KINETICS OF RUMINAL NITROGEN DIGESTION OF WHEAT FORAGE AND HIGH PROTEIN FEEDSTUFFS AND THE EFFECTS OF SUPPLEMENTAL PROTEIN ON THE PERFORMANCE OF GROWING CATTLE ON WHEAT PASTURE

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CHAPTER I

INTRODUCTION

Rate of weight gain is a key figure in determining the profitability of stocker cattle enterprises. Gains of stocker cattle grazing wheat pasture are potentially good because of the high quality of wheat forage. However, year to year fluctuations in daily gain are quite large because of differences in forage availability and cattle types (i.e. breed, sex and body composition differences). Where weight gains are low supplementation programs can be instituted to increase stocker cattle weight performance. In addition to improved weight gains supplementation of stocker cattle on pasture has several advantages (Wagner et al., 1984). These include 1) increased stocking rates or carrying capacity, 2) extending available forage supplies during periods of adverse weather, 3) inclusion of feed additives such as ionophores and poloxalene to improve gains and reduce health and disease problems, and 4) improving the overall nutrient balance.

In most cases, high energy grain-based supplements have been used as the supplement of choice on wheat pasture. Typically, weight gains are improved by approximately .1 to .15 kg/d when these supplements are fed on pasture. However,

the efficiency of supplement use is often quite low. Elder (1967) and Gulbransen (1976) indicated that efficiency of grain use was approximately 9.4 and 10.3 kg of grain per kg of increased weight gain.

Recent studies have investigated the responses of inclusion of high protein feedstuffs in supplements for stocker cattle grazing wheat pasture. At first, this seems odd because wheat forage contains 25 to 30% crude protein on a dry matter basis. However, considerable quantities of wheat forage N exist as soluble N (30 to 40% of total N) and NPN (10 to 20% of total N) which are rapidly degraded in the rumen. As a result, large quantities of dietary N may fail to reach the small intestine. However, limited information is currently available which characterizes the digestion and utilization of wheat forage. Therefore, one objective of this research was to provide some "baseline" data which characterizes the digestion and utilization of wheat forage and will serve as a catalyst for future work. Most comparable studies have been conducted in the United Kingdom on other temperate forages. These studies have demonstrated that considerable quantities of dietary N do fail to reach the small intestine. Consequently, it has been proposed that the performance of stocker cattle grazing wheat pasture is limited by the flow of non-ammonia N to the small intestine. Indeed, this was a primary conclusion drawn by Beever (1984) at the National Wheat Pasture Symposium. MacRae and Ulyatt (1974) reported that 63% of the variation in liveweight gain

of sheep grazing ryegrass or white clover pasture was associated with the amount of non-ammonia N absorbed from the small intestine and, that there was no relationship between liveweight gain and volatile fatty acids (i.e. a measure of energy status). Therefore, the second objective was to investigate the effects of inclusion of high protein feedstuffs in supplements on the performance of stocker cattle grazing wheat pasture.

The final objective of this research was to evaluate rate and extent of ruminal nitrogen degradation of several high protein feedstuffs which might be included in supplements for stocker cattle grazing wheat pasture. Protein supplements have been broadly classified as high, medium or low-bypass proteins. However, as demonstrated by Orskov et al. (1983) and Ganev et al. (1979) ruminal degradation is altered depending upon the diet consumed. Rate of passage from the rumen is another factor that affects extent of ruminal degradation and is influenced by roughage (or forage) level of diet, forage quality and level of intake. It is therefore unlikely that results from previous studies which have been conducted for given types of diets and levels of intake and have led to the classification of some protein supplements as "high bypass" supplements can be broadly extrapolated to all dietary regimes.

CHAPTER II

REVIEW OF LITERATURE

Composition of High Quality Forages

The chemical composition of forages often has a major impact on both the quantity and quality of forage consumed. Variation in the composition of forages occurs due to choice of species (grass or legume), level of nitrogen fertilizer, stage of forage maturity and other seasonal or environmental effects.

Wheat and other small grain forages are often characterized by low dry matter (DM) contents, and high crude protein (CP) and dry matter digestibility values. For perspective, Johnson et al. (1974) reported that wheat forage contained 25 to 31% CP on a DM basis while Horn (1984) reported in vitro dry matter digestibility (IVDMD) values ranging from 70 to 80%.

The CP content in forages is often classified as either true protein or non-protein-nitrogen (NPN). The primary components of the NPN fraction include amino acids, amides, nitrates, alkaloids, purines and pyrimidines (McDonald et al., 1988). Fresh forages often contain large quantities of NPN and soluble N. Beever and Siddons (1986) indicated that the NPN fraction may constitute from 15 to 50% of total N

with most being soluble and rapidly fermented within the rumen. Johnson et al. (1974) reported that NPN in wheat forage comprised from 15 to 33% of total N while Horn et al. (1977) reported that soluble N and soluble NPN concentrations of wheat forage ranged from 45 to 62% and 25 to 37% of total N, respectively. The soluble N and NPN content of forages can have a large impact on the amount of N reaching the small intestine. Beever et al. (1976) found a significant negative relationship ($r=-.98$; $P<.001$) between the amount of N flowing to the small intestine and the solubility of N of perennial ryegrass conserved by different methods.

The carbohydrates present in forages are very diverse. The water soluble carbohydrates and pectin represent the more rapidly digestible carbohydrates while the degree of cellulose and hemicellulose digestion depends on the extent of lignification (Van Soest, 1982). Fresh temperate forages typically contain large quantities of water soluble carbohydrates. Johnson et al. (1974) reported the water soluble carbohydrates in wheat forage averaged between 20 to 25% of DM in early January and increased up to 30% of DM by mid-February. Beever et al. (1986b) reported soluble carbohydrate content of ryegrass ranged from 14.5 to 17.9% of DM depending on stage of forage maturity. The cell wall content generally increases with advancing forage maturity. Horn (1984) found the neutral detergent fiber (NDF) content (i.e. cell wall) of wheat forage increased from roughly 30%

in November to greater than 45% of DM in April. Similar results were observed by Weston and Hogan (1968) in which NDF content of ryegrass increased from 46.4 to 80% of DM. The significance of the increased NDF concentration relative to N digestion was discussed by Nocek and Grant (1987). They observed significant negative relationships between rates of N disappearance and NDF ($r=-.83$; $P<.001$) and ADF ($r=-.87$; $P<.001$) content of alfalfa, timothy, orchardgrass and red clover preserved at different DM percentages. These correlations suggest that rate of N digestion in the rumen is related to the fibrous components in forage.

The primary factor that influences forage quality is maturity. As plants mature they tend to decline in nutritive value. These changes are due to the altered chemical composition including increased lignification and the decreased proportion of leaf to stem. Mangan (1982) reported that with increasing forage maturity the proportion of ryegrass stem increased from 5 to 60% of DM. Consequently, cell wall content increased from 37 to 56% while CP content decreased from 19 to 10% of DM.

With advancing forage maturity, rate of N disappearance tends to decrease. Beever et al. (1984) reported the rate of N disappearance of ryegrass decreased from 13.5%/hr on the early and mid-cut ryegrass to 9%/hr on the late cut ryegrass. Part of the decrease may be due to decreases in soluble N and NPN contents and increased N associated with the cell wall. Vogel (1988) in this dissertation observed

significant correlations between the size of a highly soluble rapidly disappearing N pool and soluble N ($r=.69$; $P<.05$) and NPN ($r=.67$; $P<.05$) content of wheat forage.

Digestion of High Quality Forages

Extent of Ruminal N Digestion

Estimates of apparent N digestibility of fresh forages are often high. Cammell et al. (1983) reported that total tract N digestibility of ryegrass and white clover at 3 stages of forage maturity exceeded 95% on all diets except for the mid (88%) and late (90%) white clover. Corbett et al. (1982) reported that N digestibility of Phalaris, Lucerne and native pastures were also very high. They reported digestibility coefficients of 91.5, 95.0 and 75.5 for Phalaris, Lucerne and native pasture, respectively. Although these studies indicate total tract N digestibility is high, few studies have attempted to quantify the extent of ruminal N digestion. Anderson et al. (1988) using a modified dacron bag technique found that 80 to 90% of total protein in bromegrass was potentially digestible in the rumen. After assuming a passage rate of 5%/hour, calculated extent of ruminal N degradation was 91.8 and 86.1% for bromegrass during the spring and fall grazing seasons, respectively. Ulyatt et al. (1975) using sheep fed perennial ryegrass, short rotation ryegrass and white clover reported that ruminal digestion of dietary N was 69.1, 69.7, and 72.5%, respectively. Beever et al. (1986) compared perennial

ryegrass and white clover at three stages of maturity. Extent of ruminal N digestion ranged from 64 to 87%. However, differences due to forage species (ryegrass, 74,4; clover, 78.6%) and stage of forage maturity (early, 78.3; mid, 75.2; late 78.6%) were small. In contrast, Hume and Purser (1974) indicated that extent of ruminal N digestion depended on stage of forage maturity. They reported more ($P<.05$) N was degraded ruminally in sheep consuming immature (73.5%) than mature (43 to 53%) subterranean clover. Zorrilla-Rios et al. (1985a) observed similar results when comparing ruminal digestion of wheat forage at two stages of forage maturity. Ruminal N digestion of wheat forage decreased from 72.2 to 44.4% with increasing forage maturity.

The extensive breakdown of dietary N in the rumen is most likely because of the high quantity of soluble N and NPN in fresh forage as previously mentioned and the rapid rates of N digestion. Rate of N degradation affects not only microbial protein synthesis but also flow of feed N to the small intestine. Currently, limited information on rate of N disappearance of high quality forages is available. Vogel (1988) in this thesis reported that wheat forage N exists kinetically as two distinct N pools. Approximately 50 to 75% of wheat forage N was present in a highly soluble rapidly degrading pool which disappeared at rates of 16 to 19%/h. Beever et al. (1986b) reported the rates of N disappearance of ryegrass and white clover each at three stages of forage

maturity differed. Rate of N disappearance was 41.6% faster ($P<.01$) for the white clover (17 vs 12%/hr) than ryegrass. Effects due to stage of maturity were noted particularly for the late cut forages. On the ryegrass forage, rate of N disappearance decreased from 13.5%/hr on the early and mid cut ryegrass to 9%/hr on the late cut ryegrass. Rates of N disappearance for the white clover were 16, 22 and 13%/hr for the early, mid and late cut forages, respectively. Anderson et al. (1988) found that rate of N disappearance of bromegrass averaged 12.9%/h in situ. They indicated that greater than 86% of the potentially digestible N had disappeared within 12 h.

Losses of N Prior to the Small Intestine

As a result of the rapid rates of N disappearance, Beever and Siddons (1986) concluded that ruminal losses of N were the result of an imbalance between degraded N and energy supply required for optimal microbial growth. They suggested that a ratio of 25 to 35 g degraded N per kg of organic matter (OM) truly digested in the rumen was needed to meet optimal microbial requirements. For perspective, degraded N per kg of OM truly fermented was 42.2 g/kg on wheat pasture as reported by Andersen (1988) and 51.9 g/kg as reported by Vogel (1988) in this thesis. These results suggest that an oversupply of N is present in the rumen from the extensive degradation of forage N which is presumably lost as ammonia.

As a result, large losses of ingested N prior to the small intestine have been observed in forages containing medium to high levels of N. Beever and Siddons (1986) reported that as much as 30% of ingested N may not reach the small intestine. Similarly, Egan (1974) when studying the digestion of N in 17 forages in sheep reported losses of up to 40% of N intake. Egan indicated that while the dietary N intake of the 17 forages varied greater than 30 fold, the range of N yields at the duodenum was only 12 fold.

Beever et al. (1986a) developed an equation relating non-ammonia N (NAN) flow per unit of N intake (Y) and dietary N content in the forage OM (X) for steers fed white clover and perennial ryegrass. The equation was Y= 1.5074 - .01854X (r^2=.86). Their equation demonstrated that NAN flow to the small intestine would be less than N intake when forage N was greater than 27.5 g N/ kg OM (i.e. 15.3% CP) and suggested that efficiency of utilization of N in fresh forages was more closely related to forage N content than forage species per se. Using their equation and assuming that wheat forage contains 4% N and 90% OM, NAN flow to the small intestine would only be 68% of N intake. This value is similar to that reported by Andersen (1988). Hogan and Weston (1970) also developed a similar equation : Y = 1.4304-.01691X. They concluded that NAN flow would be less than N intake when forage N exceeded 25.5 g N/kg DM (i.e. 15.9% CP). Again, using a value of 4% N for wheat forage, NAN flow to the small intestine would be 75.4% of N intake.

Hogan (1982) found the amount of NAN digested in the small intestine was less than N intake when he related the ratio of N/digestible organic matter (DOM) to the amount of NAN digested in the small intestine in sheep consuming a wide variety of forages. He found that when the N/DOM ratio was greater than 3%, NAN flow to the small intestine was less than N intake. For perspective, the N/DOM ratio in wheat forage is approximately 5.

Because large losses of N are observed prior to the small intestine, it would appear that ruminal ammonia concentrations would be high. Indeed, numerous studies have reported ruminal NH_3 concentrations far above the minimal requirements for bacterial growth. Zorrilla-Rios et al. (1985a) found rumen NH_3 concentrations were 43.0 and 19.8 mg/dl for steers consuming immature and mature wheat forage, respectively. Beever et al. (1986a) reported that NH_3 concentrations varied greater than 10 fold for steers consuming ryegrass and white clover at 3 stages of forage maturity. Rumen NH_3 levels for cattle consuming ryegrass were 5.9, 5.9 and 24.2 mg/dl on the early, mid, and late forages, respectively while NH_3 concentration were 28.3, 37.2 and 59.0 mg/dl, respectively on the white clover. Nevertheless, in each of the above studies rumen NH_3 concentrations were above the "minimum" requirement of 5 mg/dl needed for maximum microbial protein production as suggested by Satter and Slyter (1974). These researchers reported that increases in NH_3 concentrations above this

level would have no effect on microbial protein production. Consequently, it would appear that excess NH_3 produced during the degradation of forage N above the capacity of the rumen microbes to assimilate it into microbial protein would be lost.

Because large losses of ingested N occur prior to the small intestine, the supply of NAN to the small intestine may limit performance of rapidly growing cattle on wheat pasture. Indeed, this was a primary conclusion of Beever (1984). MacRae and Ulyatt (1974) reported that 63% of the variation in liveweight gains of sheep grazing ryegrass and white clover pastures was associated with the amount of NAN absorbed from the small intestine, and that there was no relationship between liveweight gain and energy absorbed as volatile fatty acids (i.e. a measure of "energy status" of the animal). A similar conclusion was reached by Barry et al. (1982) who observed that infusion of sodium caseinate (44g/day) and L-methionine (.5g/day) increased ($P<.05$) deposition of protein of both wool and body protein tissue in lambs fed perennial ryegrass. They concluded that protein deposition was limited by amino acid absorption from the small intestine. Therefore, the traditional concept that performance of stocker cattle grazing wheat pasture is not limited by protein supply and(or) a deficiency of specific amino acids in the small intestine needs further study.

Evaluation of Protein Supplements for Ruminal Bypass

Use of the Dacron Bag Technique

The supply of protein reaching the small intestine is a function of the amount of dietary protein escaping ruminal degradation and the quantity of microbial protein synthesized in the rumen. Of primary importance in understanding protein flow to the small intestine is estimating extent of ruminal N degradation. Although several methods for estimating ruminal N degradation exist, the in vivo approach using cannulated animals is generally considered to be the most accurate. However, as Stern and Satter (1982) indicated this procedure is labor intensive, time consuming and does not allow for a rapid broad screening of feedstuffs. Consequently, other attempts to estimate ruminal degradation using chemical, in vitro and in situ techniques have been used. The primary advantage of the in situ technique over the chemical and in vitro techniques is that it allows for a rapid broad screening of feedstuffs in a rumen environment similar to actual conditions. However, several factors influence N disappearance estimates using the in situ technique including bag pore size, sample size to bag surface area ratios, microbial contamination and animal and diet effects.

Bag Pore Size. Perhaps one of the most important factors affecting disappearance estimates from dacron bags is the pore size of the material used to construct the dacron bags. With increasing pore size rate of disappearance appears to be increased. Nocek (1985) observed that rates of disappearance of soybean meal DM and N were slowest ($P<.01$) from bags with a mean pore size of 6 and 20 um, intermediate with 40 and 59 um, and greatest ($P<.01$) with 80 and 102 um pore sizes. Uden et al. (1974) also observed an increase in disappearance of Guinea grass occurred as pore size increased from either 36 or 20 um to 53 um. They suggested that lack of gas release from the bags with smaller pore sizes limited digestion. Certainly there are two key factors that affect disappearance from dacron bags with varying pore sizes. First, bags with smaller pores may limit accessibility of the microbial population to the substrate, while second, larger pores may allow physical losses of the substrate to occur which may cause an apparent increase in disappearance.

Meyer and Mackie (1986) conducted a microbiological evaluation of the residues contained in dacron bags of various pore sizes. Their results demonstrated that the microbial population inside the dacron bag differed from the surrounding digesta. Less than 30% of the cultured rumen bacterial count (i.e. bacterial count/g of digesta) was present inside dacron bags with pore sizes of 5 and 10 um when compared to the surrounding ruminal digesta. Even with

the largest pore size (i.e. 53um), the cultured bacterial count was only 60% of that present in the digesta. Protozoa followed a similar trend with less than 10% of the protozoa count being present inside bags with pores of 5 and 10 um. They found that bacterial and protozoa counts increased linearly with increasing pore size up to 30um while extent of disappearance did not increase in bags with pores beyond 20 um. On this basis they suggested that a minimum pore size of 30 um be adopted.

Passive influx of digesta inside the dacron bags can also lead to error. Van Hellen and Ellis (1977) reported no influx of NDF into bags occurred with pores smaller than 10 um while .3 and .9 g of NDF entered bags with pore sizes of 75 and 100 um after 48 h. Uden et al. (1974) also reported that "appreciable but variable amounts of rumen material" entered bags with a pore size of 35 um. Both studies suggest that limiting influx of digesta into the bags is necessary to obtain accurate estimates of disappearance. On the contrary, Weakley et al. (1983) observed that particulate influx was less than .01 g after 24 h using material with a pore size of 52 um while Playne et al. (1978) observed no increase in DM inside dacron bags (25 um) containing polystyrene particles after 48 h although an increase of .3% of DM was noted following 168 h in situ. Nevertheless, although passive influx of digesta can be a potential problem, failure to correct this error leads to only small changes in disappearance estimates. Mehrez and Orskov (1977)

reported that failure to correct for entry of particulate matter into dacron bags lead to an underestimation of digestion of .7 percentage units.

Sample Weight to Surface Area Ratio. The effects of sample size relative to available surface area of the bags on digestion have been well documented. Mehrez and Orskov (1977) found that decreasing the sample size to surface area ratio from 62.5 to 16.3 mg DM/cm^2 increased DM disappearance of rolled barley after 24 h from 37.5 to 80% and also reduced variability between bags. A further decrease to 6.7 mg DM/cm^2 had no further effect on DM disappearance. Similarly, Van Hellen and Ellis (1977) reported that digestibility of buffelgrass was decreased by 21% when sample size was increased from .5 to 1 g in 3.5 x 15.5 cm bags (i.e. surface area ratios of 9.2 vs 18.4 mg/cm^2). However, digestion was not altered when sample size was increased by the same amount in bags which were 5.5 x 15.5 cm (i.e. surface area ratios of 5.9 vs 11.9 mg/cm^2). As a result they concluded the optimal ratio was approximately 10 mg DM/cm^2 of surface area. Similarly, Lindberg (1981) indicated that only small differences in DM disappearance were observed as the sample size to surface area ratio was increased from 5 to 10 mg DM/cm^2. Increasing the ratio to 15 mg DM/cm^2 decreased ($P<.05$) DM disappearance. However, N disappearance of hay was not affected by sample size which indicates different ratios may exist for forages vs concentrates. Nocek (1985) used ratios of 2.5, 12.6, 25.3

and 37.9 mg DM/cm^2 to estimate ruminal available protein of soybean meal. Use of bags with only 2.5 mg DM/cm^2 overestimated ruminal degradable protein while bags containing 25.3 and 37.9 mg DM/cm^2 underestimated degradable protein. They concluded that 12.6 mg DM/cm^2 resulted in an estimate of ruminal available protein similar to in vivo values.

Ultimately the size of bag and weight of sample will be determined by the number and type of analyses to be conducted on the residues. Nevertheless, based on current literature values an acceptable range should be between 10 and 15 mg DM/cm^2.

Microbial Contamination. The dacron bag technique has been used widely to study rate and extent of ruminal N degradation. However, most studies have assumed that the contribution of microbial N is negligible. Errors in N disappearance estimates resulting from microbial N contamination are quite variable and appear to be dependant on incubation time, type of feedstuff, and N content of the feedstuff. Varvikko and Lindberg (1985) reported that errors (%) in N loss resulting from microbial contamination after 5, 12 or 24 h incubation were 3.1, 2.6 and .8% for rapeseed, 10.2, 5.3 and 4.2% for ryegrass, and 193.4, 228.2 and 744.6% for barley straw, respectively. They concluded the magnitude of error was dependant on the N content of the feedstuff as well as its degradation rate. Similarly, Mathers and Aitchison (1981) indicated after 24 h of in situ digestion

approximately 18 and 2% of the residual N present in lucerne hay and fishmeal, respectively was present as bacterial N. Blair and Cummins (1983) estimated that microbial contamination of dehydrated alfalfa meal was only 4.1, 11.7 and 8.7% of the residual N content after 12, 18 and 30 h, respectively. Olubobokun et al. (1987) reported that microbial contamination of alfalfa hay, bermudagrass hay and orchardgrass hay ranged from 46 to 95 % of residual N following 96 h incubation. Although correlation coefficients were not given they reported the quantity of microbial N present on residues differed due to forage type and was "highly correlated" to dry matter digestibility.

In the above studies, bacterial contamination appears to be greatest for forages. Nocek and Grant (1987) in studying the digestion kinetics of alfalfa, red clover, orchardgrass and timothy hay preserved at different DM percentages, reported that bacterial N contamination increased linearly ($P<.05$) but decreased quadratically ($P<.05$) with time suggesting that bacteria attached up to a particular time afterwhich bacterial attachment appeared to be a function of site availability. Latham et al. (1978) and Akin et al. (1974) have indicated that bacterial adhesion and digestion are quite variable depending upon the specific type of cell wall or structure (i.e. phloem and epidermis, extensive; bundle sheath and vessel, minimal bacterial attachment). Consequently, bacterial contamination appears

to be a problem associated more with warm season rather than cool season forages.

As a result of large quantities of microbial N being present on particular feedstuffs, failure to correct for this problem may lead to large errors. Again, however this problem appears to be associated with forages only. Nocek (1985) reported that correction of soybean meal residues for microbial contamination did not alter rate of N digestion (10.3 vs 10.6%/h). Mathers and Aitchison (1981) reported that ruminal N degradation of fishmeal was not affected although ruminal degradation of lucerne hay increased ($P<.01$) from 61 to 65% when corrected for microbial contamination. Nocek and Grant (1987) found that microbial contamination of four hays preserved at different DM percentages decreased digestion lag times and altered rates of disappearance depending on forage type and DM. However, Vogel (1988) in this thesis reported that correction for microbial contamination of fresh wheat forage did not alter ($P>.40$) the kinetics of wheat forage digestion.

Animal and Diet Effects. The effects due to animal and diet can have a large impact on estimates of disappearance obtained using the dacron bag technique because degradation estimates from in situ studies appear to be very sensitive to the conditions of measurement. Mohammed and Smith (1977) reported a three fold increase in rate of N disappearance of fishmeal when the host animal was adapted to a diet containing fishmeal while Vik-Mo and Lindberg (1985)

reported that rate of N disappearance of several protein supplements was increased when the crude protein content of the basal diet was increased from 15 to 25%. The studies by Orskov et al. (1983) and Ganev et al. (1979) showed that in situ extent of ruminal degradation of plant protein supplements was decreased sharply when sheep and cattle were fed a high-concentrate, whole-barley diet vs a dried grass hay diet. Ganev et al. (1979) postulated that if cellulose digestion of protein supplements is as rapid as grass, the protein may be exposed to degradation at a greater rate on a forage diet rather than a concentrate diet. Nevertheless, disappearance rates using the nylon bag technique should be determined under similar conditions to which the results will be applied.

The effects due to animal appear to be relatively small. Weakley et al. (1983) observed no differences among cows in rate or extent of DM disappearance of soybean meal while Orskov et al. (1983) observed no consistent differences in rates of degradation of six protein supplements incubated in both cattle and sheep. They concluded that if sheep and cattle were given the same diet the microbial population would be similar which would result in similar rates of disappearance. However, Mehrez and Orskov (1977) indicated that greatest variation for in situ disappearance of rolled barley occurred between animals, followed by variation among days within animals with

variation in bags among days and animals having the least variability.

Factors Affecting Protein Degradation in the Rumen

The NRC which recently published "Ruminant Nitrogen Usage" (NRC, 1985) summarized current trials where ruminal N degradation of common feedstuffs was determined using sheep and(or) cattle cannulated with duodenal or abomasal cannulas. Ruminal N degradation of the protein supplements reviewed was different and varied considerably. For perspective, mean ruminal N degradation and standard deviations of soybean meal, meat and bone meal, fishmeal and cottonseed meal (direct solvent) were 72 $\pm$ 14%, 60 $\pm$ 11%, 20 $\pm$ 12%,and 59 $\pm$ 12%, respectively. They concluded that information on many feedstuffs is non-existent and estimates of ruminal degradation are highly variable. Numerous factors can affect ruminal degradation of protein. These include differences in solubility, structural differences in proteins, processing and rumen factors such as diet, level of feed intake and retention time.

Protein Structure. The three dimensional structure of protein appears to be a primary factor affecting ruminal degradation. The study which most researchers refer to is that of Nugent and Mangan (1978). Rate of ruminal proteolysis was measured using rumen fluid obtained from sheep for three soluble proteins: casein, bovine serum albumin and fraction I leaf protein. Rate of proteolysis was

greatest for casein while bovine serum albumin had the slowest degradation rate. Treatment of bovine serum albumin with dithiothreitol, which breaks disulphide bridges crosslinking the protein, resulted in a several fold increase in proteolysis. They concluded that rate of proteolysis was limited by structural and not solubility differences. In a similar manner, treatment of proteins with formaldehyde results in protection from ruminal degradation by changing the structure of the protein. The formaldehyde alters the structure of the proteins by forming a stable methylene cross bridge within proteins which is resistant to ruminal digestion (Barry, 1976).

Roughage to Concentrate Ratio. The effect of diet can have a large impact on ruminal degradation of proteins. As previously mentioned, Orskov et al. (1983) and Ganev et al. (1979) reported that ruminal N degradation of protein sources of vegetable but not animal origin was decreased when sheep were fed a whole barley diet vs grass hay. They suggested the cellulose present in the vegetable sources had a protecting effect on N disappearance on the whole barley diet. In contrast, Barrio et al. (1985) reported that N disappearance independent of source (i.e. soybean meal or meat meal) decreased in steers when concentrate level increased from 20 to 80%. Their conclusion was that differences in microbial type or activity rather than chemical characteristics of the substrate were responsible for greater protein loss with lower concentrate diets.

Loerch et al. (1983a) also reported that in situ N disappearance of casein, soybean meal and dehydrated alfalfa was affected by concentrate level more than blood meal, meat and bone meal or fishmeal. This effect was most pronounced with soybean meal. When cows were fed 60 or 80% high-moisture corn, soybean meal N disappearance was similar to meat and bone meal and dehydrated alfalfa. Consequently, they proposed on high concentrate diets rumen escape of soybean meal protein would be similar to meat and bone meal or dehydrated alfalfa. Nevertheless, the above studies indicate that diet and its subsequent effects on ruminal fermentation can alter the digestion of protein supplements. Most studies suggest that changes in ruminal pH may be a key factor in altering ruminal digestion. The effects of pH on ruminal digestion of protein supplements are probably two fold. First, decreasing pH alters solubility of feed protein. Wohlt et al. (1973) demonstrated that mean solubility of several feedstuffs in either rumen fluid or Burrough's mineral mixture which was diluted 10 fold decreased from 57 to 27% as pH decreased from 7.5 to 5.5. In addition, shifts in microbial species and enzyme activity were noted at different pHs (Erfle et al., 1982). Although many bacteria possess proteolytic activity, the numbers of proteolytic species are decreased at low pH values (i.e. < 6, Tamminga, 1979).

Retention Time. Another factor which affects protein degradation is ruminal retention time. The significance of

length of ruminal retention was emphasized by Orskov et al. (1983) who indicated that ruminal N degradation of a feedstuff cannot be expressed as a single value because it will vary considerably with rate of passage. If the degradable fraction is degraded rapidly, retention time will influence actual degradability to a lesser extent than if the degradable fraction is slowly degraded. They calculated that ruminal N degradation of linseed meal would vary from 86.8 to 39.6% as passage rate increased from 1 to 10%/h.

Several factors affect retention time and ultimately ruminal degradation of protein supplements. Lindberg (1982) fed cows a mixed diet containing Cr-mordanted soybean meal, cottonseed meal and rapeseed meal at maintenance and at three times maintenance levels of intake. Ruminal passage rate of all supplements was similar at each level of feeding, but was increased (5.16 vs 4.01%.h) with increased level of feeding. Eliman and Orskov (1984a) reported rate of passage of Cr-mordanted fishmeal was greater in cows offered roughage diets compared to high-concentrate diets. Rate of passage increased from 6.4 to 8%/h as roughage level increased from 25 to 100% of the total diet. Similar increases in rate of passage with increasing roughage content were observed by Owens et al. (1979).

Several studies have indicated that retention time of different protein supplements are similar under different dietary regimes provided that particle size and density are similar. Eliman and Orskov (1984b) fed sheep either Cr-

mordanted fishmeal or soybean meal and passage rates for both supplements averaged 2.21%/h for sheep fed a maintenance level of dried grass hay. In contrast, Stern et al. (1983) reported that ruminal retention time for corn gluten meal was lower ($P<.05$) than soybean meal or brewers dried grains. They concluded the faster movement of corn gluten meal through the rumen occurred because of the finer particle size and greater density of corn gluten meal.

Processing. Ruminal degradation of specific protein sources is often decreased during processing. Several methods for decreasing ruminal degradation have been proposed including the use of formaldehyde (Barry, 1976; Amos et al., 1974) and tannins (Hartnell and Satter, 1978; Dreidger et al., 1972). However, the most common method of decreasing ruminal degradation of protein is heat which acts by decreasing protein solubility. Goestch and Owens (1985) reported soluble N content of cottonseed meal decreased with increasing amounts of pressure and heat during processing. Soluble N content of cottonseed meals produced by direct solvent, prepress solvent extraction and mechanical processes was 28.8, 27,4 and 14.7% while estimates of ruminal N degradation were 63.3, 64,7 and 43.0%, respectively. Similarly, Broderick and Craig (1980) estimated that ruminal N degradation of cottonseed meal produced by direct solvent and mechanical processes was 62.5 and 37.4%. Plegge et al. (1983) reported as roasting temperature increased from 102 to 185^{o}C less N disappeared

from soybean meal in dacron bags suggesting that increased heat reduces the rate of degradation in the rumen. However, heating at 185^{o}C increased acid detergent insoluble N to 59.5% of total N suggesting that heating may sometimes be counterbalanced by decreases in total tract digestibility of N.

Effects of Protein Supplementation on the Performance of Cattle Grazing High Quality Pastures

Grigsby (1982) attempted to evaluate the responses of stocker cattle grazing winter wheat pasture to additional protein in 2 experiments. In the first experiment, heifers received either no supplement, or 11, 26 or 38% CP supplements using soybean meal to supply the additional protein. Supplements were fed 3 times weekly at the rate of 1.36 kg DM/head/day. Heifers receiving the 11 and 26% CP supplements gained 20% faster ($P<.05$; .67 vs .80 kg/day) than the unsupplemented controls while no additional response was observed with increasing amounts of supplemental protein beyond 26% crude protein. In the second trial, steers received either no supplement, an 11% CP supplement with or without monensin (160 mg/head/day), or a 23% CP supplement again using soybean meal as the primary protein source. Supplements were fed 3 times weekly at a rate of .92 kg DM/head/day. Daily weight gains were 21% higher ($P<.05$; .80 vs .66 kg/day) for steers receiving the 11% CP supplements and were increased by an additional .07

kg/d with the inclusion of monensin. As a result of these experiments, they concluded that optimum performance of stocker cattle could be achieved by feeding low levels (i.e. < 1 kg DM /head/day) of grain based supplements containing monensin. One possible explanation for the lack of response to additional protein could be related to the protein source used. As discussed previously, wheat forage is extensively degraded in the rumen and it is unlikely that supplementation with a protein source high in ruminal degradability would have any benefit.

Grigsby et al. (1987) reported results of a 90 d trial where cattle grazing Bonel rye and Marshall ryegrass pastures were supplemented with fishmeal, corn or corn plus rumen stable lysine and methionine. They found that daily weight gains (kg/day) were lower ($P<.01$) for calves grazing pasture alone (1.08) or supplemented with fishmeal (1.19) than for calves supplemented with corn (1.58) or corn plus the protected amino acids (1.48). Their conclusion was energy rather than protein limited weight gains. However, this conclusion may have been misleading because daily consumption of the fishmeal was less than half of the other supplements (i.e. .34 vs .80 and .73 kg/day). Nevertheless, it was interesting to note that a significant positive relationship ($P<.01$, $r^2=.74$) was found between average daily gain and intake of fishmeal. This tends to indicate that although cattle reluctantly consumed fishmeal, there was an added response in animal performance with increased fishmeal

consumption. Rouquette et al. (1987) reported similar results for calves grazing rye pastures in which average daily consumption of fishmeal and corn were .15 and .51 kg/day for Simmental X Brahman cattle and .20 and .34 kg/day for Brahman cattle, respectively. Daily gains of Brahman cattle grazing pasture only, or supplemented with fishmeal or corn were .87, .85 and 1.04 kg/day. Daily gains of the Simmental X Brahman cattle were 1.09, 1.15 and 1.26 kg/day, respectively.

Other studies however, have been consistent with the premise that performance of stocker cattle can be increased when fed a high ruminal bypass protein source. Lee (1985) found that steers receiving .68 kg/day of a supplement containing 15% meat meal gained 9% faster ($P<.05$; 1.09 vs 1.00 kg/d) when compared to the same hominy based supplement excluding meat meal. Anderson et al. (1987) also reported that steers receiving .68 kg/day of supplemental feed using meat and bone and feather meal as protein sources resulted in an 8.1% increase ($P<.05$; 1.03 vs .91) in rate of weight gain over calves fed the dry rolled corn based control supplement.

Significant increases in rate of weight gain have also been reported on other high quality forages. Anderson et al. (1988) supplemented cattle grazing bromegrass pastures with .58 kg/d of supplements formulated to provide graded levels of escape protein (0, .11, .23 and .34 kg/day) using bloodmeal and corn gluten meal. Increasing levels of escape

protein resulted in significant linear (P<.01) and quadratic (P<.05) increases in rate of weight gain. In a recent study by Worrell et al. (1988) steers grazing ryegrass pasture were supplemented with .45 kg/day of cottonseed meal (mechanically extracted) with and without 150 mg of lasalocid daily. Although no control, energy-based supplement was used, supplementation with cottonseed meal resulted in a nonsignificant increase in daily gains of 12.7% (1.42 vs 1.26 kg/day) while inclusion of lasalocid with the cottonseed meal resulted in a 23% increase (P<.05) in daily gains compared to the unsupplemented steers (1.55 vs 1.26 kg/day).

Responses to protein supplementation have also been observed by lactating ewes and cows grazing high quality pastures. Penning and Treacher (1981) reported results of a study where ewes grazing perennial ryegrass pastures received a high-energy barley or maize starch supplement or supplements containing soybean meal, fishmeal or a combination of soybean meal and fishmeal as the protein source. Supplements containing fishmeal increased milk production by 24% while only a 4% increase was noted for ewes fed the energy supplement. As a result, lambs suckling the ewes receiving the fishmeal supplements gained 12% greater than ewes receiving energy supplements and 18% greater than the unsupplemented ewes. Rogers et al. (1980) reported that supplementation with formaldehyde-treated casein of dairy cows consuming a "high quality pasture"

(2.8% N) increased milk production by 13% and milk protein by 15%. However, the increases in milk yield and milk protein were not associated with any increases in forage or total DM intake. Consequently, they concluded that milk synthesis was limited by the amount of protein absorbed post-ruminally and that the utilization of the digestible energy of the forage was improved by the protected casein.

Several mechanisms for increasing performance of animals when supplemented with protein other than an increase in protein flow to the small intestine have been proposed. First, the supplemental protein could correct an amino acid imbalance. Harper and Benevenga (1978) reported the classical response of an amino acid imbalance is decreased feed intake and rate of gain which can be corrected by supplementation of the limiting amino acid. Andersen (1988) reported that supplementation of stocker cattle grazing wheat pasture with meat meal resulted in slight ($P<.10$) increases in forage intake of approximately 4 to 14%. Based on the equations of the net energy system (NRC, 1984) for a 200 kg medium frame steer consuming 2.5% of body weight, a 7% increase in wheat forage intake would increase rate of weight gain by .1 kg/day which is similar to that observed in performance trials (Lee, 1985; Anderson, 1987). This assumes the NEm and NEg of wheat forage are 1.73 and 1.11 Mcal/kg, respectively.

Another proposed mechanism as suggested by MacRae and Lobley (1982) is that additional protein increases the

efficiency of metabolizable energy (ME) use. MacRae et al. (1985) observed a 27% increase in efficiency of ME utilization by sheep consuming autumn-harvested grass hay when casein was infused into the abomasum. They suggested the increased efficiency was due to an increase in NADPH production from glucogenic amino acids supplied by the additional protein. On forage based diets where acetate is the primary product of ruminal fermentation, NADPH levels may be inadequate for efficient energy use. As a result, excess acetate is probably lost in some futile cycle. Increasing the supply of NADPH would increase efficiency of ME use by suppling a source of reducing equivalents for fatty acid synthesis. However, Black et al. (1987) using a computer simulation model concluded that increased animal performance with additional protein on forage based diets was not related to increased NADPH production but rather increased protein absorption which increased ATP utilization for body protein synthesis.

Summary

In summary, these data indicate that high quality forages are extensively degraded in the rumen and that considerable quantities of dietary N do not reach the small intestine. Losses of N prior to the small intestine on forages containing medium to high levels of N can be exceptionally high (i.e. 40 to 45% of ingested N). As a result the concept that animal performance on these pastures is limited by

protein supply in the small intestine should be evaluated using protein sources of low ruminal degradability. However, literature estimates for ruminal N degradation of protein supplements are quite variable depending on roughage level of the diet, forage quality and level of intake. Consequently, it is unlikely that results from previous studies which have been conducted on given types of diets and levels of intake and which have led to the classification of protein supplements as "high bypass" supplements can be broadly extrapolated to all dietary regimes.

CHAPTER III

EFFECTS OF FORAGE MATURITY AND MICROBIAL CONTAMINATION ON THE KINETICS OF WHEAT FORAGE NITROGEN DISAPPEARANCE IN SITU BY CATTLE GRAZING WHEAT PASTURE

Abstract

Five trials were conducted over 5 yr to evaluate effects of forage maturity and microbial contamination on the kinetics of ruminal nitrogen (N) disappearance in situ. In each of 4 yr eight multi-cannulated steers were used to evaluate ruminal N disappearance of wheat forage in situ at two distinct stages of forage maturity. Duplicate dacron bags containing 10 g "as is" of wheat forage were incubated in the rumen of each steer at various time intervals with rates of N disappearance being determined by curve peeling. In yr 5, three multi-cannulated steers were used to determine the effects of microbial contamination on N disappearance in situ by analyzing wheat forage residues for D-alanine as a bacterial marker. Wheat forage N existed kinetically as two distinct N pools. Approximately 75.3% of the N in immature wheat forage was present in a rapidly disappearing N pool (Pool I) with a fractional rate of N

disappearance of 16.1%/h. With increasing forage maturity, less (P<.05) N was present in Pool I (50.4%) although the rate of N disappearance was greater (P<.10; 19.2 vs 16.1 %/h). Ruminal degradation decreased (P<.05) by 23% with advancing forage maturity. In the microbial contamination trial increasing incubation times increased (P<.05) microbial contamination although contamination was no greater than 14.4% of the residual N. Errors in measurement of extent of N disappearance were small (i.e. .54 to 1.16%) with no differences (P>.40) in the kinetics of N disappearance being observed. These data indicate that due to the rapid rates of wheat forage N disappearance, large quantities of dietary N fail to reach the small intestine. Consequently, performance of animals consuming wheat forage may be limited by the supply of non-ammonia nitrogen reaching the small intestine.

Introduction

Approximately 10 million ha of winter wheat are grown in the Southern Great Plains with as many as 6 million stocker cattle grazing wheat pasture annually (Horn, 1984). Despite this fact, relatively few studies have been conducted to evaluate the nutritive value of wheat forage. Very limited information is available on the rate of ruminal degradation of wheat forage protein during ruminal fermentation. Rate of forage degradation affects not only microbial protein synthesis but also feed N flow to the

small intestine. Recent studies (Anderson, 1988; Lee et al. 1985) have demonstrated a beneficial response to protein supplementation of stocker cattle grazing wheat pasture when fed supplemental protein. This indicates that extensive degradation of wheat forage protein occurs in the rumen and non-ammonia-nitrogen flow to the small intestine may limit animal performance.

Although attachment by ruminal microorganisms to feed particles has been demonstrated in numerous studies (Cheng and Costerton, 1987; Craig et al., 1987) only a few attempts have been made to estimate the errors associated with failing to correct for microbial N contamination on in situ N disappearance estimates. Varvikko and Lindberg (1985) and Olubobukun et al. (1987) have demonstrated that errors in N disappearance are potentially large and suggested that N disappearance values be corrected for microbial contamination. However, the previous studies were conducted on medium to low quality forages. Therefore, the objectives of this research were to evaluate the kinetics of ruminal disappearance of wheat forage N in situ in cattle grazing wheat pasture at two stages of forage maturity and to evaluate the effects of microbial contamination of wheat forage residues on rate and extent of N disappearance.

Experimental Procedure

Forage. Wheat forage variety TAM-105, fertilized with 112 kg N/ha in the form of anhydrous ammonia was used in

each of the experiments. Grazing periods represented two distinct forage maturities. Immature wheat forage was characteristic of rapidly growing wheat forage in early spring while mature wheat forage represented wheat forage which would be consumed during the "grazeout" period and was characteristic of wheat forage shortly after heading.

Wheat Forage In Situ Trials. In each of 4 yr, eight multi-cannulated Hereford or Hereford X Angus steers were used to evaluate in situ ruminal N disappearance of wheat forage at two stages of forage maturity. The mean weights and standard deviations of the steers in years 1 to 4 (i.e. 1984 to 1987) were 440 $\pm$ 44 kg, 573 $\pm$ 47 kg, 443 $\pm$ 53 kg and 522 $\pm$ 52 kg, respectively. As part of other experiments relative to site and extent of digestion of wheat forage as affected by lasalocid or protein supplementation, steers were randomly allotted to two treatments each year in a split plot experimental design with steers as main units and grazing periods as subunits. In yr 1 and 2, steers received either 0 or 300 mg lasalocid daily. In yr 3 and 4, steers received approximately 900 g/d of a corn based (control) or a 16 to 20% crude protein supplement containing 18 to 25% meat meal. The composition of the supplements fed in yr 3 and 4 was reported by Vogel (1988).

The experimental periods for the immature and mature forages were from approximately March 20 to 22 and May 5 to May 7, respectively. The steers were placed on a 6 ha pasture divided into 2 paddocks in early December each yr

and remained on pasture through the grazing season. Steers were rotated among the pastures as needed to ensure that enough wheat forage was available.

Duplicate dacron bags containing approximately 10 g "as is" of hand clipped wheat forage (i.e. about 2 g of wheat forage DM) were incubated in situ in the rumen of each steer at various time intervals. In yr 1 bags were incubated for 3, 6, 12, 24 and 48 h while in yr 2 bags were incubated for 4, 8, 12, 18, 24, 36, 48 and 60 h. In yr 3 and 4 the bags were incubated for 4, 8, 12, 24, 36 and 48 h. The hand clipped samples of immature wheat forage were obtained by clipping the wheat pasture approximately 3 cm above ground level. On mature wheat pasture the hand clipped samples were obtained by cutting off the top one-third of the wheat forage plant (i.e. 20 to 25 cm). The clipped wheat forage samples were cut to an average particle length of 2.5 cm before being inserted into the dacron bags. The dacron bags measured 8 X 12 cm, and had a mean pore size of 40 $\pm$ 12 um. Seams of the bags were sewn with polyester thread, sealed with waterproof glue and the edges were burned to prevent fraying in the rumen. After removal from the rumen, bags were initially rinsed under tap water to remove digesta from outside the bag. This was followed by successive washings with deionized water until the effluent from the bags was clear. After washing, all bags were dried in a forced air oven at 55^{o}C for 48 h and then reweighed. Contents of the

bags were subsequently analyzed for N content by the Kjeldahl procedure (AOAC, 1975).

Estimates of rate of N disappearance of wheat forage were obtained by the "curve peeling" technique of Shipley and Clark (1972). Initially, a "break point" (i.e. the point where the contribution from the more rapidly disappearing pool (i.e. Pool I) becomes insignificant) was determined by visual inspection of the plots. Break points of 24 and 12 h were used for the immature and mature forages, respectively. After the break point was established, the slope (K2) and intercept of the more slowly degraded pool (i.e. Pool II) were determined by linear regression of the natural logarithm of the proportion of N remaining vs time. The contribution of this pool to the earlier points was subsequently subtracted and the slope (K1) and intercept of the more rapidly disappearing pool were determined by linear regression. Nitrogen pool sizes (i.e. A1 and A2) were estimated from the anti-logarithm of the intercepts and were set equal to one (i.e. A1 + A2 = 1). The time required for one-half of the N to disappear from each pool was estimated as .693/rate of N disappearance (Shipley and Clark, 1972). Ruminal N degradation of wheat forage was calculated using the equation of Broderick and Craig (1980) where ruminal N degradation = (A1*K1)/(K1+Kp) + (A2*K2)/(K2+Kp) where Kp represents rate of passage of wheat forage obtained from concurrent site and extent of digestion trials using ytterbium-labelled wheat forage (Andersen, 1988).

Microbial Contamination Trial. Three multi-cannulated steers (544 ± 24 kg) were used to evaluate the effects of microbial contamination of in situ residues on N disappearance using D-alanine as a bacterial marker. Steers grazed immature wheat pasture for 20 d prior to the experimental period (March 31 to April 1, 1988; i.e yr 5). Quadruplicate dacron bags containing approximately 10 g "as is" (i.e. 2 g DM) of hand clipped wheat forage were incubated in the rumen of each steer for 4, 8, 12, 18 and 24 h while eight bags were incubated for 36, 48 and 60 h. Dacron bags and wheat forage residues were prepared, washed and dried as previously described. After samples were dried wheat forage residues were ground and composited on an equal weight basis within steer and incubation time. Composite samples were analyzed for N and D-alanine. Duplicate samples (.5 g DM) for D-alanine analysis were hydrolyzed in 100 ml of 6 N HCl at 100°C for 24 h under N_2. After hydrolysis, .2 g of activated charcoal (Fisher Scientific; 50 - 200 mesh) was added to decolorize the sample. Hydrolysates were filtered through Whatman No. 54 filter paper and subsequently evaporated to dryness in a flash evaporator at 50°C. Evaporated samples were washed with 200 ml of distilled water, evaporated to dryness, diluted with an additional 100 ml of water, evaporated to dryness and diluted to a final volume of 10 ml. Duplicate subsamples were subsequently assayed for D-alanine as outlined by Garrett et al. (1987).

In addition, approximately 750 ml of rumen fluid were obtained from each steer through the rumen cannula at the conclusion of the in situ incubation period. Ruminal fluid samples were strained through four layers of cheesecloth, and ruminal bacteria were isolated by differential centrifugation. Samples were initially centrifuged at 5000 x g for 10 minutes to remove sedimented feed particles and protozoa, then at 20,000 x g for 15 minutes to isolate bacteria. The isolated bacteria were washed with 25 ml of .9% (w/v) NaCl and recentrifuged at 20,000 x g. Bacterial pellets were lyophilized, ground in a coffee mill and subsequently analyzed for N and D-alanine as previously described. The proportion of bacterial N present in the wheat forage residues was calculated as the ratio of N to D-alanine in isolated bacteria multiplied by the amount of D-alanine present in the residue. Nitrogen disappearance values at each incubation time were corrected for bacterial contamination by subtracting bacterial N present in the wheat forage residues from the residual N content. Corrected and uncorrected estimates of N disappearance were subjected to the "curve peeling" technique as previously described. Also, ruminal N disappearance was calculated as previously described. However, because rate of passage of wheat forage was not measured it was assumed to be 4.6%/h (i.e. the mean rate of passage observed during the previous trials on immature wheat forage).

Forage Composition. In each experiment hand clipped wheat forage samples were obtained at randomly selected locations within the pasture two times during the experimental period to characterize forage composition. In yr 1 and 2, hand clipped samples were returned to the laboratory, frozen and lyophilized. In the remainder of the trials, hand clipped samples were frozen immediately after clipping by suspension over liquid N, and subsequently lyophilized. Lyophilized wheat forage samples were ground through a 2 mm mesh screen in a Wiley mill and analyzed for total N by the Kjeldahl procedure (AOAC, 1975). Also, soluble N was determined following a 1 h incubation at 39°C in a shaking water bath using the mineral mixture (2% v/v; pH 6.5) of the "Ohio" buffer in vitro fermentation media (Johnson, 1969). Non-protein nitrogen (NPN) was determined using 25 ml of the filtrate of the soluble N procedure by sodium tungstate precipitation with 5 ml of 1.07 N H_2SO_4 and 5 ml of 11.2 % sodium tungstate. Samples were also analyzed for soluble carbohydrates by the procedure of Balwani (1965) and in vitro dry matter disappearance (IVDMD) using a modification of the Tilley and Terry (1963) procedure. Each sample was analyzed in triplicate using .5 g DM in 40 ml of buffered rumen fluid which consisted of equal parts (v/v) of strained rumen fluid and McDougall's buffer (McDougall, 1948). The McDougall's buffer contained one-tenth the specified concentration of $CaCl_2$ and 1 g of urea/liter of buffer. The rumen fluid was obtained from a steer maintained

on prairie grass hay and .9 kg/d of a protein supplement that contained (% as-fed): soybean meal (44% crude protein), 93; sugarcane molasses, 3; dicalcium phosphate 2; trace-mineralized salt, 2.

Statistical Analysis. Data were analyzed using least squares analysis of varience using the General Linear Models procedure of SAS (SAS, 1982). The statistical model for the in situ trial included yr, treatments within yr, steers within treatments X yr, period, yr X period and treatment X period within yr as sources of variation. The F test for treatments within yr was conducted using steers within treatments X yr as the error term. Data for the microbial contamination trial were analyzed as a completely randomized design using the Student's t-test (Steel and Torrie, 1980). In addition, correlation coefficients (r) and standard errors of estimates (Sy.x) were obtained by regressing chemical components present in wheat forage against N pool size and rate of N disappearance using the mean values obtained for each period and yr (i.e. n=9)

Results and Discussion

Forage Composition. Chemical composition of the wheat forage grazed during the in situ and microbial contamination trials is presented in Table 1. With advancing forage maturity, crude protein (CP) content decreased from about 24.7 to 12.8 % of DM, and IVDMD decreased from 76.6 to 69.4%. These values are similar to those reported by Horn

(1984), and the decreases in CP and IVDMD were most likely attributable to the decreased proportion of leaf to stem and the increased structural carbohydrate content observed with advancing forage maturity. Soluble N and NPN (% of DM) decreased from 1.42 to .80 and from .52 to .34, respectively with advancing forage maturity. Approximately 28 to 49% of total N was soluble N while NPN accounted for 9 to 20% of total N. However, changes in the absolute amounts of soluble N and NPN consumed by the animal would be impacted mostly by forage content. Losses of N from the rumen would therefore be expected to increase with increasing amounts of soluble N and decrease with advancing forage maturity. Beever et al. (1976) observed a significant negative relationship ($r=-.98$, $P<.001$) between the amount of N flowing to the small intestine of sheep and the solubility of forage N of perennial ryegrass conserved by different methods.

Wheat Forage In Situ Trial. Data from four steers (2 on immature and 2 on mature wheat forage) were not obtained because of health problems which occurred during the trials. Nevertheless, observations were made on 30 animals over four yr in each grazing period. Because of the loss of two steers in each period and because of differences in incubation times each yr N disappearance estimates were obtained from 60 dacron bags at 12, 24 and 60 h in situ, 46 bags at 4, 8 and 36 h and 16 bags at 3, 6, 18 and 60 h on immature wheat forage. On mature wheat forage two less N disappearance estimates obtained at 4, 8, 18, 36 and 60 h.

The main effect due to treatment (i.e. lasalocid or protein supplementation) within yr was not significant ($P>.10$). Therefore, the data were pooled across treatments within yr. Visual examination of the plots of the proportion of N remaining vs incubation time (Figures 1 and 2) were curvilinear suggesting the presence of two N pools in wheat forage. Using break points of 24 and 12 h for immature and mature wheat forage, respectively, different rates of N disappearance were obtained between 3 and 24 and 24 and 60 h in immature wheat forage and between 3 and 12 and 12 and 60 h in mature wheat forage. For perspective, greater than 85.9 and 55.6% of wheat forage N had disappeared after 24 and 12 h on the immature and mature forages, respectively.

In immature wheat forage, 75.3% of total N was present in a rapidly disappearing pool which had a rate of N disappearance of 16.1%/h (Table 2). Rate of N disappearance of this pool was 5.5-fold greater ($P<.05$) than the second more slowly disappearing pool (i.e. Pool II). In mature wheat forage, the N pool sizes were similar ($P>.85$) although rate of N disappearance in Pool I was 8.7-fold greater ($P<.05$) than Pool II (i.e. 19.2 vs 2.2%/h).

With increasing forage maturity there was a shift in the size of the N pools. Less ($P<.05$, 75.3 vs 50.4%) N was present in Pool I in mature wheat forage. However, rate of N disappearance of Pool I in mature wheat forage was greater ($P<.10$) than in immature wheat forage. Surprisingly, differences were also observed in the rate of N

disappearance in Pool II. Rate of disappearance in Pool II was greater ($P<.05$) in immature (2.9 %/h) than mature (2.2%/h) wheat forage. This is possibly a reflection of increased bound N to the cell wall in mature wheat forage (Van Soest, 1982).

Currently, limited information is available on rate of N disappearance of high quality forages is currently available. Nevertheless, on comparable forages rates of N disappearance in situ are very rapid. Anderson (1988) reported that rate of N degradation of bromegrass averaged 12.9%/h. They found that greater than 86% of the potentially digestible N disappeared within 12 h. Beever et al. (1986) reported that rate of N disappearance of ryegrass declined from 14%/h to 9%/h with advancing forage maturity. In both studies they assumed only one N pool with a single rate of N disappearance.

Estimates of ruminal N disappearance indicated that approximately 67.9% of wheat forage N present in immature wheat forage was degraded ruminally (Table 2). With advancing forage maturity, ruminal N disappearance decreased ($P<.05$) to 55.1%. Similar values were reported by Andersen (1988) who reported that true ruminal N disappearance ranged from 48.6 to 79.4% and 39.0 to 44.5% for immature and mature wheat forage, respectively. These values are lower than those of Beever et al. (1986) who found that ruminal N disappearance of ryegrass exceeded 72% regardless of forage maturity. Nevertheless, these studies indicate that ruminal

degradation of N of high quality forages is extensive. Because of the rapid rates of N disappearance, large losses of N may occur because of the failure of rumen microorganisms to incorporate ammonia-N into microbial protein. Vogel (1988) reported that ruminal losses of N on immature wheat forage exceeded 45% of intake. Egan (1974), Ulyatt and Egan (1979) and Egan and Ulyatt (1980) have also reported large losses (i.e. 40 to 45%) of ingested N from the rumen in sheep fed high protein ryegrass.

Microbial Contamination Trial. The effects of incubation time on the amount of microbial N contamination are shown in Figure 3. With increasing length of incubation bacterial contamination increased ($P<.05$). However, after 60 h of ruminal incubation, microbial N accounted for only 14.4% of the residual N. Consequently, correction of N disappearance estimates for microbial N contamination did not alter ($P>.30$) extent of N disappearance at any incubation time (Table 3). Errors in extent of N disappearance values resulting from microbial contamination were low ranging from .54% (60 h) to 1.16% (4 h). These values contrast to those reported by Varvikko and Lindberg (1985) who reported errors in extent of N disappearance from microbial corrected residues of 10.2, 5.3 and 4.2 % and 193.4, 228.2 and 744.6% after 5, 12 and 24 h incubation in ryegrass forage and barley straw, respectively. Olubobokun et al. (1987) reported that microbial contamination of alfalfa hay, bermudagrass hay, and orchardgrass hay ranged

from 46 to 95% of residual N following 96 h incubation. Although correlation coefficients were not given they reported the quantity of microbial N present on residues differed due to forage type and was "highly correlated" to dry matter digestibility.

Correction of wheat forage residues for bacterial N did not affect ($P>.40$) the kinetics of ruminal degradation of wheat forage N in situ (Table 4) although correction for microbial N did result in numerically faster rates of N disappearance. This differs from Nocek and Grant (1987) who reported that correction of alfalfa, orchardgrass, red clover and timothy residues for bacterial N decreased digestion lag times and altered digestion rates depending on forage type and DM. Mathers and Aitchison (1981) also reported that correction for bacterial N on lucerne hay residues increased ($P<.01$) ruminal N degradation from 61 to 65%. Nevertheless, the same trends were observed as in the previous studies. Approximately 75% of wheat forage N was present in Pool I which had a rate of disappearance of 17.5%/h. Rate of N disappearance of Pool I was 6.3-fold greater ($P<.05$) than Pool II. Extent of ruminal degradation of wheat forage N was again extensive with ruminal degradation being 67.6% which is similar to that previously observed.

Correlation coefficients relating chemical constituents present in wheat forage to N pool size and rate of disappearance are presented in Table 5. Correlation

coefficients were obtained using the combined data from the wheat forage in situ and microbial contamination trials (i.e. n=9). The strongest correlations observed were between the size of the N pools and the nitrogenous constituents present in wheat forage. The size of the rapidly degraded pool (i.e. Pool I) was positively correlated with total N ($r=.83$, $P<.01$), soluble N ($r=.69$, $P<.05$) and NPN ($r=.67$, $P<.05$) and negatively correlated to DM ($r=-.64$, $P<.05$). Conversely, the slowly degraded pool (Pool II) was inversely correlated to the above parameters. Surprisingly, no significant correlations were observed between any chemical component in wheat forage and rate of N disappearance in Pool I. However, rate of N disappearance of Pool II was positively correlated to N ($r=.60$, $P<.10$), soluble N ($r=.64$, $P<.10$) and IVDMD ($r=.62$, $P<.10$).

In summary, these data indicate that wheat forage protein is rapidly degraded in the rumen, and that large quantities of dietary N may not reach the small intestine because of the loss of ammonia-N that is not incorporated into microbial protein. These data suggest that performance of cattle grazing wheat pasture may potentially be improved by feeding protein supplements of low ruminal degradability which may partially compensate for the N lost during ruminal fermentation. In addition, although microbial N contamination has been observed to be extensive in previous studies using low to medium quality forages, the errors associated with using uncorrected N disappearance estimates

on wheat forage are probably too small to be biologically significant to warrant correction.

TABLE 1. CHEMICAL COMPOSITION OF WHEAT FORAGE GRAZED DURING THE IN SITU AND MICROBIAL CONTAMINATION TRIALS.

	Year 1		Year 2		Year 3		Year 4		Year 5	
Forage Maturity:	Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature	Immature	SEM[a]
Dry Matter (DM), %	24.4	27.1	23.3	27.1	24.7	28.3	27.7	24.9	20.3	.58
Organic Matter, % of DM	92.5	93.7	93.7	95.7	93.4	94.1	95.3	93.4	93.1	.60
Crude Protein, % of DM	27.4	12.7	24.4	13.2	27.2	11.4	19.3	13.8	25.5	1.44
Nitrogen (N), % of DM	4.39	2.03	3.91	2.11	4.35	1.82	3.09	2.20	4.03	.23
Soluble N										
% of DM	1.22	.66	1.42	.97	1.71	.79	1.50	.76	1.25	.07
% of total N	27.9	32.6	36.2	46.3	39.2	43.7	48.5	34.2	31.0	1.53
Non-protein Nitrogen										
% of DM	.44	.20	.45	.40	.66	.40	.28	.37	.77	.04
% of total N	10.1	9.9	11.4	19.0	15.1	19.4	8.9	18.5	19.2	1.13
Soluble Carbohydrates, % of DM	22.5	34.7	27.1	16.5	27.1	16.5	30.2	21.4	41.04	2.28
IVDMD[b]	75.6	66.4	76.2	65.7	76.4	64.4	84.7	80.9	70.0	1.41

[a]SEM= Standard error of the mean (n=2)
[b]In vitro dry matter digestibility

TABLE 2. KINETICS OF IN SITU NITROGEN (N) DISAPPEARANCE AND RUMINAL N DEGRADATION OF WHEAT FORAGE IN STEERS GRAZING IMMATURE AND MATURE WHEAT PASTURE

	Pool I			Pool II		
Forage Maturity:	Immature	Mature	SEM[a]	Immature	Mature	SEM[a]
Rate of N disappearance , %/h	16.1^{bf}	19.2^{bg}	1.18	2.9^{cd}	2.2^{ce}	.16
N pool size, %	75.3^{bd}	50.4^{e}	2.40	24.7^{cd}	49.6^{e}	2.40
Half-life of N pool, h	4.8^{b}	4.8^{b}	.46	48.4^{c}	36.2^{c}	14.41

	Forage maturity		
	Immature	Mature	SEM[a]
Rate of passage, %/h	4.6	4.9	.18
Ruminal N degradation, %	67.9^{h}	55.1^{i}	1.68

[a]Standard error of the mean (n=30)
[bc]Means in the same row within forage maturity with different superscripts differ (P<.05).
[defg]Means in the same row within pool with different superscripts differ: de (P<.05) fg (P<.10)
[hi]Means in the same row with different superscripts differ (P<.05)

TABLE 3. COMPARISON OF EXTENT OF IN SITU NITROGEN DISAPPEARANCE ESTIMATES (%) CORRECTED AND UNCORRECTED FOR MICROBIAL NITROGEN CONTAMINATION IN STEERS GRAZING WHEAT PASTURE

INCUBATION TIME	NITROGEN DISAPPEARANCE[b]		SEM[a]
	UNCORRECTED	CORRECTED	
4	54.2	54.8	2.20
8	61.4	62.2	2.50
12	74.7	75.4	3.38
18	83.5	84.1	.46
24	88.6	89.3	2.76
36	91.2	91.9	1.53
48	93.7	94.2	1.50
60	96.0	96.6	.83

[a]Standard error of mean
[b]Treatments means within incubation times are similar (P>.30)

TABLE 4. EFFECTS OF MICROBIAL NITROGEN (N) CONTAMINATION ON THE KINETICS OF IN SITU N DISAPPEARANCE OF WHEAT FORAGE IN STEERS GRAZING WHEAT PASTURE.

	Pool I[c]			Pool II[c]		
Measurement	Uncorrected	Corrected	SEM[a]	Uncorrected	Corrected	SEM[a]
Rate of N disappearance ,%/h	17.5[d]	18.7[d]	5.48	2.8[e]	3.0[e]	.21
N pool size, %	75.3[d]	76.2[d]	4.49	24.7[e]	23.8[e]	4.49
Half-life of N pool, h	4.6[d]	4.5[d]	1.28	25.2[e]	23.4[e]	14.54
Ruminal N degradation[b], %	67.6[f]	69.0[f]	5.06			

[a]Standard error of the mean (n=3)
[b]Ruminal N degradation calculated assuming a passage rate of 4.6%/h.
[c]Correction for microbial N contamination did not alter wheat forage kinetics (P>.40)
[de]Means across pools within corrected or uncorrected estimates with different superscripts differ (P<.05).
[f]Means in the same row are similar (P>.85).

TABLE 5. CORRELATION COEFFICIENTS (r) AND STANDARD ERRORS OF ESTIMATES ($S_{y.\hat{x}}$) FOR REGRESSION OF CHEMICAL COMPONENTS PRESENT IN WHEAT FORAGE VS SIZE OF NITROGEN (N) POOLS AND RATE OF N DISAPPEARANCE.

	Pool I				Pool II			
	Size		Disappearance Rate		Size		Disappearance Rate	
Measurement	r	$S_{y.x}$	r	$S_{y.x}$	r	$S_{y.x}$	r	$S_{y.x}$
Dry Matter (DM),%	-.64*	11.7	.18	2.6	.64*	11.7	-.41	.5
Organic Matter, %	-.42	13.8	.15	2.6	.42	13.8	-.45	.5
Nitrogen (N), % of DM	.83***	8.5	-.51	2.3	-.83***	8.5	.60*	.5
Soluble N								
% of DM	.69**	11.0	-.35	2.5	-.69**	11.0	.64*	.5
% of total N	-.25	14.8	.24	2.5	.25	14.8	-.26	.6
Non-Protein Nitrogen								
% of DM	.67**	11.3	-.16	2.6	-.67**	11.3	.33	.6
% of total N	.06	15.3	.39	2.5	-.06	15.3	-.40	.5
Soluble Carbohydrates								
% of DM	.08	15.2	-.07	2.7	-.08	15.2	-.68	.4
IVDMD[a]	.49	13.3	-.40	2.4	-.49	13.3	.62*	.5

[a]In vitro dry matter digestibility
*(P<.10)
**(P<.05)
***(P<.01)

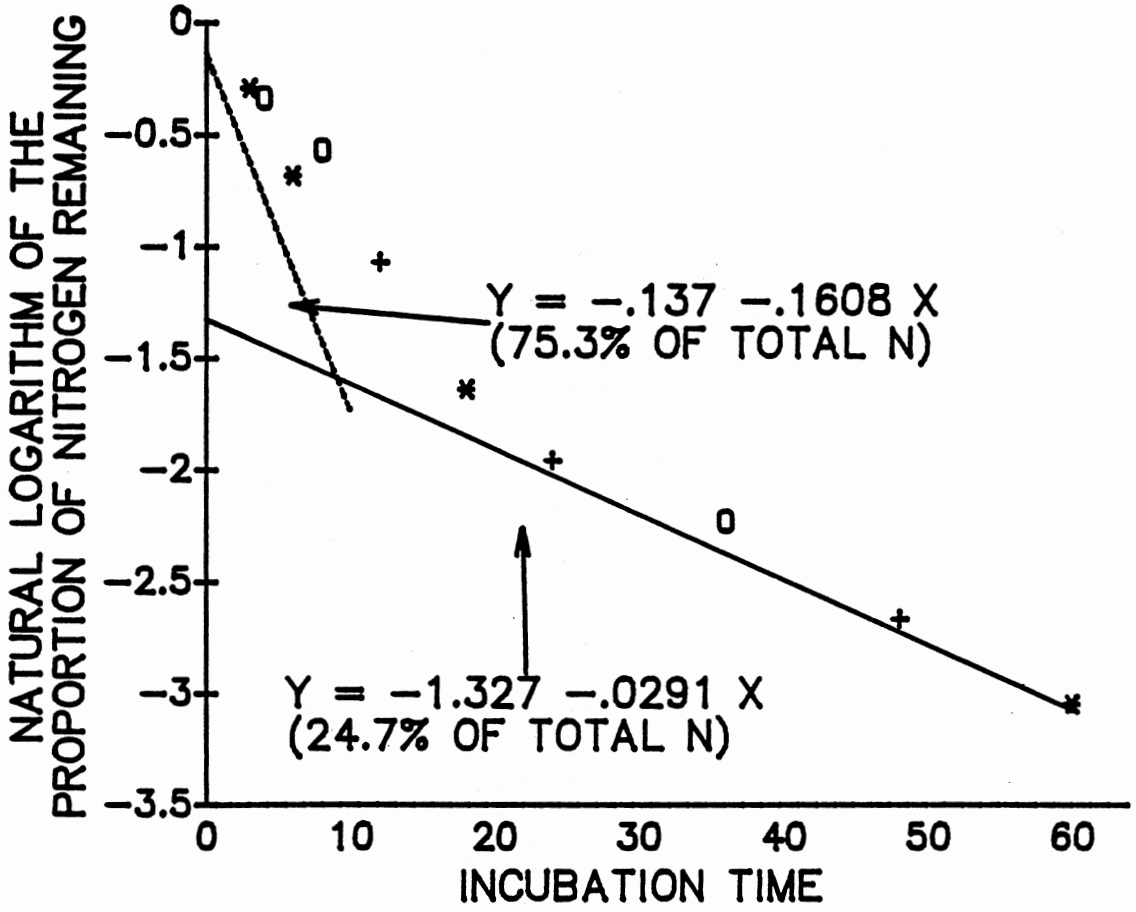

Figure 1. In Situ Nitrogen Disappearance of Two Nitrogen Pools Present in Immature Wheat Forage. (*, 0, and + represent the mean disappearance for 14, 46 and 60 observations, respectively).

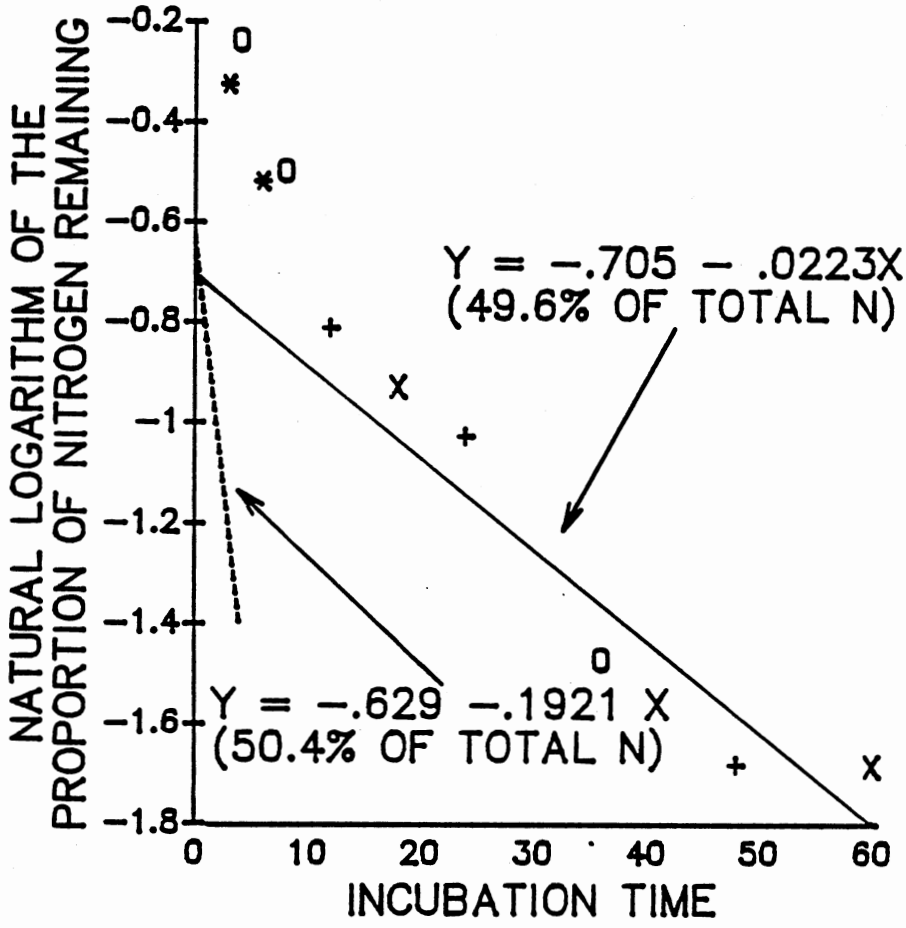

Figure 2. In Situ Nitrogen Disappearance of Two Nitrogen Pools in Mature Wheat Forage. (*,O, + and x represent the mean disappearance for 16, 44, 60 and 14 observations, respectively).

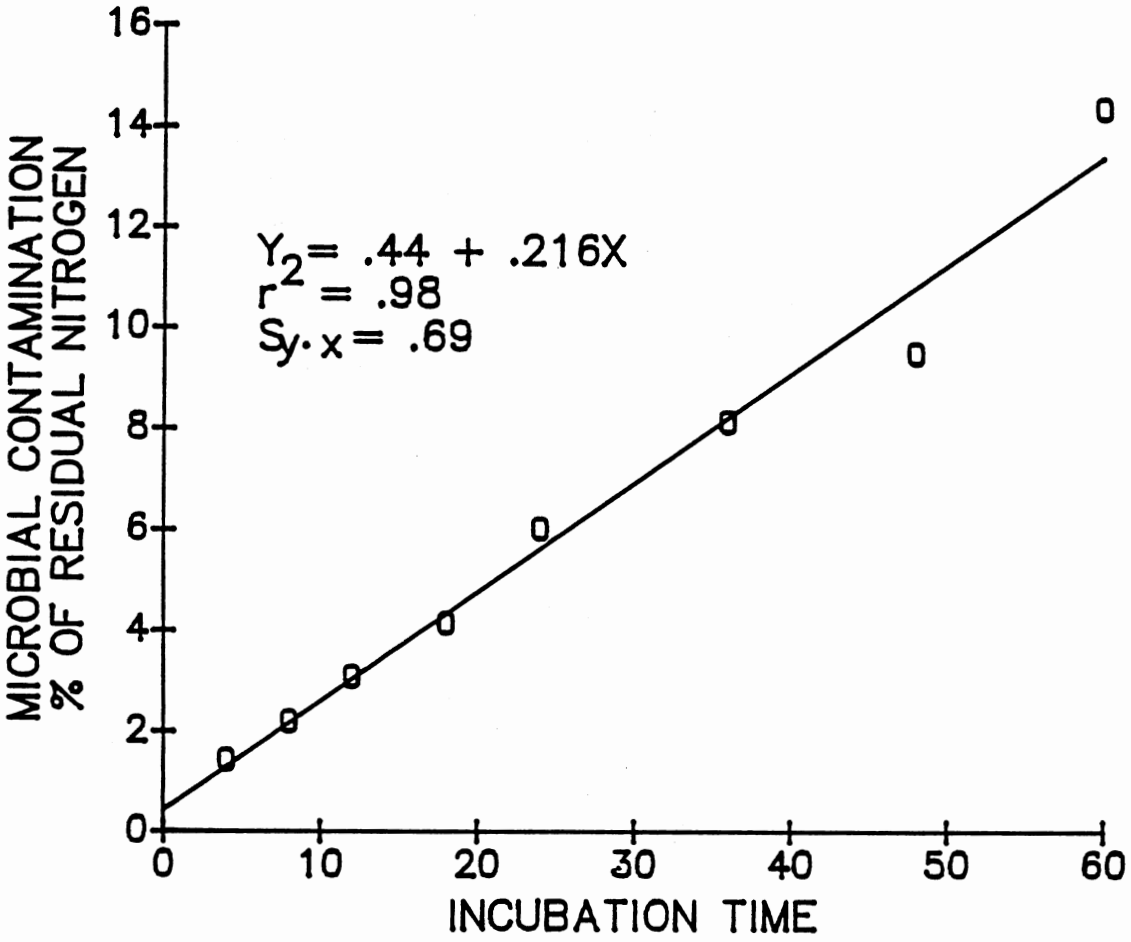

Figure 3. Effect of Incubation Time on Microbial Nitrogen Contamination of In Situ Residues in Steers Grazing Immature Wheat Pasture.

CHAPTER IV

THE DIGESTION AND UTILIZATION OF WHEAT FORAGE BY CATTLE GRAZING WHEAT PASTURE DURING THE LATE FALL AND EARLY SPRING

Abstract

Two experiments were conducted to evaluate forage intake and nutrient flow to the small intestine by steers grazing wheat pasture during the late fall and early spring grazing periods. Forage intake, ruminal digestion and nutrient flow to the small intestine were evaluated in seven steers in each grazing period using chromic oxide as an indigestible marker. True ruminal digestion of organic matter (OM) and nitrogen (N) was high and averaged 73 and 77%, respectively. Apparent loss of N prior to the duodenum was substantial and was greater than 57 and 35% of N intake in the two grazing periods. Consequently, flow of non-ammonia nitrogen (NAN) was only .36 and .48 g/kg body weight (i.e. 41 and 63% of N intake) while OM flow was 5.7 and 8.0 g/kg body weight (29 and 52% of OM intake). As a result, the performance of stocker cattle grazing wheat pasture may be limited by the supply of NAN or by a deficiency of specific amino acids in the small intestine.

Introduction

Approximately 10 million ha of winter wheat are grown in the Southern Great Plains with as many as 6 million stocker cattle grazing wheat pasture annually (Horn, 1984). Despite this fact surprisingly few studies have been conducted to evaluate the nutritive value of wheat forage. Wheat and other small grain forages are high quality forages and commonly contain 24 to 30% crude protein. However, Beever and Siddons (1986) reported as much as 30% of ingested N from fresh forages containing medium to high levels of N may be lost prior to the small intestine. Recently, Vogel (1988) reported that approximately 50 to 75% of wheat forage N was present in a highly soluble rapidly disappearing pool with rates of N disappearance of 16 to 19%/h. Beever (1984) in reviewing the literature in the United Kingdom concluded that the performance of animals grazing fresh temperate forages is limited by the supply of NAN flowing to the small intestine. However, information relative to the digestion and utilization of wheat forage is limited. Therefore, the objective of this research was to study the digestion and utilization of wheat forage by cattle grazing wheat pasture during the late fall and early spring.

Experimental Procedure

Two experiments were conducted utilizing seven mature Hereford and Hereford X Angus steers fitted with ruminal and duodenal t-type cannulas to characterize ruminal digestion of wheat forage and nutrient flow to the small intestine by steers grazing immature wheat forage during the late fall and early spring. The mean weights and standard deviations of the steers were 615 $\pm$ 52 kg and 559 $\pm$ 28 kg during the late fall and early spring grazing periods, respectively. At slaughter, location of the duodenal cannulas was checked. Duodenal cannulas were located approximately 15 to 20 cm distal from the pyloric sphincter.

Wheat forage variety TAM-105 fertilized with 112 kg N/ha as anhydrous ammonia was used in each experiment. Experimental periods were from November 18 to 23, 1987 and from March 26 to 31, 1988. The steers were placed on a 6 ha pasture divided into two paddocks in early November and remained on pasture through the grazing season. Steers were rotated between the paddocks as needed to ensure that enough wheat forage was available for the experimental periods. Seven days prior to the onset of the experimental period, marker dosing began. Chromic oxide (4 g/d) was ruminally dosed in gelatin capsules twice daily at 0800 and 2000 h. Marker dosing continued through the duration of the experimental period. The experimental period consisted of a 72 h fecal collection period such that a fecal grab sample

was obtained every 9 h. A similar 72 h collection pattern was conducted for duodenal digesta during which 250 ml of duodenal digesta was obtained at each sampling time. On the last d of the experimental period rumen fluid was obtained via rumen cannula at approximately 1100 h. Ruminal fluid samples were strained through 4 layers of cheesecloth and subsequently analyzed for pH using a pH meter with a glass electrode. Approximately 100 ml of rumen fluid was acidified with 2 ml of 20% H_2SO_4 for ammonia analysis. Also, 250 ml of strained rumen fluid from each steer were obtained for bacterial isolation. Ruminal fluid samples were stored on ice until ammonia analyses and bacterial isolation could be conducted (i.e. approximately 1 to 2 h). Ammonia analyses on rumen fluid were conducted by a modification of the magnesium oxide distillation procedure (AOAC, 1975). Ten ml of acidified rumen fluid, 1 g of magnesium oxide, .5 g of pumice stone, 1 ml $CaCl_2$ (25% w/v) and 5 drops of caprylic acid were added to the Kjeldahl flasks. Ruminal bacteria were isolated by differential centrifugation. Samples were initially centrifuged at 5000 x g for 10 minutes to remove sedimented feed particles and protozoa, then at 20,000 x g for 15 minutes to isolate bacteria. The isolated bacteria were washed with 25 ml of .9% (w/v) NaCl and recentrifuged at 20,000 x g. Bacterial pellets were lyophilized, and subsequently ground in a coffee mill. Bacterial pellets and duodenal digesta were analyzed for RNA using the procedure of Zinn and Owens (1986).

In each experiment, forage availability was estimated by hand clipping to ground level three .34 M^2 plots at randomly selected locations within the pasture. Also, hand clipped wheat forage samples were obtained to characterize forage composition at two times during the experimental period. Hand clipped samples were frozen immediately after clipping by suspension over liquid N, and subsequently lyophilized. In addition, two esophageal cannulated steers were used to collect esophageal masticate for in vitro organic matter digestibility determination.

Analytical Procedures. Fecal grab samples were dried in a forced air oven at 55°C and subsequently ground in a Wiley mill through a 2 mm mesh screen. Duodenal samples were frozen, lyophilized and ground in a coffee mill[1] and composited on a equal weight basis within animal and period. Approximately 1 g from each fecal and duodenal sample was ashed at 500°C for 8 h and analyzed for Cr concentration by atomic absorption spectrophotometry using an air-acetylene flame as outlined by Williams et al. (1962).

Fecal, duodenal and bacterial N content were determined by the Kjeldahl procedure (AOAC, 1975). Duodenal samples were analyzed for ammonia-N after reconstituting with .1 N HCl using the procedure of Broderick and Kang (1980). Non-ammonia nitrogen (NAN) of duodenal digesta was calculated by difference of total N and ammonia-N.

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[1]Electric Coffee and Spice Mill. Moulinex Regal Inc., Virginia Beach, VA

Lyophilized wheat forage samples were ground through a 2 mm mesh screen in a Wiley mill and analyzed for total N by the Kjeldahl procedure (AOAC, 1975) and soluble N following a 1 h incubation at 39°C in a shaking water bath using the mineral mixture (2% w/v pH 6.5) of the "Ohio" buffer in vitro fermentation media (Johnson, 1969). Non-protein nitrogen (NPN) was determined using 25 ml of the filtrate from the soluble N procedure by sodium tungstate precipitation with 5 ml of 1.07 N H_2SO_4 and 5 ml of 11.2% sodium tungstate. Samples were also analyzed for soluble carbohydrates by the procedure of Balwani (1965) and in vitro organic matter disappearance (IVOMD) using a modification of the Tilley and Terry procedure (1963). Each sample was analyzed in triplicate using .5 g DM in 40 ml of buffered rumen fluid which consisted of equal parts (v/v) of strained rumen fluid and McDougall's buffer (McDougall, 1948). The rumen fluid was obtained from a steer maintained prairie grass hay and .9 kg/d of a protein supplement which contained (% as-fed): soybean meal (44% crude protein), 93; sugarcane molasses, 3; dicalcium phosphate, 2; trace-mineralized salt, 2. The McDougall's buffer contained one tenth the specified concentration of $CaCl_2$ and 1 g of urea/liter of buffer.

Calculations. Fecal output and digesta flow to the small intestine were estimated by dividing daily Cr intake by the fecal and duodenal Cr concentrations, respectively. Organic matter intake was subsequently calculated by

dividing fecal organic matter output by the in vitro organic matter indigestibility of esophageal masticate.

Nutrient flow to the small intestine was calculated by multiplying the daily digesta flow by the nutrient concentration in the small intestine. The proportion of bacterial N present in duodenal samples was calculated as the ratio of total N to nucleic acids in isolated bacteria multiplied by the reciprocal of the ratio of total N to nucleic acids in duodenal digesta. True ruminal digestion of N was calculated as the difference between N intake and forage N flow to the small intestine while true ruminal digestion of OM was calculated after correcting for bacterial OM flow assuming that bacteria were 80% OM.

Statistical Analysis. Data were analyzed using least squares analysis of varience using the General Linear Models procedure of SAS (SAS, 1982). The statistical model included grazing period as the only source of variation. However, because of differences in forage intake and its potential effects on site and extent of digestion the data were not compared statistically.

Results and Discussion

Chemical composition of the forage grazed is presented in Table 1. Crude protein content and IVOMD averaged 24.8% of DM and 79.4%, respectively which are values typical of wheat forage during this season of growth (Horn, 1984). Soluble N and NPN averaged 1.38 and .79% of DM,

respectively. Approximately 31 to 39% of total N was soluble N while NPN accounted for 19 to 21% of total N. These values are consistent with those reported previously by Vogel (1988). Beever et al. (1976) observed a significant negative relationship ($r=-.98$, $P<.001$) between the amount of N flowing to the small intestine in sheep and the solubility of forage N of perennial ryegrass conserved by different methods. Soluble carbohydrates averaged 24.3% of DM in both experiments. Johnson et al. (1974) reported that soluble carbohydrate content of wheat forage ranged from 10 to 36% of DM through the growing season.

Values for forage intake, ruminal digestion and nutrient flow to the small intestine are reported in Table 2. Forage OM intake averaged 19.5 and 15.5 g/kg body weight in the late fall and early spring grazing periods, respectively. The decreased forage intake in early spring was attributed to differences in forage availability and unusually high precipitation which occurred during the experimental period. Forage availability decreased from 1042 to 802 kg/ha (i.e. 60.5 to 51.2 kg DM/100 kg body weight).

True ruminal digestion of wheat forage OM and N were high in both grazing periods and averaged 73.3 and 77.6%, respectively. Similar values were reported by Andersen (1988) who reported that true ruminal digestion of OM and N was 80.0 and 79.4% for steers grazing wheat pasture fed corn or meat meal based supplements. For comparison, Ulyatt et al. (1975) reported that true ruminal N digestion for sheep

consuming perennial ryegrass, short rotation ryegrass or white clover averaged 70% while Anderson et al. (1988) estimated ruminal N degradation of bromegrass was greater than 86%.

Apparent loss of N prior to the duodenum was substantial and was greater than 57 and 35% of N intake for steers during the late fall and early spring periods, respectively. Egan (1974), Egan and Ulyatt (1980) and Ulyatt and Egan (1979) have all reported large losses (i.e. 40-45%) of ingested N from the rumen in sheep fed high protein ryegrass. These large losses may be related to the rate at which forage N is degraded. Rate of forage N degradation affects not only microbial protein synthesis but also feed N flow to the small intestine. Vogel (1988) reported that approximately 50 to 75% of wheat forage N was present in a highly soluble rapidly disappearing pool which disappeared at rates of 16 to 19%/h. Beever and Siddons (1986) concluded ruminal losses of N were the result of an imbalance between degraded N and energy supply required for optimal microbial growth. They suggested that a ratio of 25 to 35 g degraded N per kg of OM truly digested in the rumen was needed to meet optimal microbial requirements. For perspective, forage degraded N per kg of OM truly digested in the rumen averaged 51.9 g/kg which is greater than that reported (42.2 g/kg) by Andersen (1988). These results indicate that an oversupply of N is present in the rumen from extensive degradation of forage N. This oversupply is presumably lost as ammonia.

Because of the large losses of N ruminally, NAN flow to the small intestine was only .36 and .48 g/kg body weight during the late fall and early spring grazing periods (i.e. 41 and 63% of N intake). Organic matter flow to the small intestine followed a similar trend and was only 5.7 and 8.0 g/kg body weight. These values are lower than those found by Beever et al. (1986a) who reported that NAN and OM flow to the small intestine for steers grazing perennial ryegrass pastures ranged from .41 to .76 and 6.5 to 11.5 g/kg body weight, respectively. Of the NAN flowing to the small intestine approximately 56% was of microbial origin which is similar to values reported by Walker et al. (1975) for sheep consuming perennial ryegrass (43.1%), short rotation ryegrass (57.1%) and white clover (52.9%). However, Beever et al. (1986b) reported that microbial N comprised over 72% of NAN flow to the small intestine in steers grazing perennial ryegrass.

In summary, these data indicate that ruminal degradation of N is extensive and that large quantities may fail to reach the small intestine because of the loss of ammonia-N that is not incorporated into microbial protein. As a result, performance of rapidly growing stocker cattle on wheat pasture may be limited by the supply of NAN or by a deficiency of specific amino acids in the small intestine. In consideration of the above, the traditional concept that performance of growing cattle on wheat pasture is not limited by protein status should be reevaluated.

TABLE 1. CHEMICAL COMPOSITION OF WHEAT FORAGE GRAZED DURING THE WHEAT FORAGE GRAZING TRIALS

Forage Maturity:	LATE FALL	EARLY SPRING	SEM[a]
Dry Matter (DM), %	23.4	20.3	.68
Organic Matter, %	97.6	93.1	1.32
Crude Protein, % of DM	24.4	25.2	.35
Nitrogen (N), % of DM	3.91	4.03	.06
Soluble N			
% of DM	1.51	1.25	.08
% of total N	39.1	31.0	2.35
Non-protein Nitrogen			
% of DM	.81	.77	.02
% of total N	21.0	19.2	.73
Soluble Carbohydrates, % of DM	22.2	26.3	1.01
IVOMD[b]	81.6	77.1	1.80
Forage Availability			
kg DM/ha	1042	802	89.9
kg DM/100 kg body weight	60.5	51.2	4.82

[a]SEM= Standard error of the mean (n=4)
[b]In vitro organic matter digestibility

TABLE 2. FORAGE INTAKE AND NUTRIENT DIGESTION IN STEERS GRAZING WHEAT PASTURE

Grazing Period	Late Fall	Early Spring	SEM[a]
Nutrient Intake			
Organic Matter (OM)			
kg	12.0	8.7	.62
g/kg Body Weight (BW)	19.5	15.5	1.06
Nitrogen (N) Intake			
g	543	432	2.61
g/kg BW	.88	.77	.046
Rumen pH	5.90	5.91	.128
Rumen Ammonia, mg/dl	26.8	37.6	3.16
True Ruminal Digestion, %			
OM	81.5	65.0	1.38
N	81.3	73.9	1.90
Ruminal N Loss, %	57.6	35.3	1.48
Microbial Efficiency[b]	14.4	38.9	3.49
Deg. Forage N/kg OMTDR[c]	54.3	49.4	3.26
Nutrient Flow to Small Intestine			
Organic Matter			
kg	3473	4497	198
g/kg OM Intake	291	520	17.6
g/kg BW	5.7	8.0	.41
Non-ammonia Nitrogen			
g	222	268	10.6
g/kg N Intake	410	630	14.5
g/kg BW	.36	.48	.022
Bacterial N, %	54.8	57.8	4.08
Wheat Forage N, %	45.2	42.2	4.08

[a]Standard error of mean
[b]g microbial N per kg OM truly fermented
[c]OM truly degraded in rumen

CHAPTER V

RATE AND EXTENT OF RUMINAL NITROGEN DEGRADATION OF HIGH PROTEIN FEEDSTUFFS BY CATTLE GRAZING WHEAT PASTURE

Abstract

Two experiments were conducted to evaluate rate and extent of ruminal nitrogen (N) disappearance of protein supplements in stocker cattle grazing wheat pasture. In experiment I, eight multi-cannulated steers were used in a split plot design with two grazing periods in each of 3 yr in which soybean meal (SBM), cottonseed meal (CSM), corn gluten meal (CGM), meat and bone meal (MBM) and fish meal (FSM) were studied. Fifteen multi-cannulated steers were used in each of two yr in experiment II in which cottonseed meals produced by direct solvent and mechanical proccesses (CSMds and CSMm) and meat meal (MM) were studied. In each experiment duplicate dacron bags were incubated at various time intervals with N disappearance values being fit to a nonlinear exponential equation. In experiment I, data from yr 1 and CGM were not fit because of lack of convergence to the equation. Ruminal N degradation was estimated by combining the values from the nonlinear equation with rate of passage estimates. Rate of passage was assumed to be 5%/h

in yr 2 of experiment I, while rate of passage was measured in yr 3 and in experiment II using chromium (Cr) mordanted protein supplements. Estimated ruminal N degradation (%) was greatest (P<.05) for SBM (62.5), while CSM (53.7) was intermittent and MBM (44.0) and FSM (40.9) had the lowest values. In experiment II, extent of ruminal N degradation for CSMds (65.8) was greater (P<.05) than CSMm (49.1) or MM (51.8). These protein supplements differ with regard to rate and extent of ruminal degradation by cattle grazing wheat pasture, and these differences should be considered in formulating supplements for rapidly growing cattle on wheat pasture.

Introduction

Wheat and other small grain forages are high quality forages and commonly contain 24 to 30% crude protein on a dry matter (DM) basis. Because of the rapid rate of ruminal degradation of wheat forage N (Vogel, 1988) and loss of ammonia-N that is not incorporated into microbial protein, the performance of rapidly growing stocker cattle on wheat pasture may be limited by inadequate amounts of non-ammonia-nitrogen flowing to the small intestine. Indeed, this was the conclusion of Beever (1984). Lee (1985) reported that weight gains of stocker calves fed .68 kg/d of a supplement containing meat and bone meal were increased by .09 kg/d as compared with calves fed control, milo- or hominy feed-based supplements. Conversely, Grigsby (1982) did not observe any affect of increased protein intake on the performance of

stocker cattle fed soybean meal based supplements. Differences in these trials may be related to the amount of ruminal degradable protein fed. Rate of passage from the rumen is a primary factor that affects extent of ruminal degradation and is influenced by roughage (or forage) level of the diet, forage quality and level of intake. It is therefore unlikely that results of previous experiments, which have been conducted for given type of diets and levels of intake and which have led to the classification of some protein supplements as "high bypass" supplements can be broadly extrapolated to other dietary regimes. Two experiments were conducted to evaluate rate and extent of in situ ruminal N disappearance of several protein supplements by cattle grazing wheat pasture. Also, ruminal degradation of cottonseed meals produced by direct solvent and mechanical processes and meat meal were studied in experiment II.

Experimental Procedure

Forage. Wheat forage variety TAM-105 fertilized with 112 kg N/ha as anhydrous ammonia was used in each of the experiments. Grazing periods represented two distinct forage maturities. In experiment I immature wheat forage was characteristic of rapidly growing wheat forage in early spring while mature wheat forage represented wheat forage shortly after heading which would be consumed during the "grazeout" period. In experiment II steers consumed immature

wheat forage during either winter dormancy or early spring. In each experiment steers were placed on a 6 ha pasture divided into two paddocks in early December each yr and remained on pasture through the entire grazing season. Steers were rotated among the pastures to ensure that enough forage was available for the experimental periods.

Experiment I. In each of 3 yr eight multi-cannulated Hereford and Hereford X Angus steers were used to evaluate in situ rate and extent of ruminal N degradation of soybean meal (SBM), cottonseed meal (CSM), corn gluten meal (CGM), meat and bone meal (MBM) and fishmeal (FSM). The experimental periods for the immature and mature grazing periods were from approximately March 17 to 20 and May 2 to 4, respectively. The mean weights and standard deviations of the steers in yr 1 to 3 (i.e. 1985 to 1987) were 573 $\pm$ 47 kg, 443 $\pm$ 53 kg and 522 $\pm$ 52 kg, respectively. As part of other experiments relative to site and extent of digestion of wheat forage as affected by lasalocid or protein supplementation, steers were randomly allotted to two treatments each yr in a split plot experimental design with steers as main units and grazing periods as subunits. In yr 1, steers received either 0 or 300 mg lasalocid daily. In yr 2 and 3, steers received approximately 900 g/d of a corn based (control) or a 16 to 20% crude protein supplement containing 18 to 25% meat meal. The composition of the supplements was reported by Vogel (1988).

Duplicate dacron bags containing approximately 10 g of SBM, CSM (unknown origin), CGM, MBM and FSM were incubated in situ in the rumen of each steer for 4, 12, 24 and 36 h in yr 1. In yr 2 and 3 the sample size was reduced to 2.5 g to decrease the sample size to surface area ratio near the values of 10.0 mg/cm^2 recommended by Van Hellen and Ellis (1977) and 16.3 mg/cm^2 as suggested by Mehrez and Orskov (1977). The calculated ratios were 52.1 mg/cm^2 in yr 1 and 13.0 mg/cm^2 in yr 2 and 3. In addition, an 8 h incubation time was added in yr 2 while 8 and 48 h incubation times were added in yr 3. The dacron bags measured 8 X 12 cm, and had a mean pore size of 40 $\pm$ 12 um. Seams of the bags were double sewn with polyester thread, sealed with waterproof glue and the edges were burned to prevent fraying in the rumen. In each experimental period all bags were removed simultaneously to reduce variation in the washing procedure. After removal from the rumen, bags were initially washed under tap water to remove digesta from outside the bags. This was followed by successive washings with deionized water until the effluent from the bags was clear. Washing time averaged 2.5 minutes per bag. All bags were dried in a forced air oven at 55^{o}C for 48 h and subsequently reweighed. Contents of the bags were analyzed for N by the Kjeldahl procedure (AOAC, 1975).

In yr 3 rate of ruminal passage (Kp) of the protein supplements was estimated by mordanting MBM with a solution of sodium dichromate such that the mordanted meal contained

approximately 4 g Cr/100 g DM using the procedure of Uden et al. (1980). Using this procedure, approximately 2 kg of MBM was submerged in a sodium dichromate solution containing Cr equivalent to 10% of the dry weight of the supplement in an oven at 100°C for 24 h, and subsequently washed with tap water and filtered through cheesecloth. After filtering, the MBM was suspended in tap water, which contained ascorbic acid in amounts equal to one-half the dry weight of the supplement, for 1 h and was then washed and filtered until the effluent was clear. The MBM was dried in a forced air oven at 55°C for 48 h, and ground through a Wiley mill back to its original mean particle size of 1 mm which was determined by dry sieving. On day 1 of the experimental period, each steer was given a 200 g intraruminal dose of the mordanted MBM. Approximately 250 ml of duodenal digesta were subsequently collected at 0, 4, 8, 12, 16, 24, 32, 36 and 48 h post dosage. Duodenal samples were lyophilized and ground in a coffee mill[1]. Approximately 1 g from each sample was ashed at 500°C for 8 h and analyzed for Cr concentration by atomic absorption spectrophotometry using an air-acetylene flame (Williams et al., 1962). Rate of ruminal passage was calculated by regression of the natural logarithm of duodenal Cr concentration vs time.

Experiment II. In each of 2 yr fifteen multi-cannulated Hereford and Hereford X Angus steers were used in a completely randomized design to compare in situ rate and

[1]Electric Coffee and Spice Mill. Moulinex Regal Inc., Virginia Beach, VA.

extent of ruminal N degradation of cottonseed meal produced by direct solvent[2] and mechanical processes[3] (CSMds and CSMm) and meat meal[4] (MM). Steers were randomly allotted by weight to one of three treatments yearly (CSMds, CSMm and MM). The mean weights of the steers were 493 ± 46 kg and 509 ± 58 kg in yr 1 and 2, respectively. The experimental periods were from March 19 to 21, 1986 (yr 1) and from January 5 to 7, 1987 (yr 2). Each meal was obtained from the same plant each yr so that variation would be minimized. Duplicate dacron bags containing 2.5 g of either CSMds, CSMm or MM were incubated in situ for 4, 8, 12, 24 and 36 h in yr 1 and also 48 h in yr 2. Bags were prepared, washed and analyzed for N as described in experiment I.

In addition, rate of ruminal passage of each meal was measured each yr by mordanting each meal with sodium dichromate as previously described such that each steer received the mordanted supplement of their respective treatment.

Calculations. Estimates of N disappearance from each experiment were fit (Marquardt method, SAS, 1982) by a nonlinear iterative procedure to estimate potential degradation (P) using the equation of Orskov and McDonald (1979): $P = A + B*(1-e^{-CT})$ where:

A = the highly soluble rapidly disappearing fraction;

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[2]Obtained from Producers Cooperative Oil Mill, Oklahoma City, OK
[3]Obtained from Traders Oil Mill, Fort Worth, TX
[4]Obtained from Iowa Beef Producers, Inc. West Point, NE

B = the fraction other than fraction A which disappears at a constant fractional rate;

C = rate of N disappearance;

T = time.

Estimation of potential degradation (P) from the N disappearance values in the first yr of experiment I was unsuccessful because of the lack of fit of the data to the equation. This might have been attributable to the fact that only four incubation times were used or possibly because the sample size to surface area ratio was large (i.e. 52.1 mg/cm^2). In addition, the N disappearance values for CGM in yr 2 and 3 of experiment I also failed to converge to the equation because N disappearance of CGM was linear after 48 h. Consequently, rate of N disappearance of all data was also calculated by regression of the natural logarithm of the proportion of N remaining vs time to allow for comparisons across experiments.

Where the N disappearance values did fit the equation, fitted parameters (i.e. A, B and C) were used to calculate extent of ruminal N degradation (RD) by the equation Orskov and McDonald (1979) where RD = A + (B*C)/(C+Kp) where Kp represents rate of ruminal passage of the supplements obtained previously. Because rate of passage was not calculated in yr 2 in experiment I it was assumed to be 5%/h.

Supplement Composition. In each experiment triplicate samples of the protein supplements were obtained to

characterize the protein composition. Samples were analyzed for total N (Kjeldahl procedure; AOAC, 1975), soluble N in .15 N NaCl (Waldo and Goering, 1979), and pepsin insoluble N (PIN; AOAC, 1975). In addition, samples were analyzed for organic matter by ashing at 500°C for 8 h.

Statistical Analysis. Data were analyzed by least squares analysis of variance using the General Linear Model procedure of SAS. (SAS, 1982). The statistical models used in experiment I are shown in Table 1. Because of the failure of the data in yr 1 of experiment I to fit the equation of Orskov and McDonald (1979) it was analyzed separately. The model for analysis of data in yr 2 and 3 in experiment I is also presented in Table 1 due to its complexity. The statistical model for analysis of the data in experiment II included treatment, year and the treatment X year interaction as sources of variation. F values for treatment were initially calculated using the treatment X year interaction as the error term while the residual mean square was used to test for year effects and the treatment X year interaction. Because of significant ($P<.05$) treatment X year interactions for all the in situ data, data are reported by year and F values for treatment were calculated using the residual mean square. In both experiments differences among means were separated using the least significant difference procedure (Steel and Torrie, 1980) if the source of variation was significant.

Results and Discussion

Supplement Composition. The chemical composition of the wheat forage grazed was reported previously by Vogel (1988). The chemical composition of the supplements used in experiments I and II are reported in Tables 2 and 3, respectively. Total N content ranged from 6.5 to 10.4% of DM with soluble N comprising from 6.1 to 23.2% of total N which is similar to values reported by Loerch et al. (1983) and Zinn et al. (1981). Pepsin insoluble N ranged from 5.2 to 15.0% and 12.5 to 22.7% of total N in experiments I and II, respectively. In experiment II, PIN of CSMds and CSMm tended to parallel differences in heat and pressure exposure during processing with PIN increasing from 12.5 to 15.6% and from 13.2 to 22.7% in yr 1 and 2, respectively. These values compare to estimates of 14.1% and 19.9% of total N for CSMds and CSMm reported by Goetsch and Owens (1985).

Experiment I. Rate (i.e. regression of the natural logarithm of the proportion of N remaining vs time) and extent of N disappearance of the protein supplements in yr 1 are shown in Table 4. The main effect due to lasalocid did not affect rate ($P>.10$) or extent of N disappearance ($P>.15$) after 36 h in situ. However, a significant protein source X grazing period interaction was detected ($P<.05$) for both rate and extent of N disappearance. Although rates of N disappearance of CSM, CGM and FSM were similar during both grazing periods, SBM and MBM had different ($P<.05$) rates of

disappearance in each period. For SBM, rate of N disappearance (%/h) was greater (P<.05) on immature (7.59) than mature (5.78) wheat forage. Similar results were found by Zorrillo-Rios et al. (1985) in which rate of N disappearance of SBM was 6.45 and 4.97%/h on immature and mature wheat forage, respectively. Rate of N disappearance of MBM was greater (P<.05) for steers grazing mature (3.43%/h) than immature (1.89%/h) wheat forage. It is possible that solubility of SBM and MBM N may have been influenced by the change in rumen pH associated with increasing forage maturity. Ruminal pH measurements in steers obtained during concurrent site and extent of digestion trials were 5.8 and 6.5 on immature and mature wheat forage (Andersen, 1988). Nevertheless, whether these differences were due to altered solubility of the feed protein or altered proteolytic activity of the bacteria remains uncertain. When the data were pooled across grazing periods, rate of N disappearance (%/h) was greatest (P<.05) for SBM (6.67). Meat and bone meal (2.66) and CSM (2.37) were intermediate, while FSM (.85) and CGM (.70) had the lowest values (P<.05). These disappearance rate constants are similar to those of Zorrillo-Rios et al. (1985) who, under similar conditions, reported rates of N disappearance (%/h) for CGM, CSM and SBM of .81, 4.39 and 5.71, respectively in steers grazing wheat pasture.

Extent of N disappearance (%) after 36 h in situ tended to parallel rate of N disappearance with SBM (87.6) being

greatest and MBM (66.0) and CSM (66.9) being intermediate ($P<.05$). However, although CGM was degraded at a rate similar to FSM, the extent of N disappearance was only 45% ($P<.05$) of FSM (20.8 vs 45.8%). This difference can be attributed to differences in N solubility. Initially, 23.2 % of FSM N was present as soluble N while only 6.1% of CGM N was soluble (Table 2). In addition, because CGM is a glutinous material which tends to stick together when wet this may have resulted in less exposure of surface area for ruminal digestion and consequently, resulted in a decreased extent of digestion.

The parameters from the exponential equation describing N disappearance in situ and estimates for ruminal degradation for yr 2 and 3 are shown in Table 5. Data from one steer grazing mature wheat forage in yr 3 were not obtained because of health problems which occurred during the trial. The main effects due to treatment ($P>.40$) and grazing period ($P>.10$) were not significant and therefore, the data were pooled across these effects. However, there was a significant protein source X yr interaction ($P<.05$) for all parameters except rate of digestion. Therefore, the data are reported by yr.

It was disappointing that data for CGM would not converge to the equation. Zerbini and Polan (1985) were able to fit N disappearance values from CGM to the equation of Orskov and McDonald (1979) using incubation times of 2, 12, 24 and 72 h. As a point of information they reported that

fractions A and B and rate of disappearance (C) were 26.4%, 38.4%, and 2.2%/h, respectively for steers consuming a mixed diet of corn and orchardgrass hay. Assuming a passage rate of 5%/h ruminal N degradation would have been 38.1%.

Of the N present in the remaining protein supplements virtually all was potentially degradable for SBM (97.4%) while approximately 77.3% was potentially degradable within the rumen for CSM. The animal protein sources (i.e. MBM and FSM) were the most resistant ($P<.05$) to ruminal degradation with approximately 57% being potentially degradable within the rumen. Most likely, differences in the physical structure and the amount of heat applied during drying makes these meals more resistant to ruminal degradation. When the potentially degradable N was partitioned into soluble N (i.e. fraction A) and insoluble but potentially degradable N (i.e. fraction B) SBM contained the smallest ($P<.05$) proportion of soluble N (17.6%) and the largest ($P<.05$) proportion of insoluble but potentially degradable N (79.8%). Cottonseed meal (33.1%), MBM (23.7%) and FSM (28.8%) each contained greater ($P<.05$) quantities of N in fraction A. It is interesting to note that fraction A for FSM was approximately 52.3% of the potentially degradable N indicating that after the initial loss of soluble N little was degraded ruminally. Nevertheless, these estimates are similar to those reported by Orskov et al. (1983) who fed sheep and cattle grass hay and reported values for CSM, FSM and MBM of 33.3, 30.4 and 23.7%, respectively. Fraction B as

mentioned previously was greatest for SBM (79.8%) and was similar in both yr. However, for CSM, MBM and FSM there was an 8 to 12 percentage unit decrease ($P<.05$) in yr 3. It is possible that ruminal pH may have altered the digestion kinetics of these protein supplements. Ruminal pH measurements in steers obtained during concurrent site and extent of digestion trials were decreased by .6 units ($P<.05$) in yr 3 (Andersen, 1988). Barrio et al. (1985) reported that extent of N disappearance was decreased for SBM and MM as concentrate level increased from 20 to 80% and pH decreased from 6.9 to 6.5. In contrast, Ganev et al. (1979) found no effect of diet per se (i.e. pH) on extent of N disappearance of animal protein supplements while extent of N disappearance of plant protein supplements were decreased. Nevertheless, these studies demonstrate that diet and its subsequent effects on ruminal fermentation can alter the digestion kinetics of protein supplements.

Rate of N disappearance (%/h) of fraction B was greatest ($P<.05$) for MBM (8.03) while SBM (6.57) was intermediate. Both CSM (4.75) and FSM (5.06) had the lowest ($P<.05$) rates of N disappearance. If the rates of N disappearance were expressed on a logarithmic basis for comparison to yr 1, the rates of N disappearance would be, .47, 6.39, 1.78, 1.06 and .72%/h for CGM, SBM, CSM, MBM and FSM, respectively which are lower than those observed previously. When expressed in this manner, SBM had the

fastest rate of N disappearance while FSM (.72) and CGM (.47) had the slowest rates ($P<.05$).

Rate of passage in yr 3 was measured using Cr-mordanted MBM. Treatment of protein sources with sodium dichromate renders the protein totally undegradable (Uden et al., 1980) and has little effect on particle size distribution or particle density (Eliman and Orskov, 1984). Therefore, Cr-treated protein supplements should behave similarly to the original feedstuff. Numerous studies have indicated that rate of passage of different protein supplements are similar under different dietary regimens provided that particle size and density are similar. Eliman and Orskov (1984) fed sheep either Cr-mordanted FSM or SBM and passage rates for both supplements averaged 2.21%/h for sheep fed a maintenance level of dried grass hay. Moreover, Lindberg (1982) fed cows a mixed diet containing Cr-mordanted SBM, CSM and rapeseed meal at maintenance and at three times maintenance. Ruminal passage rates of all supplements were similar at each level of feeding, but were increased (5.16 vs 4.01%/h) with increased level of feeding. Therefore, in our study MBM was used to represent rate of passage of all protein supplements in yr 3 and averaged $4.85 \pm .96$%/h.

Extent of ruminal N degradation was 9.5% greater ($P<.05$) for SBM in yr 2 than yr 3 while ruminal N degradation of CSM was 11.2% greater ($P<.05$) in yr 3 than yr 2. Although no explanation is available for SBM the increased ruminal degradation of CSM in yr 3 was attributed

to the observed 10 percentage unit increase in fraction A in yr 3. Nevertheless, when the data were pooled across years, ruminal N degradation was greatest ($P<.05$) for SBM (62.5%) while CSM (53.7%) was intermediate. Meat and bone meal (44.0) and FSM (40.9%) were the most resistant ($P<.05$) to ruminal degradation although FSM had the lowest value ($P<.05$). Consequently, greater amounts of N from supplemental MBM and FSM would be expected to pass to the small intestine.

Protein degradation estimates from in situ studies appear to be very sensitive to the conditions of measurement. Mohammed and Smith (1977) found a three fold increase in rate of N disappearance of FSM when the host animal was adapted to a diet containing FSM while Vik-Mo and Lindberg (1985) reported an increased rate of N disappearance when protein level of the basal diet was increased (15 vs 25% crude protein). Orskov et al. (1983) and Ganev et al. (1979) reported that extent of ruminal degradation was sharply decreased for sheep fed a high concentrate whole barley based diet vs a dried grass hay. These studies indicate that basal diet has a dramatic effect on ruminal degradation of N, and it is not likely that results from other dietary regimes can be broadly extrapolated.

Experiment II. Parameters from the exponential equation describing N disappearance in situ, rate of passage and extent of ruminal N degradation are presented in Table

6. Data are reported by year because of a significant ($P<.05$) treatment X year interaction for all parameters except rate of passage.

Of the N present in the supplements in yr 1, approximately 90% was potentially degradable for the two CSM while only 67.7% was potentially degradable within the rumen for MM. These values are in agreement with data of Orskov et al. (1983) who reported that 92.4% and 59.5% of CSM and MBM were potentially degradable ruminally. Similar values were obtained in yr 2 for CSMds (96.9%) and MM (66.6%). However, only 66.7% of CSMm in yr 2 was potentially degradable which represented a 38% decrease ($P<.05$) from yr 1. This decrease may have been the result of overheating of the supplement during processing. Pepsin insoluble N estimates, which supposedly represent unavailable N increased from 15.6% (yr 1) to 22.7% (yr 2) of total N in CSMm (Table 3). Plegge et al. (1982) found that less SBM N disappeared from dacron bags as roasting temperature increased while Craig and Broderick (1981) demonstrated that true digestibility of CSM in rats decreased from 90.6 to 70.8% after 2 h of autoclaving at 121°C.

Fraction A in yr 1 for CSMm was 63.5% and 75.3% lower ($P<.05$) than that of CSMds and MM while fraction B was 28.4% and 123.4%, greater ($P<.05$), respectively. This is consistent with in vitro studies of Broderick and Craig (1980) which demonstrated that CSMds possessed a larger protein fraction that was rapidly degraded and a smaller

quantity of the more slowly degraded protein than CSMm. Fractions A and B for CSMds and MM were similar in yr 2. However, for CSMm fractions A and B were 64.5% larger and 92.4% smaller ($P<.05$), respectively than observed the previous year. The marked changes in the N fractions may have been due to heat damage of the protein supplement as mentioned previously.

Rate of N disappearance (%/h) in yr 1 was almost twofold greater ($P<.05$) for CSMds than either CSMm or MM (i.e. 8.65 vs 3.95 and 4.91). In yr 2, rates of N disappearance were similar ($P>.05$) for all protein supplements although they were 75%, 28%, and 26% slower than yr 1 for CSMds, CSMm and MM, respectively. The decreases in N disappearance rates may have been due to differences in the protein supplements used or possibly from changes in rumen environments. Nevertheless, when the data were pooled across years CSMds had the fastest ($P<.05$) rate of disappearance and CSMm the slowest. If the rates of N disappearance are expressed as the natural logarithm of the proportion of N remaining vs time as in experiment I, the rates of disappearance would be 4.11, 1.74 and 1.00%/h for CSMds, CSMm and MM, respectively. These differ from estimates of N disappearance from 12 to 20 h in situ for CSMds (2.61%/h) and CSMm (2.03%/h) for steers fed an 80% concentrate diet reported by Goetsch and Owens (1985) and for MM (1.52%/h) for steers fed a 60% roughage diet reported

by Zinn and Owens (1983) further indicating the effects of diet on ruminal degradation of N.

Rate of passage estimates of the mordanted supplements were similar (P>.95) and averaged 4.85%/h. These results confirm the work of Lindberg (1982) and Eliman and Orskov (1984) who reported that passage rates of different protein sources tend be similar under the same conditions.

Ruminal N degradation of CSMds was about 20 (70.1 vs 50.7 and 51.1%) and 11 (61.5 vs 47.5 and 53.4%) percentage units higher (P<.05) in yr 1 and 2, respectively than either CSMm or MM. These values compare to those of Goetsch and Owens (1985) who reported extent of ruminal N degradation was 66.1% and 59.4% for CSMds and CSMm, respectively, while Broderick and Craig (1980) estimated ruminal degradation in vitro at 62.5% and 37.4%, for CSMds and CSMm assuming a passage rate of 4%/h. Consequently, greater amounts of N from supplemental CSMm and MM would be expected to pass to the small intestine. The increased temperature and pressure to which CSMm is exposed during processing may improve N utilization by increasing ruminal escape.

In conclusion, these data are interpreted as indicating that rate and extent of ruminal degradation of N of the protein supplements which were studied are different when given to cattle grazing wheat pasture. The method of processing was also shown to affect the extent of ruminal degradation of CSM by cattle grazing wheat pasture. Based on the findings of previous studies it is unlikely that results

can be broadly extrapolated across dietary regimes. Application of these results should be important in formulation of supplements for growing cattle on wheat pasture and(or) other small grain pastures if further studies indicate that stocker cattle performance is limited by flow of inadequate amounts of non-ammonia N to the small intestine. Alterations in flow of individual amino acids to the small intestine and its subsequent effects on empty body protein synthesis and(or) forage intake may also be part of the mechanism whereby protein supplementation of growing cattle on wheat pasture improves performance although more research is needed.

TABLE 1. STATISTICAL MODEL FOR ANALYSIS OF IN SITU NITROGEN DISAPPEARANCE OF PROTEIN SUPPLEMENTS IN STOCKER CATTLE GRAZING WHEAT PASTURE (EXPERIMENT I)

SOURCE	DEGREES OF FREEDOM[a]
Year 1	
Treatment[b]	1
Steer(Treatment)	6
Grazing Period[c]	1
Period * Treatment[c]	1
Steer * Period(Treatment)	6
Protein Source[d]	4
Protein Source * Treatment[d]	4
Protein Source * Period[d]	4
Protein Source * Period * Treatment[d]	4
Residual	
Protein Source * Steers(Period * Treatment)	48
	79
Year 2 and 3	
Treatment[b]	1
Steer(Treatment)	6
Grazing Period[e]	1
Year[e]	1
Period * Year[e]	1
Treatment * Period[e]	1
Treatment * Year[e]	1
Treatment * Period * Year[e]	1
Steer * Period * Year (Treatment)	18
Protein Source[c]	3 (4)
Protein Source * Treatment[d]	3 (4)
Protein Source * Period[d]	3 (4)
Protein Source * Year[d]	3 (4)
Protein Source * Period * Year[d]	3 (4)
Protein Source * Period * Treatment[d]	3 (4)
Protein Source * Year * Treatment[d]	3 (4)
Protein Source * Period * Year * Treatment[d]	3 (4)
Residual	
Steer * Protein Source(Treatment*Period*Year)	72 (96)
Total	127(159)

[a]Values in parentheses represent degrees of freedom for inclusion of corn gluten meal in analysis of logarithmic rates

[b]Error term for F test: Steers(Treatment)

[c]Error term for F test: Steer*Period(Treatment)

[d]Error term for F test: Residual

[e]Error term for F test: Steer*Period*Year(Treatment)

TABLE 2. COMPOSITION OF PROTEIN SUPPLEMENTS (EXPERIMENT I)

Item, DM basis	Protein supplement[a]					SEM[b] (n=9)
	CGM	SBM	CSM	MBM	FSM	
Organic matter, %	97.3	92.6	90.6	68.4	79.0	1.71
Crude protein, %	65.0	47.6	40.6	47.9	60.9	1.39
Nitrogen						
Total	10.40	7.61	6.49	7.67	9.75	.223
Soluble, % of total	6.1	17.3	15.3	15.3	23.2	1.06
PIN[c], % of total	14.4	7.5	15.0	10.9	5.2	.73

[a]CGM = corn gluten meal, SBM = soybean meal, CSM = cottonseed meal, MBM = meat and bone meal, FSM = fish meal.
[b]Standard error of the mean.
[c]Pepsin insoluble nitrogen.

TABLE 3. COMPOSITION OF PROTEIN SUPPLEMENTS (EXPERIMENT II)

Year:	1986			1987			
Protein Supplement[a]	CSMds	CSMm	MM	CSMds	CSMm	MM	SEM[b] (n=3)
Organic Matter, %	93.6	94.1	75.5	93.4	93.5	74.3	2.35
Crude Protein, %	41.9	42.8	48.9	43.9	42.5	49.3	.69
Nitrogen							
Total N	6.70	6.84	7.82	7.03	6.80	7.89	.113
Soluble, % of total	17.7	12.6	14.6	14.5	10.9	13.7	.71
PIN[c], % of total	12.5	15.6	11.7	13.2	22.7	12.7	1.14

[a]CSMds = cottonseed meal (direct solvent); CSMm = cottonseed meal (mechanical process); MM = meat meal.
[b]Standard error of the mean
[c]Pepsin insoluble nitrogen

TABLE 4. RATE AND EXTENT OF IN SITU RUMINAL NITROGEN (N) DISAPPEARANCE OF PROTEIN SUPPLEMENTS IN STEERS GRAZING IMMATURE AND MATURE WHEAT PASTURE (EXPERIMENT I)

	Protein supplement[a]					
Item	CGM	SBM	CSM	MBM	FSM	SEM[b]
Rate of N disappearance, %/h						
Immature	.53^{e}	7.59^{ch}	2.49^{d}	1.89^{dh}	.86de	.47
Mature	.88^{e}	5.78^{ci}	2.26^{d}	3.43^{di}	.84^{e}	.47
Mean	.70^{e}	6.67^{c}	2.37^{d}	2.66^{d}	.85^{e}	.33
Extent, % at 36 h						
Immature	21.7^{g}	92.5^{ch}	68.6^{d}	57.2^{eh}	44.9^{f}	1.76
Mature	19.9^{g}	82.6^{ci}	65.1^{e}	74.8^{di}	46.7^{f}	1.76
Mean	20.8^{f}	87.6^{c}	66.9^{d}	66.0^{d}	45.8^{e}	1.25

[a]CGM = corn gluten meal, SBM = soybean meal, CSM = cottonseed meal, MBM = meat and bone meal, FSM = fish meal.
[b]Standard error of the mean.
[c,d,e,f,g]Means in the same row with different superscripts are different (P<.05).
[h,i]Means in the same column with different superscripts are different (P<.05).

TABLE 5. PARAMETERS FROM THE EXPONENTIAL EQUATION DESCRIBING NITROGEN (N) DISAPPEARANCE AND EXTENT OF RUMINAL N DEGRADATION OF CSM, SBM, MBM AND FSM FOR STEERS GRAZING WHEAT PASTURE (EXPERIMENT I)

	Protein supplement[a]				
Item	CGM[b]	SBM	CSM	MBM	FSM	SEM[c]
Fraction a, %						
Year 2		18.9^{f}	28.1^{dh}	24.1^{e}	28.8^{d}	1.30
Year 3		16.4^{g}	38.0^{di}	23.2^{f}	28.7^{e}	1.40
Mean		17.6^{g}	33.0^{d}	23.7^{f}	28.8^{e}	.96
Fraction b, %						
Year 2		80.2^{d}	50.1^{eh}	39.0^{fh}	32.2^{gh}	2.21
Year 3		79.4^{d}	38.4^{ei}	31.3^{fi}	20.3^{fi}	2.38
Mean		79.8^{d}	44.3^{e}	35.2^{f}	26.2^{g}	1.63
Potentially degradable, %						
Year 2		99.0^{d}	78.2^{e}	63.1^{f}	61.0^{f}	2.07
Year 3		95.8^{d}	76.4^{e}	54.6^{f}	49.1^{f}	2.21
Mean		97.4^{d}	77.3^{e}	58.8^{f}	55.0^{f}	1.51
Rate of N disappearance (c), %/h						
Year 2		7.18^{d}	4.87^{e}	7.73^{d}	4.33^{e}	.671
Year 3		5.96^{e}	4.63^{e}	8.32^{d}	5.80^{e}	.718
Mean		6.57^{e}	4.75^{f}	8.03^{d}	5.06^{f}	.491
Logarithmic rate of N disappearance, %/h						
Year 2	.54^{g}	7.29^{dh}	1.98^{e}	1.23^{f}	.84^{fg}	.199
Year 3	.40^{g}	5.42^{di}	1.57^{e}	.89^{f}	.59^{fg}	.211
Mean	.47^{g}	6.39^{d}	1.78^{e}	1.06^{f}	.72^{fg}	.145
Ruminal N degradation, %						
Year 2		65.4^{dh}	50.8^{eh}	44.8^{f}	41.0^{f}	.70
Year 3		59.7^{di}	56.5^{ei}	43.2^{f}	39.2^{f}	.75
Mean		62.5^{d}	53.7^{e}	44.0^{f}	40.9^{g}	.52

[a]CGM = corn gluten meal; SBM = soybean meal; CSM = cottonseed meal ; MBM = meat and bone meal; FSM = fish meal
[b]CGM data would not converge and no estimates were obtained
[c]Standard error of the mean.
[defg]Means in the same row with different superscripts are different ($p<.05$)
[hi]Means in the same column with different superscripts are different ($p<.05$)

TABLE 6. PARAMETERS FROM THE EXPONENTIAL EQUATIONS DESCRIBING NITROGEN (N) DISAPPEARANCE AND EXTENT OF RUMINAL N DEGRADATION OF CSMds, CSMm AND MM FOR STEERS GRAZING WHEAT PASTURE (EXPERIMENT II)

	Protein supplement[a]			
Item	CSMds	CSMm	MM	SEM[b] (n=30)
Fraction a, %				
Year 1	33.3^{c}	20.4^{df}	35.7^{c}	2.10
Year 2	27.5^{d}	33.6^{cg}	40.6^{c}	2.10
Mean	30.4^{d}	27.0^{d}	38.1^{c}	1.49
Fraction b, %				
Year 1	55.7^{df}	71.5^{cf}	32.0^{e}	3.09
Year 2	69.3^{cg}	37.1^{dg}	26.0^{e}	3.09
Mean	62.5^{c}	54.3^{d}	29.0^{e}	2.19
Potentially degradable, %				
Year 1	89.0^{c}	91.9^{cf}	67.7^{d}	3.61
Year 2	96.9^{c}	66.7^{dg}	66.6^{d}	3.61
Mean	93.9^{c}	79.3^{d}	67.2^{e}	2.55
Rate of N disappearance, %/h				
Year 1	8.65^{cf}	3.95^{d}	4.91^{d}	.798
Year 2	4.94^{cg}	3.09^{c}	3.91^{c}	.798
Mean	6.80^{c}	3.52^{d}	4.41^{d}	.564
Logarithmic rate of N disappearance, %/h				
Year	4.04^{c}	2.71^{df}	1.18^{e}	.196
Year 2	4.17^{c}	.78^{dg}	.82^{d}	.196
Mean	4.11^{c}	1.74^{d}	1.00^{e}	.139
Passage Rate, %/h				
Year 1	4.57^{c}	5.20^{c}	4.95^{c}	.400
Year 2	5.07^{c}	4.53^{c}	4.80^{c}	.400
Mean	4.82^{c}	4.86^{c}	4.87^{c}	.383
Ruminal degradation, %				
Year 1	70.1^{cf}	50.7^{d}	51.1^{d}	1.81
Year 2	61.5^{cg}	47.5^{d}	53.4^{d}	1.81
Mean	65.8^{c}	49.1^{d}	51.8^{d}	1.29

[a]CSMds = cottonseed meal (direct solvent); CSMm = cottonseed meal (mechanical process); MM = meat meal.
[b]Standard error of the mean
[cde]Means in the same row with different superscripts are different ($p<.05$)
[fg]Means in the same column with different superscripts are different ($p<.05$)

CHAPTER VI

EFFECTS OF INCLUSION OF HIGH PROTEIN FEEDSTUFFS ON THE PERFORMANCE OF STOCKER CATTLE GRAZING WHEAT PASTURE

Abstract

A 3 yr study using 256 fall weaned steers and heifers (220 ± 29 kg) was conducted to evaluate the effects of inclusion of high protein feedstuffs in supplements on the performance of cattle grazing wheat pasture. In each of 2 yr 80 heifers or 96 steers were randomly allotted to four treatments in a randomized complete block design with two replications. In yr 3, because of constraints on available wheat forage, three treatments were assigned to replication 1, while five treatments were assigned to replication 2 in a randomized incomplete block design. Steers or heifers assigned to treatment 1 received no supplement. Cattle assigned to treatment 2 received .91 kg (as fed).head^{-1}.d^{-1} of an 8% crude protein (CP) high energy corn-based supplement while those assigned to treatments 3 and 4 received supplements which contained 16 to 20% CP containing either meat meal (meat and bone meal in yr 3) or cottonseed meal as the protein source. Rate of weight gain was

increased (P<.03) when cattle were supplemented with either corn, meat meal or cottonseed meal based supplements. Although rate of weight gain was numerically greater when cattle received supplements containing meat meal or cottonseed meal, this increase was not significant (P>.30). However, calculated efficiency of supplement use improved from 11.3 kg of supplement per kg of increased gain for cattle receiving the corn based supplement to 7.2 and 6.2 kg supplement per kg of added gain for cattle receiving the meatmeal and cottonseed meal supplements, respectively. These results suggest that stocker cattle performance can be improved by supplementation. However, the choice of supplement (i.e. energy vs protein) did not alter weight gains.

Introduction

Wheat and other small grain pastures are high quality forages and commonly contain 24 to 30% crude protein on a dry matter basis. However, Beever and Siddons (1986) reported as much as 30% of ingested N from fresh forages containing medium to high levels of N may be lost prior to the small intestine. Egan (1974), Egan and Ulyatt (1980) and Ulyatt and Egan (1979) have also reported large losses (i.e. 40 to 45%) of ingested N prior to the small intestine. Recently, Vogel (1988) and Andersen (1988) reported that non-ammonia N flow to the small intestine of cattle grazing immature wheat forage ranged from 36 to 63% of N intake.

Consequently, the traditional concept that performance of stocker cattle grazing wheat pasture is not limited by protein status should be reevaluated. Anderson et al. (1987) and Lee (1985) reported that feeding supplements containing feather meal and(or) meat and bone meal increased daily gains of stocker cattle grazing wheat pasture by .12 and .09 kg/d when compared to control, grain-based supplements. Although increases in daily gain of this magnitude appear small, they are large enough to frequently increase profits of stocker cattle by $15 to 20 per head. Therefore, the objective of this research was to determine the effects of inclusion of high protein feedstuffs on the performance of stocker cattle grazing wheat pasture.

Experimental Procedure

Cattle and Experimental Design. Eighty heifers in yr 1, 96 steers in yr 2 and 80 steers in yr 3 were used. Description of the cattle, their mean initial weights and lengths of the trials are summarized in Table 1. Mean initial weight was approximately 220 kg and the trials were approximately 111 d in length. In yr 1 and 2 the heifers and steers were randomly allotted by weight within breed groups to four treatments in a randomized complete block design with two replications. Steers or heifers assigned to treatment 1 had free-choice access to a commercial mineral[1] supplement during the entire trial whereas those of

[1]Wheat Gainer Mineral No. 2. Farmland Industries. Guaranteed Analysis: Ca 15-17%, P 4.0%, Mg 10.0% and salt 19-21%.

treatments 2, 3 and 4 received .91 kg (as fed).head^{-1}.d^{-1} of the supplements shown in Tables 2 to 4. Animals assigned to treatment 2 received a traditional "high energy" corn-based supplement while animals assigned to treatments 3 and 4 received supplements containing meat meal[2] (meat and bone meal[3] in yr 3) and cottonseed meal[4] as the protein source. In yr 3 because of constraints on available wheat pasture only three treatments (i.e. 3 supplement groups) were assigned to replication 1 while five treatments (i.e. 2 control and 3 supplement groups) were assigned to replication 2 in a randomized incomplete block design. Because of a shortage of wheat pasture in yr 2, 1 replication was deleted due to large differences in forage availability among treatments. Therefore, a total of 5 replications were used.

Initial stocking densities on wheat pasture were approximately .85, .75 and 1.05 ha/steer in yr 1 to 3, respectively. In yr 1, replication 1 consisted of a volunteer wheat pasture which was fertilized with 56 kg N/ha in late October. Replication 2 consisted of an irrigated wheat pasture which was planted late and was not ready for grazing at the onset of the experiment. Consequently, all cattle were placed according to treatment on the volunteer wheat pasture until the irrigated wheat pasture was ready.

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[2]Obtained from IBP, Inc. West Point, NE Slaughter Plant
[3]Obtained from Cargill Nutrena Feed Division, McPherson, KS
[4]Unknown origin in yr 1. Obtained from Traders Oil Mill in yr 2 and 3, Fort Worth, TX

In yr 2 and 3 dryland wheat pastures were fertilized with approximately 89 kg N/ha.

Because of snow and ice cover, heifers in replications 1 and 2 in yr 1 were removed from pasture and placed in drylot for 8 and 18 d. During this time they received their respective supplements, limited amounts of sorghum silage and haygrazer hay. In yr 2 and 3, old world bluestem hay was fed on pasture during periods of snow and(or) ice cover. Hay was fed (i.e. approximately 2.5 kg DM.head^{-1}.d^{-1}) for 6 and 21 d in yr 2 and 3, respectively.

Supplements. The composition of the supplements fed in yr 1 to 3 are reported in Tables 2 to 4, respectively. Each yr supplements were formulated to be isocaloric and to contain similar amounts of Ca, P and Mg. Monensin was also included at 145 mg/kg (as fed) supplement in yr 1 and at 165 mg/kg (as fed) supplement in yr 2 and 3. The control supplements were formulated to contain approximately 8.4% CP. In yr 1, the meat meal and cottonseed meal supplements for heifers of treatments 3 and 4 were formulated to contain 16.3% CP with approximately 17.7% meat meal and 21.9% cottonseed meal, respectively. In yr 2 and 3 the CP content of the meat meal and cottonseed meal supplements was increased to 20.2% of DM by increasing the proportion of meat meal (meat and bone meal in yr 3) and cottonseed meal to approximately 25 and 32% of DM. In an attempt to improve the acceptance and palatability of the supplements yeast culture (3% of DM) and dehydrated alfalfa (4% of DM) were

added in yr 2 and 3, respectively. In yr 3 the Ca and P contents of the meat and bone meal supplement were 2.7 and 1.5%, respectively. Because of concerns about the potential effects of high levels of dicalcium phosphate on palatability and intake if the corn and cottonseed meal supplements were increased to the same levels, the Ca and P contents were set at 2 and 1% of DM, respectively.

Animals were group fed supplements daily, with samples being taken weekly and composited across weeks within months for analyses. In yr 2 and 3, supplement refusals were weighed, sampled and dried and discarded weekly to provide estimates of daily DM consumption. Composited supplements were ground through a 2 mm mesh screen in a Wiley mill and analyzed for total N by the Kjeldahl procedure (AOAC, 1975). Samples were also ashed at 500^{o}C for 8 h and subsequently analyzed for Ca and Mg by atomic absorption spectrophotometry using an air-acetylene flame and P by colorimetric determination using molybdovanadate reagent (AOAC,1975).

Forage Composition. In yr 2 and 3 forage availability was estimated by hand clipping to ground level three .5 M^2 plots at selected times to coincide with major changes in climatic growing conditions for wheat. Forage availability estimates for yr 2 and 3 are reported in appendix Tables 4 and 5, respectively. Also, hand clipped wheat forage samples were obtained to characterize forage composition. Hand clipped wheat forage samples were frozen immediately after

clipping by suspension over liquid N, and subsequently lyophilized. Lyophilized wheat forage samples were ground through a 2 mm mesh screen in a Wiley mill and analyzed for total N by the Kjeldahl procedure. Also, soluble N was determined following a 1 h incubation at 39°C in a shaking water bath using the mineral mixture (2% v/v; pH 6.5) of the "Ohio" buffer in vitro fermentation media (Johnson, 1969). Non-protein nitrogen (NPN) was determined using 25 ml of the filtrate of the soluble N procedure by sodium tungstate precipitation with 5 ml of 1.07 N H_2SO_4 and 5 ml of 11.2 % sodium tungstate. Samples were also analyzed for soluble carbohydrates by the procedure of Balwani (1965) and in vitro organic matter disappearance (IVOMD) using a modification of the Tilley and Terry (1963) procedure. Each sample was analyzed in triplicate using .5 g DM in 40 ml of buffered rumen fluid which consisted of equal parts (v/v) of strained rumen fluid and McDougall's buffer (McDougall, 1948). The McDougall's buffer contained one-tenth the specified concentration of $CaCl_2$ and 1 g of urea/liter of buffer. The rumen fluid was obtained from a steer maintained on prairie grass hay and .9 kg/d of a protein supplement that contained (% as-fed): soybean meal (44% crude protein), 93; sugarcane molasses, 3; dicalcium phosphate 2; trace-mineralized salt, 2.

Statistical Analysis. Data were analyzed by least squares analysis of variance using the General Linear Models procedure of SAS (SAS, 1982). The initial model included

replication, treatment, replication X treatment, breed and breed X treatment as sources of variation. However, because of an incomplete replication in year 3 in order to estimate treatment differences using differences among least squares means and the replication X treatment interaction as the error term, the means for each pasture were analyzed using only replication and treatment as sources of variation. This was adequate since there was no breed X treatment interaction ($P>.90$). In addition, orthogonal contrasts were conducted to test for the following effects: 1) control vs supplementation, 2) energy vs protein supplementation and 3) meat meal vs cottonseed meal supplementation. The supplement consumption data was analyzed in a manner similar to the performance data. The means for each pasture were analyzed using replication and treatment as sources of variation with the replication X treatment interaction as the error term. Forage composition data were analyzed by year using treatment, replication and treatment X replication as sources of variation. The F test for differences among treatments was tested using the treatment X replication interaction as the error term. Since the F test for treatment was not significant ($P>.10$), the forage composition data were pooled across treatments and replication and are reported by sampling dates.

Results and Discussion

Chemical composition of the wheat forage grazed in yr 2 and 3 is presented in Tables 5 and 6, respectively. Crude protein content and IVOMD averaged 23% of DM and 80.2%, respectively which are values typical of wheat forage grazed during this season of growth (Horn, 1984). Soluble carbohydrate content of wheat forage was high in both years and averaged 25.7% of DM which is similar to that reported by Johnson et al. (1974) who found that soluble carbohydrate content of wheat forage ranged from 10 to 36% of DM through the growing season. Soluble N and NPN averaged 1.26 and .66% of DM. When expressed as a percent of total N approximately 31 to 43 % of total N was soluble N while NPN accounted for 13 to 29% of total N. Beever et al. (1976) observed a significant negative relationship ($r=-.98$, $P<.001$) between the amount of N flowing to the small intestine in sheep and solubility of perennial ryegrass N conserved by different methods. Vogel (1988) and Andersen (1988) reported that non-ammonia N flow to the small intestine of cattle grazing immature wheat forage ranged from 36 to 63% of intake which indicates that large quantities of dietary N failed to reach the small intestine. This suggests that animals grazing wheat pasture may respond to supplemental bypass protein.

Supplement consumption, mean initial and final weights and daily gains during the performance trials are presented in Table 7. Mean supplement consumption of the corn, meat

meal and cottonseed meal supplements were .80, .72 and .81 kg DM.head^{-1}.d^{-1}. In yr 1 supplement consumption was considered to be generally good until March 4 at which time supplement consumption decreased because of increasing amounts of available wheat forage. However, in yr 2 and 3 during the course of the trials it was observed that cattle consuming supplements containing either meat meal or meat and bone meal did exhibit some reluctance towards consumption of the supplements. This was evidenced by the lower supplement intakes. Mean consumption in yr 2 for steers consuming the corn, meat meal or cottonseed meal supplements was .74, .69, and .75 kg DM.head^{-1}.d^{-1} while, in yr 3 mean consumption of the corn, meat and bone meal and cottonseed meal supplements was .77, .62, and .81 kg DM.head^{-1}.d^{-1}, respectively.

Supplementation of cattle grazing wheat pasture with either the corn, meat meal or cottonseed meal supplements increased ($P<.03$) daily gains over cattle receiving no supplement. This response was certainly not surprising. Consumption of the "high energy" corn based supplement increased weight gains by .07 kg/day which is consistent with other trials where grain based supplements have been fed on small grain pastures. Elder (1967) reported results of a 3 yr study where ground corn or milo was fed ad libitum to steers grazing small grain pastures. Average grain consumption was 2.5 kg DM.head^{-1}.d^{-1} and daily gain increased by .15 kg. When calculated on a hectare basis,

efficiency of supplement use was 9.4 kg of grain per kg of increased gain.

Although rates of gain were numerically greater for cattle consuming supplements containing either meat meal or cottonseed meal no increase (P>.30) in performance was observed when compared to cattle consuming the corn based supplements. This differs from results published by Lee (1985) who reported weight gains of calves grazing wheat pasture fed .68 kg/day of a supplement containing 15% meat and bone meal were increased by .09 kg/day when compared with calves fed control, milo- or hominy-based supplements. Anderson et al. (1987) also observed that feeding .68 kg/day of a supplement containing 11.5% feather meal and 19.4% meat and bone meal increased weight gains of calves grazing wheat pasture by .12 kg/d when compared to a dry rolled corn-based supplement. However, in the present study calculated efficiency of supplement use was 11.4, 7.2 and 6.2 kg of supplement per kg of increased gain for cattle consuming the corn, meat meal and cottonseed meal supplements, respectively, suggesting the protein supplements were more efficient in promoting weight gain. The calculated efficiency of supplement use for cattle consuming the corn-based supplements is similar to values of 9.4 and 10.3 kg DM/kg of increased gain, calculated on a hectare basis, as reported by Elder (1967) and Gulbransen (1976).

It is unlikely that the slight improvements in daily gain which were observed in this trial and those reported

previously were the result of an increase in protein flow to the small intestine but rather an improvement in protein quality. In the classical studies of Egan and Moir (1965) improvements in the amount and(or) proportion of amino acids increased feed intake. Andersen (1988) reported that supplementation of cattle grazing immature wheat pasture with meat meal resulted in slight ($P<.10$) increases in wheat forage intake ranging from 4 to 14%. Based on the equations of the net energy system (NRC, 1984) for a 200 kg medium frame steer consuming 2.5% of body weight, a 7% increase in wheat forage intake would increase rate of weight gain by .1 kg/day which is similar to that previously reported. This assumes the NEm and NEg content of wheat forage are 1.73 and 1.11 Mcal/kg, respectively.

In summary, these data indicate that supplementation of stocker cattle grazing wheat pasture with either energy or protein based supplements increased stocker cattle performance. In contrast to previously reported studies, supplementation of cattle with protein did not statistically increase weight gains over cattle fed grain based supplements. However, efficiency of supplement use was increased. Further studies are needed to resolve this controversial issue.

TABLE 1. NUMBER AND DESCRIPTION OF CATTLE AND LENGTH OF TRIALS OF EACH WHEAT PASTURE YEAR

		Description			Length of trials	
Year	Number	Sex	Mean initial wt., kg	Breed	Dates	Days
1 1985-86	80	Heifers	217	Hereford x Angus x Limousin and 1/8 or 1/4 Brahman crossbred	Dec. 8 to Mar 20	103
2 1986-87	96	Steers	233	Hereford x Angus x Limousin and 1/8 or 1/4 Brahman crossbred	Nov.14 to Mar 19	125
3 1987-88	80	Steers	208	Hereford, Angus or Hereford x Angus	Dec.10 to Mar 25	106

TABLE 2. INGREDIENT COMPOSITION AND NUTRIENT CONTENT OF SUPPLEMENTS (YEAR 1)

SUPPLEMENT	CORN	MEAT MEAL	COTTONSEED MEAL	SEM[a]
Ingredient	---------- DM Basis ----------			
Corn	79.0	67.0	62.8	
Meat meal		17.7(16.6)[b]		
Cottonseed meal			21.8(21.5)	
Cottonseed hulls	9.0	9.1	4.0	
Molasses	4.4	4.4	4.4	
Limestone	2.0		2.1	
Dicalcium phosphate	3.5		2.9	
Magnesium oxide	.6	.3	.5	
Salt	1.2	1.2	1.2	
Trace Mineral Salt	.3	.3	.3	
Rumensin 60 Premix[c]	.11	.11	.11	
Nutrient content				
NE_M (Mcal/kg)	1.91	1.91	1.91	
NE_G (Mcal/kg)	1.23	1.23	1.23	
Crude protein				
Calculated	8.1	16.3	16.3	
Actual	8.3	16.1	15.4	2.04
Calcium				
Calculated	1.57	1.56	1.51	
Actual	1.28	1.25	1.32	.051
Phosphorus				
Calculated	.94	.96	1.03	
Actual	1.14	1.07	1.00	.029
Magnesium				
Calculated	.48	.49	.50	
Actual	.38	.36	.39	.017

[a]Standard error of the mean
[b]Values in parentheses represent % as fed
[c]Added to supply 145 mg monensin/kg (as-fed) of supplement

TABLE 3. INGREDIENT COMPOSITION AND NUTRIENT CONTENT OF SUPPLEMENTS (YEAR 2)

SUPPLEMENT	CORN	MEAT MEAL	COTTONSEED MEAL	SEM[a]
Ingredient	---------- DM Basis ----------			
Corn	79.3	62.2	51.1	
Meat meal		25.4(23.9)[b]		
Cottonseed meal			32.6(32.0)	
Cottonseed hulls	3.8	3.8	.4	
Molasses	4.2	4.2	4.2	
Diamond V Yeast	3.0	3.0	3.0	
Limestone	2.71		3.48	
Dicalcium phosphate	5.23		3.62	
Magnesium oxide	.68	.23	.42	
Salt	.70	.70	.70	
Trace Mineral Salt	.30	.30	.30	
Rumensin 60 Premix[c]	.14	.14	.14	
Nutrient content				
NE_M (Mcal/kg)	1.91	1.94	1.85	
NE_G (Mcal/kg)	1.25	1.25	1.22	
Crude protein				
Calculated	8.4	20.2	20.2	
Actual	8.6	21.5	19.9	3.11
Calcium				
Calculated	2.20	2.20	2.20	
Actual	2.25	2.25	2.05	.096
Phosphorus				
Calculated	1.25	1.25	1.25	
Actual	1.43	1.08	1.35	.037
Magnesium				
Calculated	.55	.55	.58	
Actual	.56	.40	.58	.013

[a]Standard error of the mean
[b]Values in parentheses represent % as fed
[c]Added to supply 165 mg monensin/kg (as-fed) of supplement

TABLE 4. INGREDIENT COMPOSITION AND NUTRIENT CONTENT OF SUPPLEMENTS (YEAR 3)

SUPPLEMENT	CORN	MEAT AND BONE MEAL	COTTONSEED MEAL	SEM[a]
Ingredient	---------- DM Basis ----------			
Corn	77.8	61.4	53.1	
Meat and bone meal		24.6(23.2)[b]		
Cottonseed meal			31.4(30.8)	
Cottonseed hulls	6.0	4.9	.4	
Alfalfa hay, ground	4.0	4.0	4.0	
Molasses	4.2	4.2	4.2	
Limestone	2.74		3.51	
Dicalcium phosphate	3.95		2.37	
Magnesium oxide	.43		.18	
Salt	.45	.45	.45	
Trace Mineral Salt	.30	.30	.30	
Rumensin 60 Premix[c]	.14	.14	.14	
Nutrient content				
NE_M (Mcal/kg)	1.89	1.92	1.88	
NE_G (Mcal/kg)	1.23	1.23	1.23	
Crude protein				
Calculated	8.6	20.2	20.2	
Actual	8.5	16.7	18.0	3.49
Calcium				
Calculated	2.00	2.71	2.00	
Actual	1.68	2.51	2.02	.209
Phosphorus				
Calculated	1.00	1.52	1.00	
Actual	1.50	1.70	1.28	.075
Magnesium				
Calculated	.39	.39	.39	
Actual	.48	.43	.55	.036

[a]Standard error of the mean
[b]Values in parentheses represent % as fed
[c]Added to supply 165 mg monensin/kg (as-fed) of supplement

TABLE 5. CHEMICAL COMPOSITION OF WHEAT FORAGE GRAZED DURING THE PROTEIN SUPPLEMENTATION TRIAL (YEAR 2)

Sampling Date	Nov 14	Dec 18	Jan 15	Mar 19	SEM[a]
Dry Matter (DM), %	32.3	30.2	34.5	23.9	1.18
Organic Matter, %	89.9	85.1	79.7	90.6	1.53
Crude Protein, % of DM	27.7	23.2	21.5	22.4	1.09
Nitrogen (N), % of DM	4.43	3.71	3.44	3.59	.174
Soluble N					
% of DM	1.37	1.29	1.06	1.53	.083
% of total N	31.0	35.2	31.3	42.6	1.96
Non-protein Nitrogen					
% of DM	.89	.60	.54	.54	.045
% of total N	20.2	16.4	15.6	15.2	.96
Soluble Carbohydrates,					
% of DM	17.7	23.1	22.1	27.7	1.20
IVOMD[b]	91.6	78.5	71.5	91.4	2.40

[a]Standard error of the mean (n=8).
[b]In vitro organic matter digestibility.

TABLE 6. CHEMICAL COMPOSITION OF WHEAT FORAGE GRAZED DURING THE PROTEIN SUPPLEMENTATION TRIAL (YEAR 3)

Sampling Date	Dec 10	Jan 26	Mar 25	SEM[a]
Dry Matter (DM), %	24.6	31.3	23.5	.69
Organic Matter, %	90.8	88.3	89.9	1.17
Crude Protein, % of DM	24.3	19.9	22.0	.77
Nitrogen (N), % of DM	3.88	3.19	3.52	.123
Soluble N				
% of DM	1.25	1.02	1.32	.047
% of total N	32.1	32.1	37.6	.97
Non-protein Nitrogen				
% of DM	.51	.53	1.00	.034
% of total N	13.2	16.7	28.6	.93
Soluble Carbohydrates,				
% of DM	32.3	35.0	21.6	1.47
IVOMD[b]	77.6	75.4	75.1	.62

[a]Standard error of the mean (n=8).
[b]In vitro organic matter digestibility.

TABLE 7. PERFORMANCE OF STEERS GRAZING WHEAT PASTURE DURING THE PROTEIN SUPPLEMENTATION TRIALS

Supplement	Control	Corn	Meat Meal	Cottonseed Meal	SEM[a]	Orthogonal Contrasts[b] 1	2	3
Number of animals	52	52	52	51				
Supplement Consumption, kg DM.head^{-1}.day^{-1}	---	.80	.72	.81	.030	---	.52	.08
Initial weight, kg	214	215	218	217	1.1	.08	.10	.31
Final weight, kg	302	310	316	318	3.6	.02	.13	.63
Daily Gain, kg	.80	.87	.90	.93	.032	.03	.31	.47
Efficiency of Supplement Use[c]	---	11.4	7.2	6.2				

[a]Standard error of the mean.
[b]Observed significance levels for orthogonal contrasts: 1 = Control vs Supplementation, 2 = Energy vs Protein, 3 = Meat meal vs Cottonseed meal
[c]kg of supplement consumed per kg of increased weight gain

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APPENDIX

TABLE 1. SAS PROGRAM USED TO ESTIMATE RATES OF DISAPPEARANCE AND NITROGEN POOL SIZES PRESENT IN WHEAT FORAGE.

```
DATA NAME;
Y=DISAPPEARANCE;     (DECIMAL FRACTION)
REMAIN= 1-Y;     LREMAIN=LOG(REMAIN);
DATA T024 T2460; SET NAME;
IF HOUR<24 THEN OUTPUT T024;    ELSE OUTPUT T2460;
COMMENT
   BREAKS DATA SET ACCORDING TO TIME TO ESTIMATE RATE OF
   DISAPPEARANCE OF SLOW POOL;
PROC SORT DATA=TO24;BY STEER HOUR;
PROC SORT DATA=T2460;BY STEER HOUR;
PROC REG DATA=T2460 OUTEST=BHAT; BY STEER;
MODEL LREMAIN=HOUR/R;  ID HOUR;
COMMENT
   LINEAR REGRESSION OF DATA POINTS IN SLOW POOL;
DATA HAT024; SET BHAT;
A2HAT=EXP(INTERCEP); K2HAT=-HOUR;
COMMENT
   N POOL SIZE ESTIMATED FROM THE ANTI LOGARITHM OF THE
   INTERCEPT;
DO HOUR= 4, 8, 12, 18;
PCTNHAT=A2HAT*EXP(-K2HAT*HOUR)
COMMENT
   ESTIMATES THE CONTRIBUTION OF THE SLOW POOL TO THE FAST
   POOL AT EACH INCUBATION TIME;
OUTPUT;END;
PROC SORT DATA=HAT024;BY STEER HOUR;
DATA T024A;MERGE T024 HAT024;BY STEER HOUR;
LOGREM=LOG(REMAIN-PCTNHAT);
COMMENT
   SUBTRACTS OUT THE CONTRIBUTION FROM THE SLOW POOL TO
   DETERMINE THE LOG OF N REMAINING OF THE FAST POOL;
PROC PRINT;
PROC REG DATA=TO24A OUTEST=BHAT2; BY STEER;
MODEL LOGREM=HOUR/R; ID HOUR;
COMMENT
   LINEAR REGRESSION OF THE CORRECTED DATA POINTS IN THE
   FAST POOL
DATA BHAT2;SET BHAT2;
A1HAT=EXP(INTERCEP); K1HAT=-HOUR;
PROC PRINT;
COMMENT   TO OBTAIN THE NORMALIZED FRACTIONS
    A1 = A1HAT/(A1HAT+A2HAT);
    A2 = A2HAT/(A1HAT+A2HAT)
    RATE OF DISAPPEARANCE = K1HAT AND K2HAT;
    HALF TIME OF N POOLS = .693/RATE OF N DISAPPEARANCE
```

TABLE 2. SAS PROGRAM USED TO CALCULATE SITE AND EXTENT OF WHEAT FORAGE DIGESTION BY STEERS GRAZING WHEAT PASTURE

```
DATA FO;INFILE AAA;
INPUT STEER 2-3 TIME 5 XBLE 6-12 WET 13-19 DRY 20-26 ASH 27-
33 AA 34-37 CRC 39-49 FOM 62-70 PERIOD 72;
FDMO=(4*.67397)/(CRC/1000);
IF PERIOD=1 THEN DMINT=FDMO/(1-.746);
IF PERIOD=2 THEN DMINT=FDMO/(1-.7028);
IF PERIOD=1 THEN OMINT=(FDMO*FOM)/(1-.816);
IF PERIOD=1 THEN NINT=(DMINT*.039138);
IF PERIOD=2 THEN OMINT=(FDMO*FOM)/(1-.7707);
IF PERIOD=2 THEN NINT=(DMINT*.042097);
PROC SORT DATA=FO;BY PERIOD STEER;
PROC MEANS;BY PERIOD STEER;VAR FDMO DMINT OMINT NINT;
OUTPUT OUT=FCRC
MEAN= FDMO DMINT OMINT NINT;
PROC PRINT DATA=FCRC;
PROC SORT DATA=FCRC;BY PERIOD STEER;
COMMENT
   DATA SET "FO" CONTAINS THE FECAL SAMPLES USED TO ESTIMATE
   FECAL OUTPUT AND FORAGE IMTAKE BASED ON CHROMIUM.
   BY DEFINITION
      XBLE= BEAKER WGT
      WET = BEAKER + WET SAMPLE WGT
      DRY = BEAKER + DRY SAMPLE WGT
      ASH = BEAKER + ASH SAMPLE WGT
      CRC = CHROMIUM CONCENTRATION IN ug/g.
      FDMO= FECAL DM OUTPUT WHICH WAS ESTIMATED BASED ON 4 g
            CR DAILY DOSE * CR CONCENTRATION DIVIDED BY CRC
      FOM = FECAL ORGANIC MATTER
      DMINT = DM INTAKE WHICH IS ESTIMATED USING THE
              INDIGESTIBILITY OF WHEAT FORAGE;
      OMINT = ORGANIC MATTER INTAKE WHICH IS CALCULATED
              AS FECAL DM OUTPUT TIME FECAL ORGANIC MATTER
              DIVIDED BY IN VITRO ORGANIC MATTER
              INDIGESTIBILITY
      NINT  = NITROGEN INTAKE WHICH IS CALCULATED AS DM
              INTAKE * NITROGEN CONTENT OF WHEAT FORAGE;

DATA DUOD; INFILE BBB;
INPUT STEER 2-3 XBLE 4-10 WET 11-17 DRY 18-24 ASH 25-31 AA
32-35 CRC 36-45 DM 46-55 DOM 56-65 PERIOD 68;
DDMFLCR=(2.69/(CRC/1000));
DOMFLCR=DDMFLCR*DOM;
PROC SORT DATA=DUOD; BY PERIOD STEER;
PROC MEANS;BY PERIOD STEER; VAR DOM DDMFLCR DOMFLCR; OUTPUT
OUT=DUOD2 MEAN=DOM DDMFLCR DOMFLCR;
PROC PRINT;
```

```
PROC SORT DATA=DUOD2;BY PERIOD STEER;
COMMENT
   DATA SET "DUOD" CONTAINS THE DUODENAL SAMPLES WHICH WERE
   ANALYZED FOR CHROMIUM.
   BY DEFINITION
      DDMFLCR = DUODENAL DM FLOW, WHICH IS CALCULATED BY
                DIVIDING CR DOSE BY CR PRESENT IN DUODENAL
                SAMPLES
      DOMFLCR = DUODENAL OM FLOW, WHICH IS CALCULATED BY
                MULTIPLYING DDMFLCR BY DUODENAL ORGANIC
                MATTER (DOM);

DATA BACT; INFILE CCC;
INPUT STEER 2-3 STRWGT BACTRNA 9-16 DUODRNA 18-25 BACTN 27-
35 DUODN 36-44 PH 55-58 RUMENNH3 60-64 DUODNHX 84-90 PERIOD
95;
DUODNH3=DUODNHX/100;
KBACNFL=((BACTN/BACTRNA)*(DUODRNA/DUODN)
PROC SORT DATA=BACT; BY PERIOD STEER;
PROC PRINT;
COMMENT
   DATA SET "BACT" CONTAINS RNA DATA FOR BACTERIAL AND
   DUODENAL SAMPLES AND RUMEN MEASUREMENTS
   BY DEFINITION
      STRWGT  = STEER WEIGHT (lbs)
      BACTRNA = RNA CONTENT FOR BACTERIAL PELLET
      BACTN   = NITROGEN CONTENT FOR BACTERIAL PELLET
      DUODRNA = RNA CONTENT FOR DUODENAL SAMPLES
      DUODN   = NITROGEN CONTENT FOR DUODNAL SAMPLES
      PH      = RUMEN PH MEASUREMENT
      RUMENNH3= RUMEN AMMONIA CONCENTRATION (mg/dl)
      DUODNH3 = DUODENAL AMMONIA CONCENTRATION
      KBACNFL = PERCENT OF THE NITROGEN IN DUODENAL SAMPLES
                WHICH IS DUE TO THE BACTERIA;

DATA TOTAL;MERGE FCRC DUOD2 BACT; BY PERIOD STEER;
WT= STRWGT/2.2;
COMMENT
   DATA SET "TOTAL" COMBINES ALL THREE DATA SETS;
ARDMDCR=(DMINT-DDMFLCR)/DMINT;
AROMDCR=(OMINT-DOMFLCR)/OMINT;
DNITFLCR=DDMFLCR*DUODN;
ARNITDCR=(NINT-DNITFLCR)/NINT;
DNANFLCR=(DDMFLCR*(DUODN-DUODNH3);
BACNFLCR=DNANFLCR*KBACNFL;
FEEDNFLW=DNANFLCR-BACNFLCR;
BOMFLCR=(BACNFLCR/(BACTN))*.80;
TROMD=(OMINT-(DOMFLCR-BOMFLCR))/OMINT;
TRND=(NINT-(DNANFLCR-BACNFLCR))/NINT;
RESCAPE=(DNANFLCR*(1-KBACNFL)/NINT)*100;
KRNLOSS=((NINT-DNITFLCR)/NINT)*100;
```

```
GDNTROMD=((NINT-(DNANFLCR-BACNFLCR))/TROMD)*100;
KOMFLINT=DOMFLCR/OMINT;
KNANFINT=DNANFLCR/NINT;
DMINTBW=(DMINT/WT)*100;
OMINTBW=(OMINT/WT)*100;
NINTBW=(NINT/WT)*1000;;
DNANFBW=(DNANFLCR/WT)*100;
DOMFLBW=(DOMFLCR/WT)*100;
KBACTOT=BACNFLCR/DNANFLCR;
KFEEDTOT=FEEDNFLW/DNANFLCR;
MICROEFF=((BACNFLCR/(OMINT-DOMFLCR))*1000;
COMMENT
   BY DEFINITION
      ARDMDCR= APPARENT RUMEN DM DISAPPEARANCE, CALCULATED
               AS DIFFERENCE BETWEEN DM INTAKE AND DUODENAL
               DM FLOW
      AROMDCR= APPARENT RUMEN OM DISAPPEARANCE, CALCULATED
               AS DIFFERENCE BETWEEN DM INTAKE AND DUODENAL
               OM FLOW
      DNITFLCR=DUODENAL FLOW OF NITROGEN, CALCULATED AS
               DUODENAL DM FLOW MULTIPLIED BY THE DUODENAL
               NITROGEN CONTENT
      ARNITDCR=APPARENT RUMEN DISAPPEARANCE OF NITROGEN,
               CALCULATED BY DIFFERENCE BETWEEN NITROGEN
               INTAKE AND DUODENAL FLOW OF TOTAL NITROGEN
      DNANFLCR=DUODENAL NON-AMMONIA NITROGEN FLOW,
               CALCULATED BY SUBTRACTING OUT THE DUODENAL
               NH3 CONTENT FROM THE NITROGEN CONTENT OF
               DUODENAL SAMPLES
      BACNFLCR=THE AMOUNT OF BACTERIAL NITROGEN FLOWING TO
               THE SMALL INTESTINE, CALCULATED BY DUODENAL
               NAN FLOW TIMES THE PROPORTION OF BACTERIAL
               NITROGEN PRESENT IN DUODENAL SAMPLES
      FEEDNFLW=THE AMOUNT OF FORAGE NITROGEN FLOWING TO THE
               SMALL INTESTINE, CALCULATED AS THE DIFFERENCE
               BETWEEN DUODENAL NAN FLOW AND BACTERIAL
               NITROGEN FLOW
      BOMFLCR= BACTERIAL OM FLOW TO THE SMALL INTESTINE;
               ASSUMES THAT BACTERIA ARE 80% OM
      TROMD =  TRUE RUMEN OM DISAPPEARANCE, CALCULATED BY
               DIFFERENCE BETWEEN OM INTAKE AND DUODENAL OM
               FLOW TO THE SMALL INTESTINE AFTER SUBTRACTING
               OUT BACTERIAL OM FLOW
      TRND =   TRUE RUMEN NITROGEN DISAPPEARANCE, CALCULATED
               BY DIFFERENCE BETWEEN N INTAKE AND DUODENAL
               NAN FLOW TO THE SMALL INTESTINE AFTER
               SUBTRACTING OUT BACTERIAL NITROGEN FLOW
      KRNLOSS= NITROGEN LOSS PRIOR TO THE SMALL INTESTINE,
               CALCULATED AS THE DIFFERENCE BETWEEN NITROGEN
               INTAKE AND NITROGEN FLOW TO THE SMALL
               INTESTINE
```

```
      GDMTROMD=GRAMS OF DEGRADED NITROGEN IN THE RUMEN PER
               KG OF OM TRULY DIGESTED IN THE RUMEN,
               CALCULATED AS THE AMOUNT OF NITROGEN
               DISAPPEARING IN THE RUMEN DIVIDED BY TRUE
               RUMEN OM DISAPPEARANCE
      KOMFLINT=OM FLOW TO THE SMALL INTESTINE EXPRESSED AS A
               PERCENT OF OM INTAKE
      KNANFINT=NAN FLOW TO THE SMALL INTESTINE EXPRESSED AS
               A PERCENT OF NITROGEN INTAKE
      DMINTBW= DM INTAKE AS A PERCENT OF BODY WEIGHT
      OMINTBW= OM INTAKE AS A PERCENT OF BODY WEIGHT
      NINTBW = N INTAKE AS A PERCENT OF BODY WEIGHT
      DNANFBW= DUODENAL NAN FLOW AS A PERCENT OF BODY WEIGHT
      DOMFLBW= DUODENAL OM FLOW AS A PERCENT OF BODY WEIGHT
      KBACTOT= PERCENT OF NITROGEN FLOW TO THE SMALL
               INTESTINE WHICH IS OF BACTERIAL ORIGIN
      KFEEDTOT=PERCENT OF NITROGEN FLOW TO THE SMALL
               INTESTINE WHICH IS FROM WHEAT FORAGE;
      MICROEFF= MICROBIAL EFFICIENCY, WHICH IS CALCULATED AS
                G BACTERIAL NITROGEN FLOW PER KG OM TRULY
                DIGESTED IN THE RUMEN
PROC PRINT DATA=TOTAL;
PROC SORT; BY PERIOD STEER;
PROC MEANS;BY PERIOD;
PROC GLM; CLASSES PERIOD;
FDMO DMINT DDMFLCR DOMFLCR STRWGT PH RUMENNH3 KBACNFL WT
OMINT NINT DMINTBW OMINTBW NINTBW ARDMDCR AROMDCR ARNITCR
DNANFLCR KOMFLINT KNANFINT BACNFL FEEDNFLW BOMFLCR TROMD
TRND KRNLOSS GDMTROMD DNANFBW DOMFLBW KBACTOT MICROEFF
KFEEDTOT=PERIOD/SS1 SS3;
LSMEANS PERIOD/STDERR PDIFF;
-------------------------------------------------------------
```

TABLE 3. SAS PROGRAM USED TO ESTIMATE THE POTENTIALLY DIGESTIBLE FRACTIONS PRESENT IN THE PROTEIN SUPPLEMENTS

```
DATA NAME;
Y=DISAPPEARANCE;  (%)
T=TIME;
PROC SORT DATA=NAME;BY STEER;
PROC NLIN ITER=100 DATA=NAME METHOD=MARQUARDT;
BY STEER NOTSORTED;
PARAMETERS
A=0
B=.9
C=.05;
COMMENT
    INITIAL PARAMETERS USED FOR THE STARTING POINTS;
BOUNDS
0<=A<=1,
0<=B<=1;
COMMENT
    SET THE BOUNDS SO THAT NEITHER FRACTION A OR B CAN BE
    GREATER THAN 1 OR LESS THAN 0;
MODEL Y = A + B*(1-EXP(-C*T));
DER.A=1;
DER.B=1-EXP(-C*T);
DER.C=B*(EXP(-C*T))*T;
COMMENT
    ACTUAL MODEL OF ORSKOV AND McDONALD (1979);
OUTPUT OUT=POINTS PREDICTED=YHAT RESIDUAL=YRES;
PROC PRINT DATA=POINTS;BY STEER NOTSORTED;
PROC PLOT;BY STEER NOTSORTED;
PLOT YHAT*T = '*' Y*T = 'D'/OVERLAY;
COMMENT
   PLOTS THE PREDICTED VS OBSERVED VALUES TO CHECK FOR THE
   FIT OF DATA;
COMMENT
   RUMEN DEGRADABILITY = A + (B*C/(C+K))
   A= THE HIGHLY SOLUBLE FRACTION
   B= THE INSOLUBLE BUT POTENTIALLY DEGRADABLE FRACTION
   C= THE RATE OF DISAPPEARANCE
   K= RATE OF PASSAGE;
```

TABLE 4. FORAGE AVAILABILITY FOR STEERS GRAZING WHEAT PASTURE DURING THE PROTEIN SUPPLEMENTATION TRIALS (YEAR 2)

	Replication 1				Replication 2				
Supplement	Control	Corn	Meat Meal	Cottonseed Meal	Control	Corn	Meat Meal	Cottonseed Meal	SEM[a]
November 14, 1986									
kg DM/hectare	620	1467	706	431	366	482	500	124	93.5
kg DM/100 kg BW[b]	154	370	177	105	106	133	143	36	24.6
December 21, 1986									
kg DM/hectare	823	442	284	697	126	306	99	40	60.9
kg DM/100 kg BW	205	112	71	171	36	85	28	12	15.6
February 4, 1987									
kg DM/hectare	374	129	126	348	125	109	91	53	68.3
kg DM/100 kg BW	93	32	32	85	36	30	26	15	17.1
March 19, 1987									
kg DM/hectare	502	253	380	580	853	763	787	897	83.7
kg DM/100 kg BW	125	64	95	142	247	211	225	261	22.9

[a]Standard error of the mean (n=3).
[b]BW=body weight

TABLE 5. FORAGE AVAILABILITY FOR STEERS GRAZING WHEAT PASTURE DURING THE PROTEIN SUPPLEMENTATION TRIALS (YEAR 3)

	Replication 1			Replication 2				
Supplement	Corn	Meat Meal	Cottonseed Meal	Control	Corn	Meat Meal	Cottonseed Meal	SEM[a]
December 10, 1987								
kg DM/hectare	561	368	548	1059	1258	998	1694	245.8
kg DM/100 kg BW[b]	238	152	231	445	501	403	661	101.1
January 26, 1988								
kg DM/hectare	524	346	453	601	553	677	700	108.7
kg DM/100 kg BW	222	143	191	252	220	273	273	45.5
March 25, 1988								
kg DM/hectare	482	450	457	605	678	991	1429	136.0
kg DM/100 kg BW	204	186	193	254	270	400	557	54.6

[a]Standard error of the mean (n=3).
[b]BW=body weight.

VITA

Gary John Vogel

Candidate for the Degree of

Doctor of Philosophy

Thesis: KINETICS OF RUMINAL NITROGEN DIGESTION OF WHEAT FORAGE AND HIGH PROTEIN FEEDSTUFFS AND THE EFFECTS OF SUPPLEMENTAL PROTEIN ON THE PERFORMANCE OF GROWING CATTLE ON WHEAT PASTURE

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Education: Graduated from Hereford High School, Hereford, Texas in May 1980; transferred from Clarendon Junior College, Clarendon, Texas in May, 1981; received Bachelor of Science degree in Animal Production from Texas Tech University, Lubbock Texas in December, 1983; received Master of Science degree in Animal Science at Oklahoma State University, Stillwater Oklahoma in December, 1985; completed the requirements for the Doctor of Philosophy degree in Animal Nutrition at Oklahoma State University, Stillwater Oklahoma in December, 1988.

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