relationship (R^2 = 44.0%), the addition of quadratic (R^2 = 44.7%) and cubic terms (R^2 = 45.5%) added little accuracy. The equation is:

$$Y = 2.37 - .000392X,$$

$$s_{bo} = .092, \; s_{b1} = .0000561, \; s_{y.x} = .438$$

In this equation Y is daily hay intake (%BW) and X is corn intake (g/d). Thus, feeding 3 kg supplemental corn/d would be expected to decrease daily hay intake from 2.37% of BW to 1.19% of BW, a 5.4 kg/d decrease in hay intake for a 454 kg cow.

Feeding large quantities of corn (more than 1 kg) appears to depress hay intake and digestibility to such an extent that the anticipated energetic advantages are much less than expected. Particulate passage and ruminal rate of disappearance data support the depressions in hay intake and digestibility reported. Furthermore, it appears that the low ruminal NH_3-N concentrations observed when high amounts of corn were fed (> 1 kg/d) may have inhibited microbial growth which resulted in depressed hay digestibility.

Feeding large quantities of corn (>1 kg/d) may be a viable option for the producer to conserve available forage. Circumstances such as drought or overgrazing may necessitate a supplementation program that will depress forage intake and maintain animal performance. Corn supplements (i.e. > 2 kg/d) may possibly spare forage (2360 g/d) without decreasing energy intake (223 g DDMI/d) to a point where cow performance would be drastically impaired.

CHAPTER IV

EFFECT OF LEVEL AND FREQUENCY OF CORN SUPPLEMENTATION ON NATIVE GRASS HAY UTILIZATION BY BEEF COWS

Summary

The effect of feeding frequency of corn-based supplements on forage utilization was determined with 12 Hereford cows and four ruminally cannulated mature Hereford x Angus heifers in four simultaneous 4 x 4 Latin squares. Two isonitrogenous corn supplements were fed (0800 h) at two levels (LOW - 1 kg/d, HIGH - 2 kg/d) and two frequencies (DAILY or ALT - 2x daily amount) in a 2 x 2 factorial arrangement of treatments. Native grass hay (5.0% CP, 46.2% ADF and 4.3% AIA) was individually offered free choice. Feeding the HIGH level depressed ($P<.02$) hay intake (9.6 to 8.8 kg/d), and digestibility of hay (47.8 to 44.8%) and all cell wall fiber constituents compared to feeding the LOW level. Feeding frequency did not affect ($P>.6$) hay intake. Feeding on alternate days, compared to feeding daily, however, tended to decrease ($P<.23$) hay (47.0 to 45.6%) and dry matter digestibility (52.5 to 51.5%) resulting in lower ($P<.03$) digestible dry matter intake (5760 to 5528 g/d). Although feeding frequency had little effect on rate of passage, the HIGH level tended to decrease ($P<.19$)

particulate passage rate. Mean ruminal pH on days when all cattle were fed tended to be lower (P<.13) for ALT heifers (6.36) when compared to DAILY (6.42) but were greater (P<.003) for ALT heifers (6.57 vs 6.43) on the nonfed day. Because of the negative effects of alternate day feeding of large quantities of corn supplement observed in this study, cattle producers using corn-based supplements should attempt to feed small quantities (<1 kg) on a daily basis.

Introduction

Supplementing beef cows on a less than daily basis would allow cow-calf producers to conserve labor and improve grazing management. Weight losses for cows wintered on native range did not differ when cottonseed meal supplements were fed at 2, 4 or 6 day intervals (Pope et al., 1963). Total dry mater intake and fiber digestibility did not appear to be affected when steers fed native grass hay were supplemented with cottonseed meal every 1, 2 or 4 days (Coleman and Wyatt, 1982). Little information, however, delineates the effects of feeding low protein, high energy supplements such as corn on a less than daily basis, particularly with respect to forage intake and utilization.

Corn supplements are commonly fed at high levels (2 or 3 kg/d) which can depress both forage intake and utilization (Chapter III). Feeding larger amounts (4 to 6 kg) on alternate days may restrict deleterious starch effects to feeding days allowing normal rumen function and forage digestion on nonfeeding days.

The objectives of this study were to evaluate two levels of isonitrogenous corn supplements fed daily or on alternate days on: (1) intake and digestibility of native grass hay, and (2) ruminal environment.

Materials and Methods

Twelve open Hereford cows (average weight, 367 kg) were blocked by weight into three groups with a fourth group of four ruminally cannulated mature Hereford x Angus heifers (average weight, 328 kg) to be utilized in four simultaneous 4 x 4 Latin squares. Two isonitrogenous corn supplements (Table VI) were fed at two levels to provide 1 or 2 kg of corn and two frequencies, fed (0800 h) daily or on alternate days (twice the daily amount) in a 2 x 2 factorial arrangement of treatments (Table VII). Cattle were individually penned and offered coarsely chopped (5 cm screen) native grass hay free choice daily (Table VIII).

Fourteen day experimental periods included 8 d for adaptation. For six consecutive days (d 8-13), supplements, hay and hay refusals were weighed and sampled to determine nutrient intake. On d 9-14, fecal grab samples were collected twice daily (0800 and 2000 h). Feed and hay samples were composited by period, while fecal and hay refusal samples were composited by animal within each period. Composite fecal samples were dried at 50 C in a

TABLE VI

SUPPLEMENT COMPOSITION (DM BASIS)

Item	Corn	
	Low	High
Ingredient (IFN), g/d[a]		
Corn, ground (4-02-931)	866	1,736
Cottonseed meal (5-01-621)	405	198
Dicalcium phosphate (6-01-080)	76	76
Trace mineralized salt	25	25
Potassium chloride (6-03-755)	18	18
Vitamin A (7-05-143)	20,000 IU	20,000 IU
Total	1,391	2,054
Total, $g \cdot kg\ BW^{-.75} \cdot d^{-1}$	16	24

[a] Estimated.

[b] Trace mineralized salt contained 16% zinc, 12% iron, 6% manganese, 3% magnesium, 1% copper, 1% potassium, .6% iodine, .3% cobalt and 1% mineral oil.

TABLE VII

SUPPLEMENTATION SCHEDULE

Treatment	Day 1	2	3	4	. . .	13	14
	Corn, kg/d						
Low-daily	.87	.87	.87	.87	. . .	.87	.87
Low-alternate	1.73	----	1.73	----	. . .	1.73	----
High-daily	1.74	1.74	1.74	1.74	. . .	1.74	1.74
High-alternate	3.47	----	3.47	----	. . .	3.47	----

TABLE VIII

NUTRIENT COMPOSITION OF HAY AND SUPPLEMENTS (DM BASIS)

Item	Hay	Corn Low	Corn High
Nutrient, %			
Crude protein	5.0	18.5	12.3
Neutral detergent fiber	68.5	19.5	16.4
Hemicellulose	22.3	11.6	12.2
Acid detergent fiber	46.2	7.9	4.2
Lignin	8.4	2.4	1.6
Cellulose	33.8	5.3	3.0
Starch	2.2	39.1	58.2
Neutral detergent fiber nitrogen	1.1	1.7	2.0
Ash	7.7	10.7	7.3
Acid insoluble ash	4.3	.16	.10
Nutrient consumption, g/d			
Crude protein		258	252
Starch		543	1195
TDN[a]		1087	1713

[a]Estimated.

forced air oven for 96 h. All composite samples were ground through a Wiley Mill (1 mm screen) and stored at -15 C.

Composite samples were analyzed to estimate dry matter, ash, acid detergent fiber, neutral detergent fiber, permanganate lignin, cellulose (Goering and Van Soest, 1970), crude protein by Kjeldahl (A.O.A.C., 1975) and acid insoluble ash by the 2 N HCl method (Van Keulen and Young, 1977). Feces, hay and supplements were analyzed for starch (MacRae and Armstrong, 1968) and neutral detergent fiber nitrogen (Goering and Van Soest, 1970; A.O.A.C., 1975). Hemicellulose content was determined by difference between NDF and ADF. Acid insoluble ash was used as an indigestible marker and nutrient digestion coefficients calculated by the marker ratio technique assuming 100% marker recovery (Schneider and Flatt, 1975).

To estimate particulate passage rate, heifers only were dosed (0800 h) on day 11 with 250 g of ytterbium (Yb) labelled (.81% Yb) native grass hay prepared by the immersion technique (Teeter et al., 1984). Fecal grab samples were obtained at 0, 36, 48, 72 and 96 h postdosing, dried at 50 C for 96 h and ground through a Wiley Mill (2 mm screen). Samples were prepared for Yb analysis as previously described (Chapter III) and Yb concentrations were determined on an atomic absorption spectrophotometer using a nitrous oxide-acetylene flame. Concentration of Yb was calculated as a percent of DM and the natural logarithm of the concentration was regressed over time yielding slopes which estimated rate of particulate passage (%/hr). The 36 h values were deleted from the regression equations because they appeared to be located on the upslope of the fecal Yb excretion curve.

Intensive rumen sampling was performed on d 13 (0800, 1100, 1400, 1700 and 2200 h), 14 (0200, 0800, 1100, 1700 and 2200 h) and 15 (0200 and 0800 h) with 1 l of rumen fluid being obtained at each sampling time. Immediately following sampling, pH of whole rumen contents was measured using a combination electrode. Rumen fluid (500 ml) was strained through four layers of cheesecloth into two 250 ml bottles and acidified with 20% sulfuric acid (1 ml H_2SO_4/50 ml rumen fluid). One bottle was stored at -15 C for ammonia-N (NH_3-N) determination by the MgO distillation procedure (A.O.A.C., 1975) and the second was centrifuged at 1000 g and 100 ml of supernatant stored at 5 C for later VFA and Co analysis.

Buffering capacity of strained rumen fluid (40 ml) was determined for each heifer at all sampling times. Initial pH was recorded and then adjusted to 8.0+ by addition of .01 N NaOH, 5 ml increments of .01 N HCl were then added and pH recorded following each addition until pH dropped below 3.0.

Composite rumen samples across all times for each heifer within each period were prepared for VFA analysis as previously described (Chapter III) and 2 ul analyzed for major VFA concentrations using standard gas chromatography techniques.

Heifers were also ruminally dosed on d 13 (0800 h) with 500 ml of a LiCo-EDTA solution (Uden et al., 1980) providing 1255 mg Co/dose to estimate liquid passage rate. In order to achieve equal distribution throughout the rumen, 100 ml were administered into the rumen in five locations (4 corners and center) of each heifer. Preserved rumen supernatant at each time was analyzed for Co concentration using an atomic absorption spectrophotometer with an air-acetylene flame. Slopes for estimating rumen fluid dilution rate were obtained by regressing the natural logarithm of the Co concentration over time excluding the 0 h samples. Dividing the dose of Co administered by the extrapolated concentration at 0 h estimated rumen volume.

Ruminal disappearance of cotton thread was used to estimate celluloytic activity. Dacron bags (6 x 10 cm; pore size 25-74 um) containing .5 g of pure cotton thread (241 cm, Coton Perle #5, Dollfus Mieg + Cie-Paris) rolled into a coil (3.5 cm diameter) were tied to weighted nylon strings (2/string, 45 cm, 2-2 cm nuts, 52 g each). Five strings (10 bags) were suspended in the rumen of each heifer beginning on d 9 (0800 h). In period 1, bags were removed at intervalsbefore 48 h and very little disappearance took place. Data from period 1 was discarded and for subsequent periods the five strings were removed at 24, 36, 48, 72 and 96 h. At the end of the experiment, the heifers were reallocated to treatments assigned in period 1 and dacron bags readministered as in periods 2-4. Following string removal, dacron bags were opened and the cotton thread removed and washed under running water until the thread was clean. Each thread was placed in a 50 ml test tube, dried at 80 C for 72 h and residual cotton thread at each time determined. Cotton thread not subjected to ruminal fermentation was also washed to determine loss from washing alone. Percent residual cotton thread remaining at each time (corrected for washing) was regressed over time (24-96 h) yielding a slope corresponding to rate of ruminal cotton thread disappearance (%/h).

Digestibility and intake data were described by the model:

$$Y_{ijklm} = u + S_i + P_j + A(S)_k + L_l + F_m + L*F + S*P + S*L + S*F + E_{ijklm},$$

where Y_{ijklm} is the variable of interest, S is square, P is period, A(S) is animal within square, L is level of supplement, F is frequency of feeding, L*F is the level x frequency interaction, S*P is the square x period interaction, S*L is the square x level interaction and S*F is the square by frequency interaction. All other interactions were assumed to be zero. Since F-tests for the L*F interaction were not significant (P>.05; Table IX and X), simple effect means for each level and frequency were averaged and differences between main effects (level or frequency) detected by F-test (Steel and Torrie, 1980). Ruminal variables were similarly analyzed except for deletion of the S_i term and associated interactions.

TABLE IX

SIMPLE EFFECTS FOR INTAKE AND DIGESTIBILITY ESTIMATES

	Corn					
	Low		High			
Item	Daily	Alternate	Daily	Alternate	L*F OSL[a]	SE
Intake						
Hay, g/d	9729	9443	8691	8820	.19	153.9
Hay, % BW/d	2.54	2.46	2.26	2.29	.17	.041
Hay, g kg $BW^{-.75}$ d^{-1}	112	109	100	101	.17	1.8
Dry matter, g/d	11119	10834	10745	10874	.19	153.9
Digestible dry matter, g/d	5853	5532	5666	5524	.37	97.4
Digestibility, %						
Neutral detergent fiber (NDF)	47.9	46.7	44.2	43.3	.91	1.24
Hemicellulose	57.3	56.8	53.0	51.8	.80	1.47
Acid detergent fiber	43.1	41.5	39.4	38.7	.68	1.15
Cellulose	53.9	52.5	49.0	48.9	.60	1.21
Lignin	18.7	16.0	17.8	15.7	.86	1.60
Hay	48.5	47.1	45.6	44.1	.98	1.17
Apparent dry matter	52.6	51.4	52.4	51.1	.93	.95
Apparent organic matter	54.7	53.4	54.4	53.0	.94	.97
Apparent crude protein	47.0	45.5	45.0	43.5	.98	1.14
NDF-nitrogen	17.2	15.6	23.4	23.0	.76	1.91
Starch	89.8	89.9	91.8	88.7	.10	.95

[a]Observed significance level for level X frequency interaction.

TABLE X

SIMPLE EFFECTS FOR RUMINAL PARAMETERS

Item	Corn level					
	Low		High			
	Daily	Alternate	Daily	Alternate	L*F OSL[a]	SE
Rumen parameter						
Particulate passage rate, %/h	3.7	3.9	3.5	3.4	.68	.22
Cotton thread disappearance, %/h	.53	.58	.49	.43	.18	.032
Fluid passage rate, %/h	7.8	7.8	8.4	7.7	.38	.35
Fluid volume, l	97.3	99.1	94.1	97.6	.86	4.51
Rumen fluid flow rate, l/h	7.4	7.5	7.8	7.5	.35	.24
Rumen turnover time, h	13.0	12.0	13.1	13.1	.34	.55
pH, d 13	6.40	6.41	6.44	6.30	.12	.039
pH, d 14	6.41	6.51	6.46	6.63	.23	.028
NH3-N mg/dl, d 13	.62	.88	.48	.47	.17	.087
NH3-N mg/dl, d 14	.52	.52	.44	.58	.44	.086
Total VFA, mM	60.2	51.5	55.2	53.5	.28	2.95
Acetate, mol/100 mol	71.7	71.6	68.6	67.1	.33	.63
Propionate, mol/100 mol	18.8	19.7	21.0	22.3	.77	.66
Butyrate, mol/100 mol	8.8	8.4	4.6	7.2	.39	1.59
Acetate/propionate ratio	3.8	3.6	3.3	3.0	.79	.14

[a]Observed significance level for level X frequency interaction.

Results and Discussion

Cattle supplemented with the HIGH corn level consumed 830 g/d less hay ($P<.0001$) than those fed the LOW corn level (Table XI). Total and digestible dry matter intake, however, were not affected ($P>.28$) by level of corn supplementation due to the additional supplement at the HIGH level. Feeding the supplements DAILY or on ALT days resulted in similar ($P>.62$) hay and total dry matter intakes. Digestible dry matter intake, however, decreased ($P<.03$) when cattle were supplemented on ALT days (5528 g/d) compared to those fed DAILY (5760 g/d).

The decrease in hay intake occurring when the HIGH corn level was fed may be partially explained by concomitant depressions ($P<.009$) in digestibility of cell wall fiber constituents (Table XII). Hemicellulose digestibility was decreased by 8.2% ($P<.003$) and cellulose digestibility by 7.9% ($P<.002$) when supplement level was increased. Hay digestibility (assuming a supplement digestibility of 80%) followed a similar trend as neutral detergent fiber digestibility, being decreased from 47.8 to 44.8%, when the LOW and HIGH levels were fed, respectively. Alternate day feeding consistently decreased the digestibility of all fiber components. The observed depressions, however, were small and nonsignificant ($P<.32$ or greater).

The substitution of 663 g of supplement for 803 g of hay allowed cattle fed the HIGH corn level to maintain

TABLE XI

EFFECT OF SUPPLEMENT LEVEL AND FEEDING FREQUENCY ON INTAKE ESTIMATES

	Corn			Frequency			
Intake	Low	High	OSL[a]	Daily	Alternate	OSL[a]	SE
Hay, g/d	9586	8756	.0001	9210	9132	.61	108.8
Hay, g·kg $BW^{-.75}\cdot d^{-1}$	110	101	.0001	106	105	.52	1.3
Hay, % BW/d	2.5	2.3	.0001	2.4	2.4	.50	.03
Dry matter, g/d	10976	10810	.29	10932	10854	.62	108.8
Digestible dry matter, g/d	5693	5595	.33	5760	5528	.03	68.9

[a]Observed significance level.

TABLE XII

EFFECT OF SUPPLEMENT LEVEL AND FEEDING FREQUENCY ON DIGESTIBILITY COEFFICIENTS

	Corn			Frequency			
Digestibility, %	Low	High	OSL[a]	Daily	Alternate	OSL[a]	SE
Neutral detergent fiber	47.3	43.8	.008	46.1	45.0	.40	.87
Hemicellulose	57.1	52.4	.004	55.2	54.3	.56	1.04
Acid detergent fiber	42.3	39.0	.009	41.3	40.1	.32	.81
Lignin	17.4	16.8	.72	18.3	15.8	.14	1.13
Cellulose	53.2	49.0	.002	51.5	50.7	.50	.86
Hay	47.8	44.8	.02	47.0	45.6	.23	.83
Apparent dry matter	52.0	51.8	.83	52.5	51.2	.20	.67
Apparent organic matter	54.1	53.7	.71	54.5	53.2	.20	.69
Apparent crude protein	46.2	44.2	.09	46.0	44.5	.22	.81
NDF-nitrogen	47.3	43.8	.01	46.1	45.0	.40	.87
Starch	90.0	90.2	.70	90.8	89.3	.12	.67

[a]Observed significance level.

similar dry matter intakes as those fed the LOW corn level. Apparent dry matter digestibilities also were not influenced (P>.82) by level of corn supplementation reflecting the highly digestible nature of the corn supplement compared to the hay which it replaced. Similar digestible dry matter intakes would not be unexpected, despite the depression in hay digestibility observed when cattle were fed the HIGH corn level. Previous results with similar supplements showed a much larger decrease in both hay intake and digestibility resulting in a greater depression in digestible dry matter intake (Chapter III).

Feeding on ALT days, compared to feeding DAILY, tended to decrease (P<.20) apparent dry matter digestibility from 52.5 to 51.2%. Although these depressions were not of great enough magnitude to significantly influence either forage or total dry matter intake, digestible dry matter intake averaged 232 g/d less (P<.03) for cattle fed on ALT days compared to those fed DAILY.

Particulate passage rate (Table XIII) tended to decrease (P<.19) when the heifers were supplemented with the HIGH level of corn (3.5%/h) compared to those fed the LOW level (3.8%/h). Feeding frequency did not alter (P>.8) particulate passage rate (3.6 vs 3.7%.h). Disappearance of cotton thread was decreased (P<.03) from .56 to .46%/h for heifers fed the LOW and HIGH corn levels, respectively. Feeding frequency, however, had no effect (P>.84) on cotton thread disappearance, (.51%/h for DAILY vs .50%/h for ALT).

TABLE XIII

EFFECT OF SUPPLEMENT LEVEL AND FEEDING FREQUENCY ON PASSAGE RATE AND RUMINAL PARAMETERS

Item	Corn			Frequency			
	Low	High	OSL[a]	Daily	Alternate	OSL[a]	SE
Passage rate, %/h							
Particulate	3.8	3.5	.19	3.6	3.7	.84	.16
Rumen fluid	7.8	8.0	.48	8.1	7.7	.36	.24
Cotton thread disappearance, %/h	.56	.46	.03	.51	.50	.85	.023
Rumen parameter							
Rumen fluid volume, l	98.2	95.9	.63	95.7	98.4	.58	3.20
Rumen fluid flow rate, l/h	7.5	7.6	.47	7.6	7.5	.67	.17
Rumen turnover time, h	13.1	12.6	.41	12.5	13.1	.33	.39
pH, d 13	6.41	6.37	.43	6.42	6.36	.14	.028
pH, d 14	6.46	6.54	.02	6.43	6.57	.003	.020
NH_3-N, mg/dl, d 13	.75	.47	.02	.55	.68	.20	.062
NH_3-N, mg/dl, d 14	.52	.51	.85	.48	.55	.45	.060
Total VFA, mM	55.9	54.4	.63	57.7	52.5	.13	2.08
Acetate, mol/100 mol	71.6	67.8	.001	70.1	69.3	.25	.45
Propionate, mol/100 mol	19.2	21.6	.01	19.9	21.1	.14	.47
Butyrate, mol/100 mol	8.6	5.9	.14	6.7	7.8	.52	1.12
Acetate/propionate ratio	3.7	3.1	.01	3.6	3.3	.16	.10

[a]Observed significance level.

The depression in cotton thread disappearance observed with the HIGH corn level combined with the trend for decreased particulate passage rate helps to explain the observed depression in forage intake. In theory, rumen fill, passage rate and the ruminal rate of breakdown of forage should all interact to influence forage intake (Ellis, 1978; Van Soest, 1982).

Rumen fluid passage rate and volume were not affected (P<.48) by level of corn supplementation (Table XIII). Feeding frequency did not alter (P<.36) rumen fluid passage rate (8.1 vs 7.7%/h) or rumen fluid volume (95.7 vs 98.4 l). Since dry matter intake was not significantly affected by frequency or level, similar rumen fluid parameters might be expected. Dry matter intake has been suggested as the single most important factor influencing rumen fluid passage rate possibly through its relationship with water intake and salivary contributions (Rogers et al., 1979; Evans, 1981).

Mean ruminal pH for heifers fed the LOW (6.41) and HIGH (6.37) corn levels was similar (P<.43) on d 13 when all cattle were fed (Table XIII). When both groups were fed (d 13), ALT heifers tended to have a lower (P<.14) mean ruminal pH than DAILY heifers (6.36 vs 6.42), probably a reflection of the larger amount of supplement fed to the ALT heifers. On the nonfed day, however, mean ruminal pH was greater (P<.003) for the ALT heifers (6.57) compared to the DAILY (6.43). A much greater shift in ruminal pH occurred between feeding times for ALT heifers compared to DAILY (Figure 3).

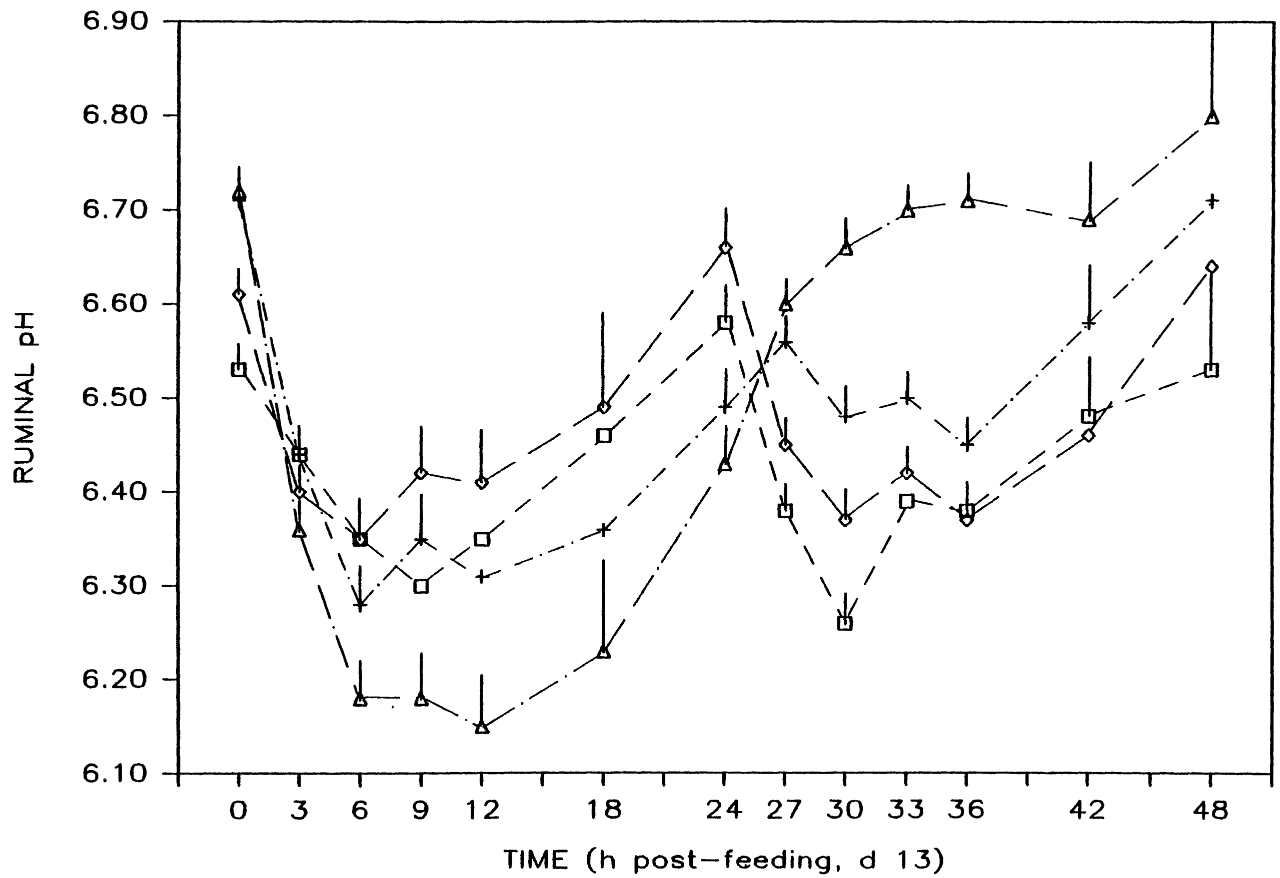

Figure 3. Effect of Level and Frequency of Corn Feeding on Ruminal pH Over 48 Hours (□-□ LOW DAILY; +-·+ LOW-ALT; ◇—◇ HIGH DAILY; △—·△ HIGH-ALT)

A longer period of higher pH on d 14 for the ALT heifers could be expected to improve fiber digestion if microbial nutrient requirements are not limiting. Ruminal pH did not appear to limit hay digestibility on the LOW (DAILY or ALT) or HIGH (DAILY) treatments. The most severe depression in hay digestibility occurred with the HIGH-ALT cattle (4 kg/feeding). Ruminal pH remained below 6.2 for at least 6 h on d 13 (feeding day), a pH where cellulolytic bacteria may be adversely affected (Orskov, 1982). Buffering capacity (ml acid required to decrease ruminal pH from 7.0 to 3.0) appeared to be lower for ALT heifers on the feeding day (d 13), probably because the ALT heifers received a larger quantity of supplement (Figure 4). On d 14, no consistent patterns were noted between heifers receiving small amounts of grain (DAILY) and those fed hay only (ALT). Low ruminal NH_3-N concentrations on d 14 (Figure 5) may have further limited fermentation for ALT cattle, even though pH was favorable. All of the ruminal NH_3-N values were below the recommended concentration of 2-5 mg/dl required for maximum bacterial growth (Satter and Slyter, 1974). Mean ruminal NH_3-N values were greater ($P<.02$) for LOW compared to HIGH heifers on the feeding day (d 13; Table XIII). Feeding on ALT days tended ($P<.20$) to increase mean ruminal NH_3-N concentrations.

Total VFA concentrations did not differ ($P>.6$) for HIGH compared to LOW heifers (Table XIII). The HIGH heifers, however, had lower ($P<.0001$) acetate, greater ($P<.01$)

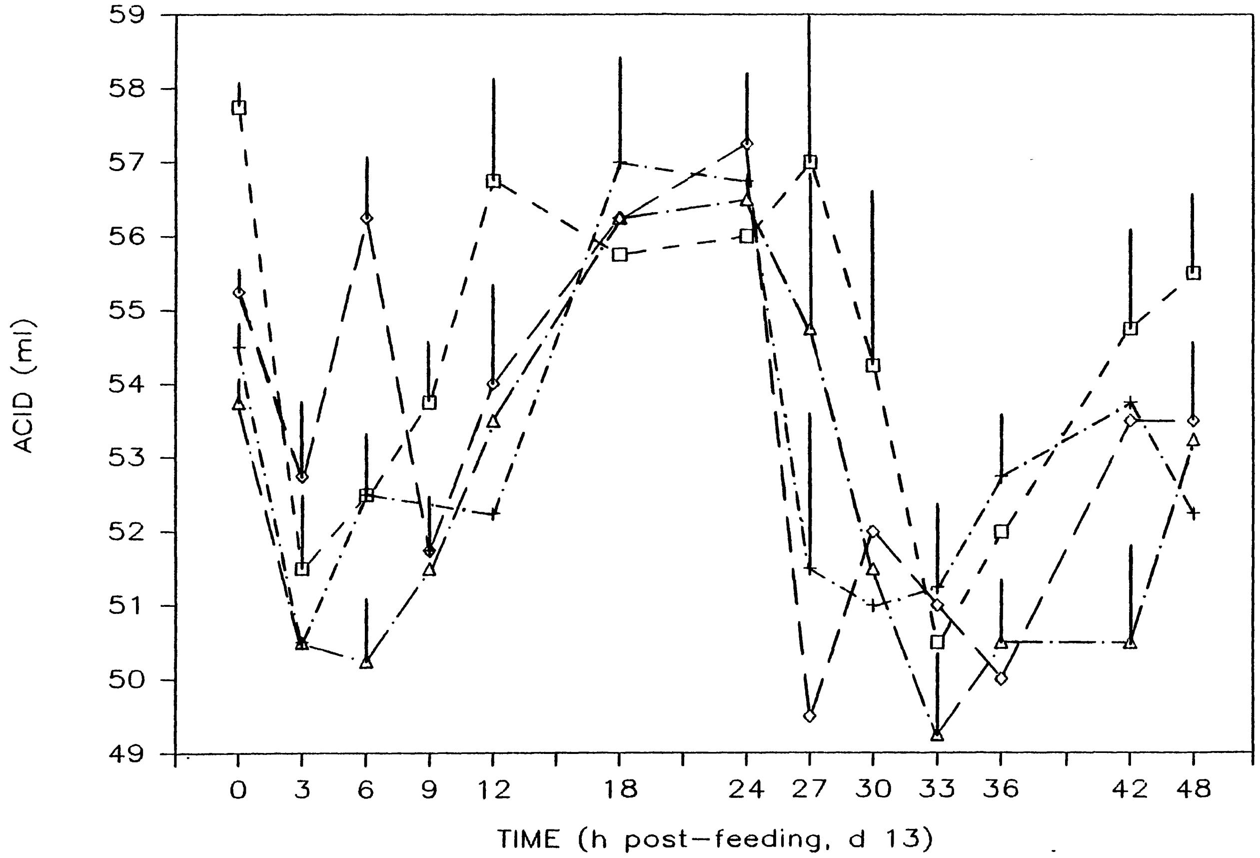

Figure 4. Effect of Level and Frequency of Corn Feeding on Buffering Capacity (ml of Acid to Drop pH From 7.0 to 3.0; □–□ LOW-DAILY; +—·+ LOW-ALT; ◇—◇ HIGH-DAILY; △—·△ HIGH-ALT)

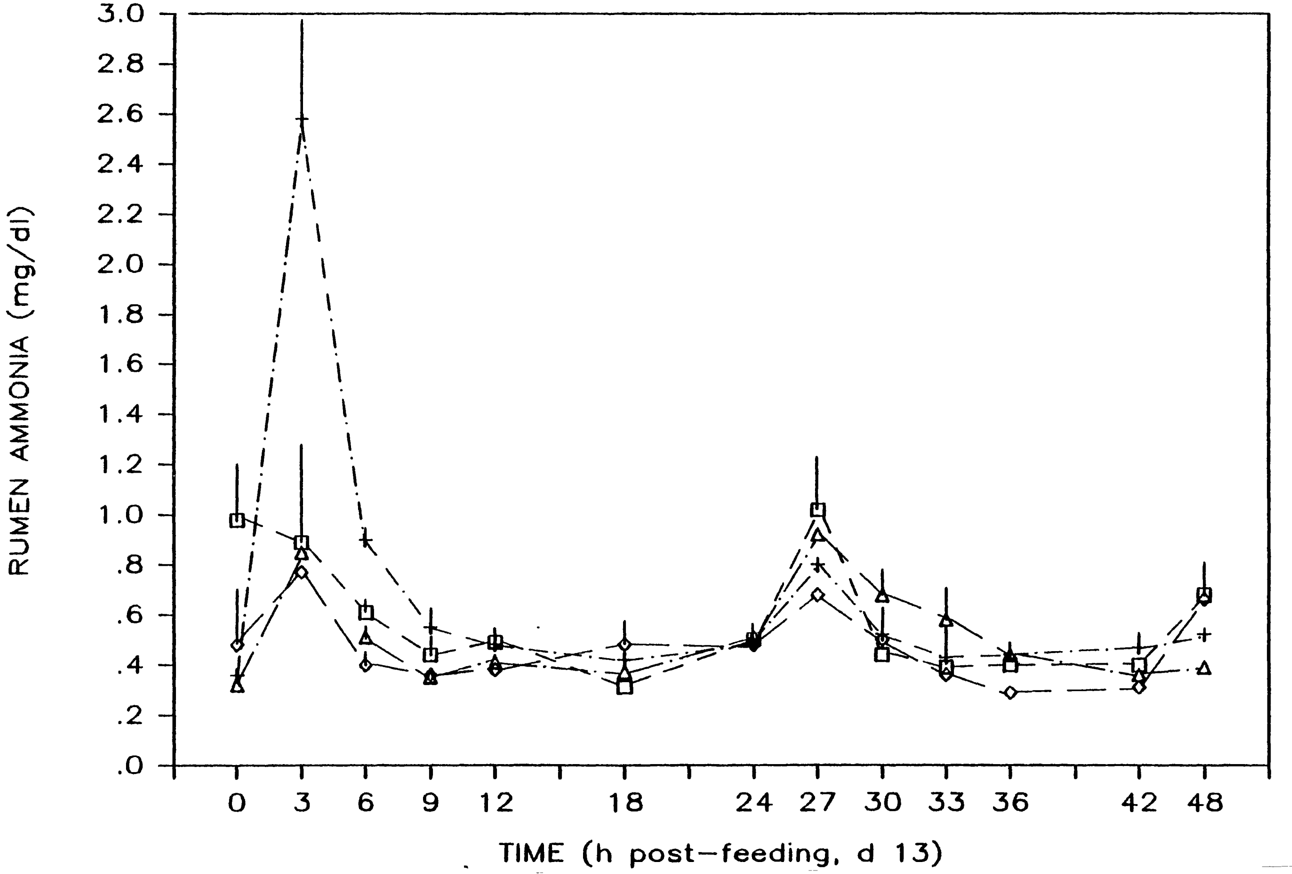

Figure 5. Effect of Level and Frequency of Corn Feeding on Ruminal Ammonia Concentrations (gl/dl) Over 48 Hours (□—□ LOW DAILY; +—·+ LOW-ALT; ◇—◇ HIGH-DAILY; △—·△ HIGH ALT)

propionate and a lower ($P<.07$) acetate/propionate ratio compared to the LOW heifers. Feeding on ALT days tended ($P<.13$) to decrease total VFA concentrations (57.7 vs 52.5 mM). Conversely, when ALT heifers were compared to DAILY, there was a trend ($P<.14$) for propionate concentration to increase (19.9 vs 21.1 mol/100 mol) as reflected in the acetate/propionate ratio (3.6 vs 3.3). Bearing in mind a number of assumptions (Orskov et al., 1968), the VFA data, in combination with the digestible dry matter intake values, suggest that the energy status of the HIGH and LOW cattle was probably similar. Feeding on ALT days, compared to DAILY, resulted in a decrease in digestible dry matter intake, a trend which was also evident in total VFA concentrations, implying that DAILY cattle were in better energy balance than ALT cattle.

The observed depressions in both hay intake and digestibility for HIGH cattle suggest that hay was being inefficiently utilized. Apparently, supplement was unequally substituted for hay resulting in little or no advantage from feeding an extra kg of corn. Feeding cattle on ALT days appeared to have no adverse effects on forage intake but slight, nonsignificant reductions in fiber component digestibilities resulted in a decrease ($P<.03$) in digestible dry matter intake of 232 g/d. The favorable ruminal pH response observed for ALT cattle on nonfeeding days apparently could not make up for the depressed ruminal environment from the previous feeding day. Feeding on ALT days elicited no adverse effects on particulate passage rate, ruminal fluid passage rate or rate of cotton thread disappearance. A trend for depressed total VFA concentrations combined with evidence for decreased digestible dry matter intake as a result of ALT day feeding, however, suggests energy balance may have been less than for DAILY fed heifers.

In a previous experiment, when similar amounts of corn were fed on a daily basis, larger depressions in hay intake and digestibility occured, resulting in a greater difference in digestible dry matter intake (Chapter III). The hay utilized in the first experiment, however, appeared to be of lower quality (4.2% CP, 52.6% ADF) compared to that fed in the present study. The addition of grain to forage diets providing low dietary crude protein may result in greater depressions in forage intake than with higher quality forages (Elliot, 1967; Andrews et al., 1972).

Consequently, from an overall utilization standpoint, small amounts of corn (< 1 kg) should be fed on a daily basis. Economically, however, feeding on a daily basis may be impractical and not worth the extra (4.2%) increase in digestible dry matter intake.

CHAPTER V

BUFFER AND/OR AMMONIA ADDITION TO CORN-SUPPLEMENTED NATIVE GRASS HAY DIETS

Summary

The effect of intraruminal dosing of buffers and/or ammonia compounds on hay intake and digestibility was determined with four ruminally cannulated mature Hereford x Angus heifers in a 4 x 4 Latin square design. Treatments were (1) NaCl (111 g/d), (2) $NaHCO_3$ (159 g/d), (3) NH_4HCO_3 (150 g/d) and (4) NH_4Cl (102 g/d) formulated on an isoionic basis. Heifers were fed 2 kg corn supplement daily and native grass hay (4.8% CP, 49.1% ADF and 4.6% AIA) was offered free choice. Hay intake was greatest ($P<.05$) with NH_4HCO_3 (9.6 kg/d), least ($P<.05$) with NH_4Cl (5.1 kg/d) and intermediate when NaCl (7.4 kg/d) or $NaHCO_3$ (6.8 kg/d) were dosed. Constituent fiber digestibilities were greater ($P<.10$) for NH_4Cl compared to $NaHCO_3$. Ammonia compounds appeared to enhance estimated hay digestibility (41.9% NaCl, 42.2% $NaHCO_3$, 45.0% NH_4HCO_3 and 48.9% NH_4Cl). Apparent dry and organic matter digestibility were increased ($P<.05$) with NH_4Cl compared to all others. Digestible dry matter intake was greatest ($P<.10$) for NH_4HCO_3 (5.7 kg/d) and did not differ ($P>.10$) for NaCl (4.5 kg/d), $NaHCO_3$ (4.3 kg/d) or

NH_4Cl (3.9 kg/d). A decreased (P<.05) rumen volume and blood pH combined with ruminal pH's below 6.2 may explain the decrease in forage intake observed with NH_4Cl dosing. Low rumen NH_3-N concentrations (<1 mg/dl) and a decreased (P<.05) rate of ruminal cotton thread disappearance for NaCl and $NaHCO_3$ compared to ammonia compounds suggests that bacterial nitrogen requirements may have exceeded the ammonia supply. Bicarbonates appeared to have little effect on ruminal pH when compared to NaCl. Ruminal fluid passage rate appeared to increase when bicarbonates were dosed. Ruminal nitrogen appeared to limit hay utilization for heifers fed native grass hay supplemented with 2 kg corn.

Introduction

Cattle fed low-quality hay supplemented with starch-containing supplements such as corn have depressed hay intake and digestibility when compared to cattle fed an isonitrogenous amount of cottonseed meal (Chapter III and IV). The cause for the depression in hay intake appears to be associated with depressed rumen function due to either a lack of available nitrogen for ruminal bacteria or a depressed ruminal pH. Although there is evidence suggesting that the addition of protein may alleviate much of the decrease in fiber digestibility associated with starch feeding (Burroughs et al., 1950; Elliot, 1967; Stern et al., 1978), others have obtained conflicting results (Arias et al., 1951; Glenn and Ely, 1981).

The addition of buffers to high concentrate rations in order to create a rumen environment more favorable for bacterial growth has been successful (Dunn et al., 1979). Little research has been conducted to assess the ability of buffers to maintain ruminal pH in cattle fed native grass hay supplemented with starch containing supplements. Thomas and Hall (1984) observed no effect on ruminal pH when $NaHCO_3$ or $Na_4P_2O_7$ (1-2.5% diet) was included in a high roughage diet containing 33% corn. Ruminal pH, however, for the control cattle was high, ranging from 6.7 to 7.5. Previous studies suggest that feeding corn supplements to heifers maintained on native grass hay results in ruminal pH's as low as 6.3 (Chapter III). A pH of 6.3 is approaching the critical pH of 6.2 which has been suggested as the point at which celluloytic bacterial growth is inhibited (Orskov, 1982).

The objectives of this study were to evaluate the effect of intraruminal dosing of buffer and/or ammonia compounds to heifers supplemented with 2 kg corn/d on: (1) intake and digestibility of native grass hay and (2) ruminal parameters.

Materials and Methods

Four ruminally cannulated mature Angus x Hereford heifers (average weight, 425 kg) were arranged in a 4 x 4 Latin square design. Heifers were individually fed (0700 h) coarsely chopped (5 cm screen) native grass hay free choice and 2 kg of a corn supplement daily (Table XIV and XV). Treatments were (1) NaCl, (2) $NaHCO_3$, (3) NH_4HCO_3 and (4) NH_4Cl formulated to provide isomolar combinations of Na, Cl, HCO_3 and NH_4 (Table XVI). Chemicals were dissolved in 500 ml H_2O (NaCl, NH_4HCO_3 and NH_4Cl) or 1000 ml H_2O ($NaHCO_3$). Heifers were fitted with cannulae stoppers that allowed chemicals to be dosed without stopper removal. Stoppers were prepared by cutting a 1.2 cm (diameter) hole in the center and forcing tygon tubing (45 cm in length, 2 cm in diameter) through the hole. This allowed approximately 15 cm of tube to be exposed in order for solutions to be funneled directly into the rumen with minimal loss of solutions or rumen contents. Experimental periods were 14 d; heifers were dosed 3x/d (0700, 1200 and 1700 h) on d 1-6 and 4x/d (0700, 1200, 1700 and 2200 h) on d 7-14 (Table XVII). Heifers were gradually adapted (d 1-3) to the chemicals by dosing 40, 60 and 80% of the total daily dose administered on d 4-14 (Table XVI). On d 9-12 of each period, supplement, hay and ort hay (from d 9) were weighed and sampled to determine nutrient intake. Fecal grab samples were obtained twice daily (0700 and 1900 h) on d 9-13. Supplement and hay samples were composited by period while ort hay and fecal samples were composited by animal within each period. Fecal samples were dried at 55 C for 72 h in a forced air oven. All samples were ground through a 1 mm screen (Wiley Mill) and stored at -15 C. Sample analyses included dry matter, ash, neutral detergent fiber

TABLE XIV

INGREDIENT COMPOSITION OF CORN SUPPLEMENT (DM BASIS)

Ingredient	IFN	Amount, g/d[a]
Corn, ground	4-02-931	1,626
Dicalcium phosphate	6-01-080	76
Trace mineralized salt[b]	----	25
Potassium chloride	6-03-755	18
Vitamin A	7-05-143	20,000 IU
Total	----	1,746
Total, $g \cdot kg\ BW^{-.75} \cdot d^{-1}$	----	19

[a]Estimated.

[b]Trace mineralized salt contained 16% zinc, 12% iron, 6% manganese, 3% magnesium, 1% copper, 1% potassium, .6% iodine, .3% cobalt and 1% mineral oil.

TABLE XV

NUTRIENT COMPOSITION OF HAY AND CORN SUPPLEMENT
(DM BASIS)

Item	Hay	Supplement
	----------- % -----------	
Crude protein	4.84	8.00
Neutral detergent fiber	71.06	15.47
Hemicellulose	21.94	12.15
Acid detergent fiber	49.12	3.32
Lignin	10.80	1.01
Cellulose	34.02	2.44
Ash	7.98	7.02
Acid insoluble ash	4.56	.084

TABLE XVI

CHEMICAL COMPOSITION OF INTRARUMINALLY DOSED COMPOUNDS (AS-IS)

Ingredient	Treatment			
	$NaCl$	$NaHCO_3$	NH_4HCO_3	NH_4Cl
	g/d			
Na	43.6	43.6	---	---
Cl	67.3	---	---	67.3
HCO_3	---	115.8	115.8	---
NH_4	---	---	34.2	34.2
Total	110.9	159.4	150.0	101.5

TABLE XVII

DOSING SCHEDULE

Item	Day 1	2	3	4	5	6	7	8	. . . .	14
Times/d dosed	3	3	3	3	3	3	4	4	. . . . .	4
% of total dosed	40	60	80	100	100	100	100	100	. . . .	100
Total dose, g/d										
$NaCl$	44	66	88	111	111	111	111	111	. . . .	111
$NaHCO_3$	64	96	128	159	159	159	159	159	. . . .	159
NH_4HCO_3	60	90	120	150	150	150	150	150	. . . .	150
NH_4Cl	41	61	81	102	102	102	102	102	. . . .	102

(NDF), acid detergent fiber (ADF), permanganate lignin (Goering and Van Soest, 1970), crude protein by Kjeldahl (A.O.A.C., 1975) and acid insoluble ash (AIA) using the 2 N HCl method (Van Keulen and Young, 1977). Hemicellulose was determined by difference between NDF and ADF. Nutrient digestion coefficients were calculated by the marker ratio technique using AIA as the indigestible marker assuming 100% recovery (Schneider and Flatt, 1975).

Heifers were dosed on d 10 (0700 h) with 250 g of .71% Ytterbium (Yb) labelled hay prepared by the immersion technique (Teeter et al., 1984). Fecal grab samples were collected at 0, 36, 48, 60, 72 and 96 h post-Yb dosing. Feces were dried at 55 C for 72 h, ground through a 2 mm screen (Wiley Mill), and prepared for analysis (Chapter III). Ytterbium concentration was determined by atomic absorption spectrophotometry using a nitrous oxide-acetylene flame. Rate of particulate passage was estimated from the slope of the regression of the natural logarithm of Yb concentration over time. The 36 h values appeared to be on the upslope of the fecal Yb excretion curve and were deleted from the regression equations.

Intensive rumen sampling was performed on d 13 (0700, 0730, 0800, 0900, 1000, 1200, 1700, 1730, 1800 and 2200 h), d 14 (0700 h) and d 15 (0700 h). Immediately following sampling, pH of whole rumen contents was obtained using a combination electrode. Rumen fluid (125 ml) was strained through four layers of cheesecloth, acidified with 20%

sulfuric acid (1 ml H_2SO_4/50 ml rumen fluid) and stored at -15 C. At a later date, samples were thawed, centrifuged at 1000 g for 10 min and 5 ml of supernatant removed for ammonia-N (NH_3-N) determination by the phenolhypochlorite procedure (Broderick and Kang, 1980).

Buffering capacity of strained rumen fluid (40 ml) was determined for samples collected on d 13 at 0700, 0800 and 1700 h. A pH measurement was made initially and pH adjusted to 8.0+ with .01 N NaOH, 5 ml increments of .01 N HCl were then added and pH recorded until pH fell below 3.0.

Heifers were additionally dosed on d 13 (0700 h) with 500 ml (973 mg Co) of a LiCo-EDTA solution (Uden et al., 1980). In order to achieve equal ruminal distribution, 100 ml was delivered in each of the four corners and center of the rumen. Preserved rumen fluid corresponding to 0, 2, 5, 10, 15, 24 and 48 h postdosing were analyzed for Co concentration by atomic absorption spectrophotometry with an air-acetylene flame. Slopes obtained by regressing the natural logarithm of Co concentration over time estimated fluid passage rate. Ruminal fluid volumes were calculated by dividing the dose of Co administered by the extrapolated concentration at 0 h.

Dacron bags containing .5 g pure cotton thread (241 cm) were secured to weighted lines (tygon tubing, 2 bags/line) and suspended in the rumen beginning on d 8 and removed at 24, 36, 48, 72 and 96 h (Chapter IV). Cotton thread was removed from the bags, washed until clean, and dried at 80 C for 72 h. Cotton thread not subjected to rumen fermentation was also washed to determine loss from washing alone. Percent residual cotton thread remaining at each time corrected for washing was regressed over time (24-36 h) yielding a slope which estimated rate of ruminal disappearance.

Blood samples were collected on d 13 (1015 and 1300 h) via coccygeal vessel puncture and pH measured immediately after sampling by injecting 5 ml into an airtight glass apparatus attached to a combination electrode.

Digestibility, intake and ruminal parameters are described by the model:

$$Y_{ijk} = u = P_i + A_j + T_k + E_{ijk},$$

where Y_{ijk} is the variable of interest, P is period, A is animal and T is treatment. All interactions were assumed to be zero. Differences between least square treatment means were detected using Tukey's HSD procedure (Steel and Torrie, 1980).

Results and Discussion

Hay and dry matter intakes were greatest ($P<.05$) for the NH_4HCO_3 treatment, least ($P<.05$) for NH_4Cl and intermediate for NaCl and $NaHCO_3$ (Table XVIII). Digestible dry matter intake did not differ ($P>.10$) between NaCl, $NaHCO_3$ or NH_4Cl but tended to be enhanced ($P<.10$) with NH_4HCO_3.

TABLE XVIII

INTAKE AND DIGESTIBILITY COEFFICIENTS AS AFFECTED BY INTRARUMINAL DOSING OF AMMONIA AND/OR BUFFER COMPOUNDS

Item	NaCl	$NaHCO_3$	NH_4HCO_3	NH_4Cl	SE
Intake					
Hay, g/d	7391[b]	6808[b]	9583[a]	5092[c]	335.7
Hay, $g \cdot kg\ BW^{-.75} \cdot d^{-1}$	79[b]	73[b]	102[a]	55[c]	3.2
Hay, % BW/d	1.7[b]	1.6[b]	2.3[a]	1.2[c]	.069
Dry matter, g/d	9137[b]	8554[b]	11329[a]	6838[c]	335.7
Digestible dry matter, g/d	4515[y]	4260[y]	5688[x]	3946[y]	283.3
Digestibility			%		
Neutral detergent fiber	43.4[ab]	40.7[b]	47.1[ab]	53.2[a]	2.34
Hemicellulose	53.0[b]	51.5[b]	57.3[ab]	65.0[a]	2.33
Acid detergent fiber	38.6[xy]	35.3[y]	42.2[xy]	47.0[x]	2.45
Lignin	24.9	17.2	23.1	27.7	3.90
Cellulose	48.3[b]	44.8[b]	53.9[ab]	59.8[a]	1.96
Hay	41.9	42.2	45.0	48.9	2.47
Apparent dry matter	49.3[b]	50.0[b]	50.4[b]	57.8[a]	1.41
Apparent organic matter	51.5[b]	52.1[b]	53.0[b]	60.6[a]	1.43
Apparent nitrogen	53.8[a]	56.9[a]	45.6[b]	55.8[a]	1.38

[a,b,c]Means in rows with different superscripts differ ($P<.05$).

[x,y]Means in rows with different superscripts differ ($P<.10$).

Nitrogen in the form of NH_4Cl enhanced ($P<.10$) digestibility of NDF and ADF when compared to $NaHCO_3$ (Table XVIII). Hay intake, however, for NH_4Cl was 25% lower than the $NaHCO_3$. Cellulose and hemicellulose digestibility were also increased ($P<.05$) for NH_4Cl heifers compared to either NaCl or $NaHCO_3$ heifers. Fiber digestibilities for the NH_4HCO_3 treatment appeared to follow a similar trend as NH_4Cl; however, treatment differences when compared to either NaCl or $NaHCO_3$ were not significant ($P>.10$). No treatment differences ($P>.10$) were observed for estimated hay digestibility. Apparent dry matter and organic matter digestibilities were greatest ($P<.05$) for NH_4Cl-dosed heifers and did not differ ($P>.10$) between NaCl, $NaHCO_3$ or NH_4HCO_3-dosed heifers.

Hay intake was so severely depressed for the NH_4Cl treatment that digestible dry matter intake was much less than might be expected from the digestibility data. The tendency for the NH_4HCO_3 treatment to enhance fiber digestibility and maintain apparent dry matter digestibility, when compared to NaCl or $NaHCO_3$, in combination with increased hay intake, may explain the trend for increased digestible dry matter intake.

Ruminal ammonia-N (NH_3-N) concentrations for the $NaHCO_3$ and NaCl treatments were much lower (<1 mg/dl) at all times than the minimum for maximum bacterial growth of 2-5 mg/dl recommended by Satter and Slyter (1974) (Figure 6). As would be expected, the ammonia treatments had elevated

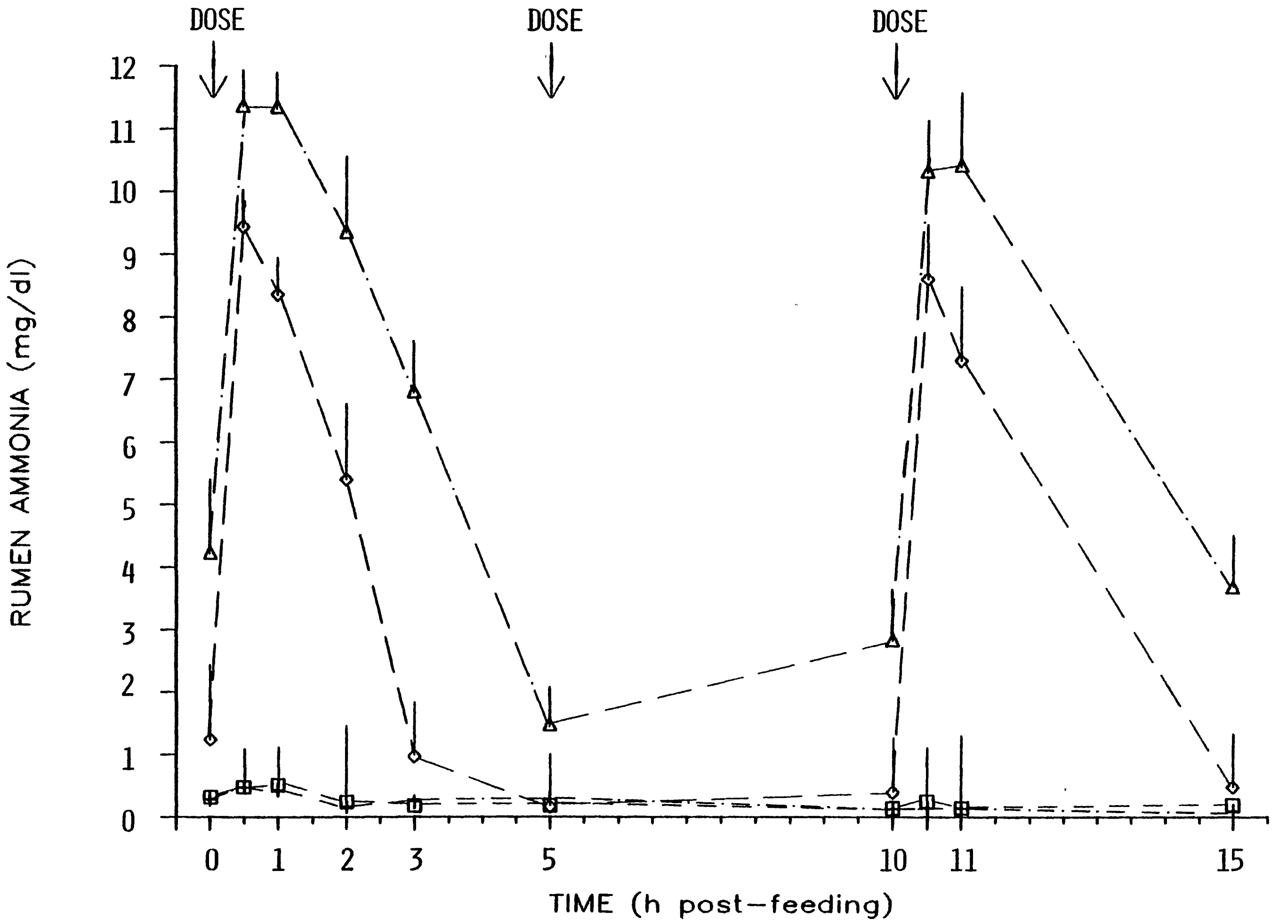

Figure 6. Diurnal Variation in Ruminal Ammonia Concentrations (mg/dl) as Affected by Intraruminal Dosing of Buffers and/or Ammonia Compounds (□—□ NaCl; +—·+ $NaHCO_3$; ◇—◇ NH_4HCO_3; △—·△ NH_4Cl)

ruminal NH_3-N (> 5 mg/dl) from .5 to at least 2 h post-dosing. The NH_4Cl treatment, furthermore, appeared to maintain higher ruminal NH_3-N concentrations over a longer period of time than the NH_4HCO_3 treatment. It appears that the trend for increased fiber digestibility observed with ammonia supplementation was probably a direct result of more closely meeting microbial demands for ammonia. Low (<1 mg/dl) rumen NH_3-N values are commonly observed when cattle are fed low quality hays supplemented with high starch grains such as corn or sorghum (Hennessy et al., 1983; Chapter III). In both of the previous mentioned studies, feeding a high protein supplement increased fiber digestibility and rumen NH_3-N levels.

Ruminal pH concentrations for the NaCl, $NaHCO_3$ and NH_4HCO_3 treatments were greater than 6.2 (Figure 7), the suggested critical point below which inhibition of celluloytic bacterial growth may occur (Orskov, 1982). Ruminal pH for the NH_4Cl treatment, however, dropped below 6.2 through 15 h postfeeding. Furthermore, ruminal pH dropped below 6.0 by 3 h post-feeding and remained there for 12 h. Note that cellulose digestibility was not impaired, in spite of low ruminal pH. In the present study, the addition of bicarbonate appeared to have little effect on ruminal pH, probably because initial ruminal pH, as reflected on the NaCl treatment, was not low. Thomas and Hall (1984) similarly found little difference in ruminal pH of cattle fed a high roughage diet (33% corn) buffered with

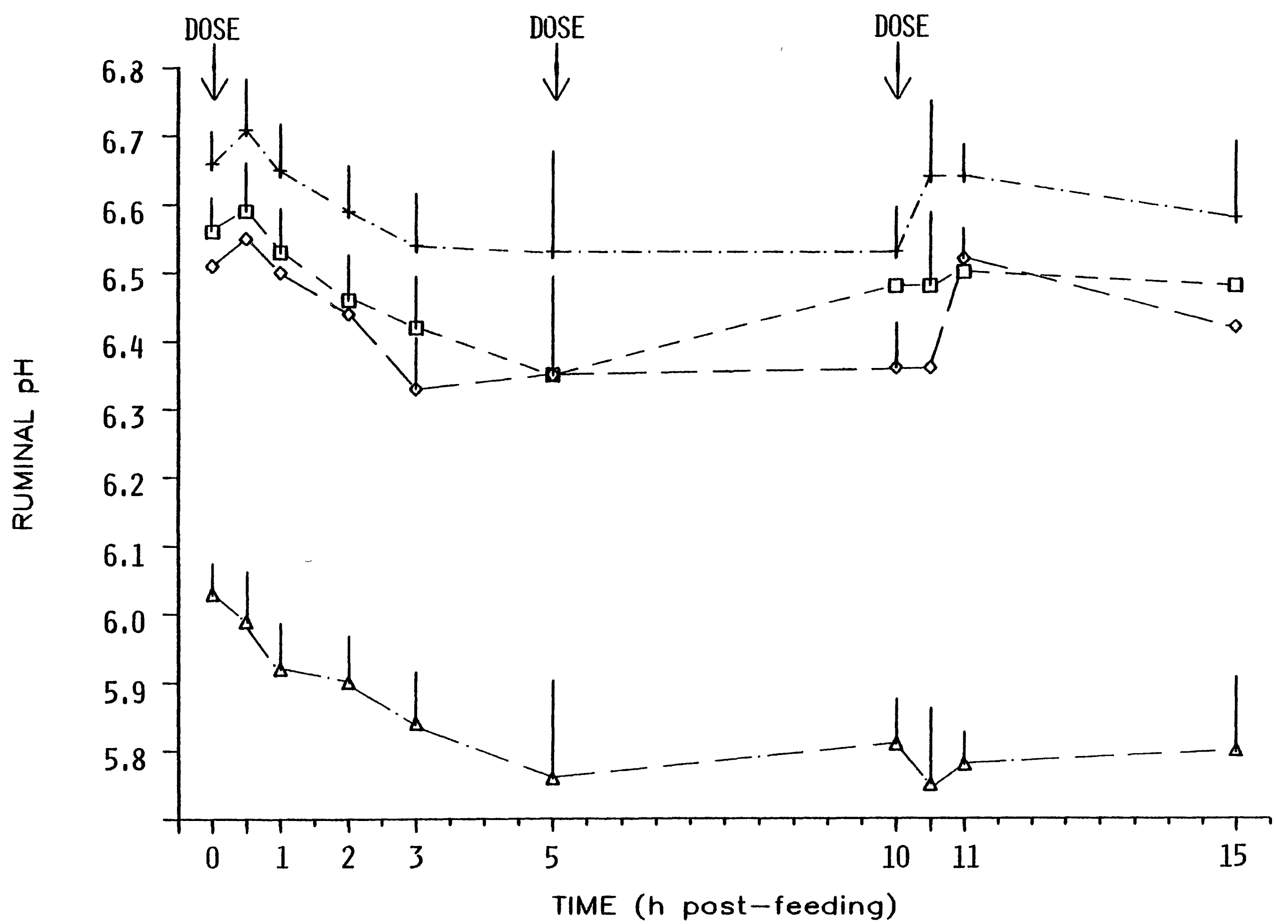

Figure 7. Diurnal Variation in Ruminal pH as Affected by Intraruminal Dosing of Buffers and/or Ammonia Compounds (□–□ NaCl; +—·+ $NaHCO_3$; ◇—◇ NH_4HCO_3; △—·△ NH_4Cl)

$NaHCO_3$ or $Na_4P_2O_7$. Kertz et al. (1983) found no adverse effects on ruminal pH when NH_4Cl (1 and 2% of diet as urea equivalent) was dosed intraruminally to dairy cows; however, ruminal pH of the control cows was below 6.0. Ruminal buffering capacity, calculated as the amount of acid required to decrease ruminal pH from 7.0 to 3.0, tended to be greater ($p<.10$) for the NH_4CO_3 heifers compared to the NaCl at 0700 h (Table XIX). The NH_4Cl (64.50 ml) heifers also appeared to be buffering at 0700 h better than the Nacl (59.00 ml) or $NaHCO_3$ (59.25 ml) heifers. Low hay intake and presumably decreased ruminal fermentation may have allowed more buffering compounds to be available for the NH_4Cl treatment. At 0730 h, buffering capacity was greater ($p<.05$) for NH_4HCO_3 (63.50 ml) compared to either NaCl (58.00 ml) or $NaHCO_3$ (59.25 ml). No treatment differences were observed at 1700 h. A greater hay intake, passage rate and possibly increased salivation may explain the greater buffering capacity observed for NH_4HCO_3 heifers.

Blood pH reflected the reduced ruminal pH occurring for the NH_4Cl treatment (Table XIX). When blood samples were collected at either 3.25 or 7 h postfeeding, blood pH was less ($P<.05$) for the NH_4Cl treatment compared to all others. Regulation of metabolic pH within a narrow range appears to be one of the primary homeostatic priorities of mammals, while economic factors such as growth are secondary (Kronfeld, 1976). Severe depressions in feed intake commonly occur when ruminants are abruptly switched from

TABLE XIX

RUMINAL PARAMETERS AND BLOOD PH AS AFFECTED BY INTRARUMINAL DOSING OF AMMONIA AND/OR BUFFER COMPOUNDS

Item	NaCl	$NaHCO_3$	NH_4HCO_3	NH_4Cl	SE
Particulate passage rate, %/h	3.1^{y}	3.1^{y}	4.1^{x}	2.9^{z}	.23
Cotton thread disappearance, %/h	$.55^{b}$	$.39^{b}$	1.08^{a}	1.11^{a}	.058
Rumen fluid passage rate, %/h	6.8^{ab}	8.2^{a}	7.9^{ab}	5.2^{b}	.60
Rumen fluid volume, l	121^{a}	116^{a}	122^{a}	80^{b}	4.0
Rumen fluid flow rate, l/h	8.2^{a}	9.4^{a}	9.6^{a}	4.1^{b}	.58
Rumen turnover time, h	15.0^{xy}	12.4^{y}	12.8^{y}	20.8^{x}	1.92
Ruminal buffering capacity, ml					
0700 h	59.00^{y}	59.75^{xy}	65.50^{x}	64.50^{xy}	1.456
0730 h	58.00^{b}	59.25^{b}	63.50^{a}	61.25^{ab}	.913
1700 h	55.25	57.50	61.75	57.00	1.871
Blood pH, 1015 h	7.61^{a}	7.58^{a}	7.61^{a}	7.42^{b}	.007
Blood pH, 1300 h	7.54^{a}	7.58^{a}	7.52^{a}	7.32^{b}	.009

[a,b]Means in rows with different superscripts differ ($P<.05$).
[x,y,z]Means in rows with different superscripts differ ($P<.10$).

roughage to concentrate diets resulting in acidotic ruminal conditions and presumably acidotic metabolic conditions as well (Ralston and Patton, 1976). The reduced hay intake observed with the NH_4Cl treatment was probably a result of metabolic acidosis (Kronfeld, 1976).

Particulate passage rate was enhanced ($P<.10$) for NH_4HCO_3 heifers compared to all others (Table XIX). Rate of cotton thread disappearance was greater ($P<.05$) when ammonia compounds were dosed. Increased particulate passage rate combined with increased rate of cellulolysis help explain the increased hay intake observed for NH_4HCO_3. McCollum and Galyean (1985) observed a 27% increase in hay intake and a 55% increase in particulate passage rate when steers fed hay were supplemented with a high crude protein supplement.

Rate of ruminal fluid passage tended ($P>.10$) to be increased with bicarbonate addition, however, a significant difference ($P<.05$) was observed only when $NaHCO_3$ was compared to the NH_4Cl treatment (Table XIX). Rumen fluid volumes and flow rates were not different ($P>.10$) when the NaCl, $NaHCO_3$ and NH_4HCO_3 treatments were compared but were lower ($P<.05$) for the NH_4Cl treatment. Rumen turnover time was reduced ($P<.10$) for the bicarbonate treatments compared to NH_4Cl, while NaCl did not differ ($P>.10$) from any treatments.

The tendency for bicarbonates to increase ruminal fluid passage agrees with the results of Rogers et al. (1979) who suggested that the increase in passage may be due to an increase in water intake. The depression in rumen fluid volume for the NH_4Cl treatment tends to reflect the decreased dry matter intake observed and may suggest that water intake was also lower than normal.

It appears that a ruminal nitrogen deficiency was present when hay and 2 kg corn were fed. When ammonia compounds more closely met bacterial N requirements, fiber digestibility tended to increase, a trend reflected in increased rate of ruminal degradation of cotton thread. The form of the nitrogen, however, appears to be quite critical in regard to total performance. Nitrogen in NH_4HCO_3 stimulated forage intake and appeared to increase digestible dry matter intake indicating a beneficial response in overall energy status. Conversely, NH_4Cl depressed forage intake so severely that the apparent advantages in digestibility were negated. Metabolic acidosis from NH_4Cl administration probably decreased hay intake. Bicarbonates appeared to have the greatest effect upon liquid flow parameters but little effect on ruminal pH.

Nitrogen content of supplements and ruminal availability of nitrogen should be carefully considered in supplementation programs designed to assure maximum forage utilization. Meeting the microbial demands for nitrogen should increase both forage intake and utilization, ultimately increasing the energy status of the animal. Furthermore, inclusion of nitrogen in high starch containing supplements, such as corn, may alleviate the adverse effects on forage digestibility commonly observed with "starchy" supplements.

CHAPTER VI

SUMMARY

When mature beef cows are maintained on native grass hay and supplemented with corn, grain intake should probably be limited to less than 1 kg/d. In the present trial, digestible dry matter intake tended to be increased with this amount of supplement. When 2 or 3 kg corn were fed, hay intake and digestibility were severely depressed resulting in digestible dry matter intakes not markedly different from cows fed the Control supplement (602 g CSM). Thus, feeding 2-3 kg corn/d may not enhance cow performance, since forage intake and digestibility would be limited and total digestible energy intake possibly not altered. Decreased forage intake would be advantageous during periods of low forage availability, for example, drought or overgrazing.

The depression in hay intake and digestibility that occurs when large quantities of corn are fed appears to be associated with a decreased rate of ruminal hay disappearance. Particulate passage rate was reduced as the amount of corn supplement increased. This suggests that intake may be limited bv inefficient ruminal fermentation of hay. Corn, due to its high starch content, can be rapidly fermented in the rumen yielding large quantities of volatile fatty acids. Resultant pH shifts could decrease cellulolytic bacterial growth. Feeding as much as 3 kg corn/d, however, did not alter ruminal pH to any great extent. Feeding large quantities of corn (3 kg), however, consistently resulted in low (<1 mg/dl) ruminal ammonia concentrations. Consequently, a celluloytic bacterial ammonia deficiency may have limited fiber digestion.

Feeding twice the daily allowance of a corn supplement, 2 or 4 kg corn, on alternate days resulted in small nonsignificant depressions in hay intake and digestibility. A 232 g/d decrease in digestible dry matter intake in combination with a trend for decreased total VFA concentrations, suggests that alternate day fed cattle may be at an energetic disadvantage. Feeding frequency had little effect on passage rates or ruminal cotton thread disappearance. Low ruminal pH (below 6.2), when 4 kg corn was fed on alternate days, may explain the trend for decreased hay intake and digestibility. The favorable rumen pH observed on nonfeeding days should allow greater hay digestion to occur if microbial requirements are met. A trend for decreased total VFA production when cattle were fed on alternate days suggests decreased rumen fermentation. Low ruminal ammonia concentrations may have limited cellulolytic bacterial growth. These results suggest that cows maintained on dormant native grass should be fed corn in small quantities (< 1 kg) on a daily basis.

Economically, however, daily feeding may not be worth the 4.2% decrease in digestible dry matter intake observed with alternate day feeding.

Feeding a greater amount of nitrogen may possibly alleviate some of the adverse effects of starch on hay intake and digestibility. Intraruminal dosing of a nonprotein nitrogen source (NH_4HCO_3) to heifers fed native grass hay and 2 kg corn, increased hay intake and tended to enhance hay digestibility, compared to NaCl or $NaHCO_3$ dosing. Digestible dry matter intake consequently increased, suggesting a positive energetic response to the ammonia addition. Rumen pH did not differ when bicarbonates were compared to NaCl. Therefore, rumen pH probably did not limit hay intake or digestibility. An increase in particulate passage rate and rate of ruminal cotton thread disappearance, when NH_4HCO_3 was added, support the hay intake and digestibility response. Low ruminal ammonia concentrations when NaCl and $NaHCO_3$ were dosed may suggest cellulolytic bacterial requirements for ammonia were not met. Ruminal ammonia concentrations when NH_4HCO_3 was dosed were much higher. Addition of nitrogen in the form of NH_4Cl decreased hay intake 25% when compared to NH_4HCO_3, presumably due to a metabolic acidosis which was verified by low rumen and blood pH measurements.

These results, obtained with nonpregnant, nonlactating beef cows fed low-quality native grass hay, suggest that corn supplementation may be practical when energy intake appears to be limited by forage availability. In times of sufficient forage supply, starchy energy supplements may be of little value to a producer unless the supplement is delivered in small quantities (< 1 kg) on a daily basis. Feeding large quantities of starchy supplements may be beneficial if they are combined with additional protein. Further study, however, of nitrogen source and amount is required before sound recommendations can be given to producers.

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VITA

Chadwick Charles Chase, Jr.

Candidate for the Degree of

Master of Science

Thesis: EFFECT OF CORN SUPPLEMENTATION ON THE UTILIZATION OF LOW-QUALITY GRASS HAY BY BEEF COWS

Major Field: Animal Science

Biographical:

Personal Data: Born in Worcester, Massachusetts, March 1, 1961, the son of Chadwick and Patricia Chase.

Education: Graduated from Brighton High School, Brighton, Colorado, December, 1979; transferred from Metropolitan State College, Denver, Colorado, June, 1979; received Bachelor of Science Degree in Animal Science from Colorado State University, Fort Collins, Colorado, July, 1983; completed requirements for the Master of Science Degree in Animal Science at Oklahoma State University, July, 1985.

Professional Experience: Intern at Texas A & M Agricultural and Research Center, Overton, Texas, 1982; Graduate Assistant at Oklahoma State University, 1983-1985.

Professional Organizations: American Society of Animal Science